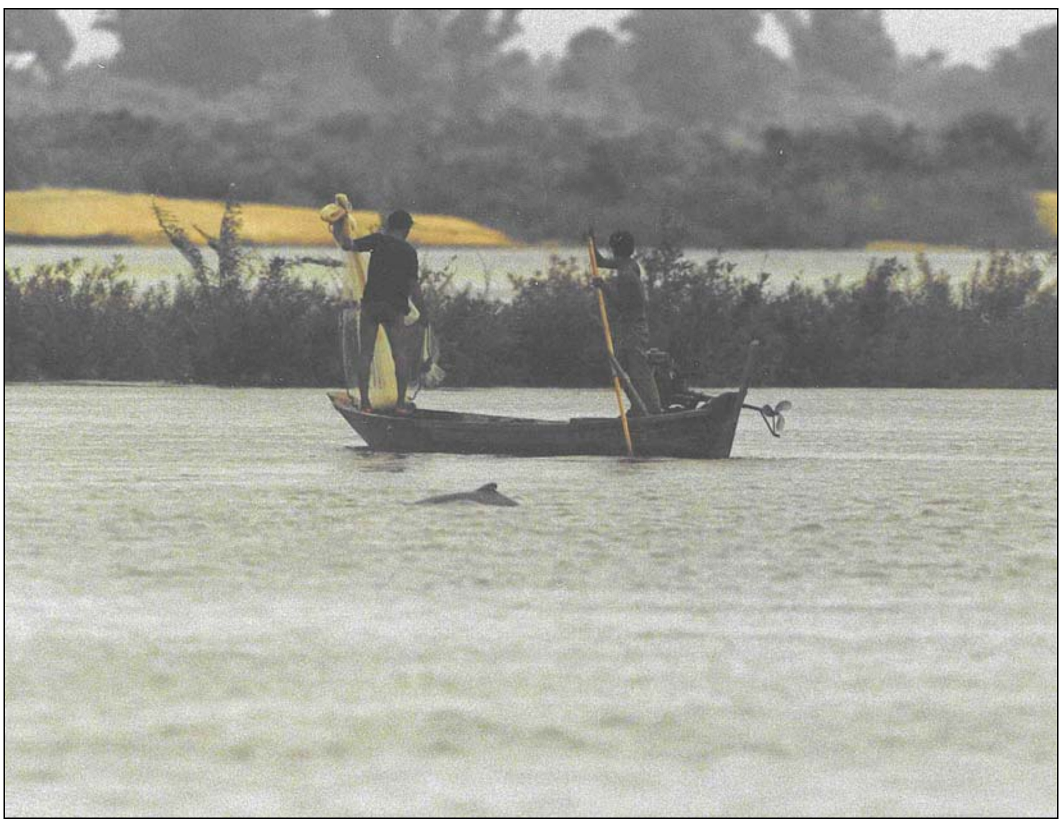
Beasley, Isabel L. (2007) ***Conservation of the Irrawaddy dolphin, Orcaella brevirostris (Owen in Gray, 1866) in the Mekong River : biological and social considerations influencing management.*** **PhD thesis, James Cook University.**

1. INTRODUCTION

For conservation of endangered species to be effective, both biological and social elements of the conservation process must be considered as a basis for minimising threats. In this chapter, I introduce the target species and study area of my thesis. I provide a background to the importance of integrating biological and social studies to assist with effective endangered species conservation, as well as discussing the theoretical elements of the conservation process relevant to my thesis. I conclude by outlining the goals, aims and objectives of my study and present the conceptual framework within which my thesis is based.



Cambodian fishers using a castnet in the Mekong River, with an Irrawaddy dolphin swimming in close association.

1. INTRODUCTION

There are six species of river dolphins in Asia and South America, distributed over 17 countries[1]. All Asian freshwater dolphin populations are listed as either *Endangered* or *Critically Endangered* by the World Conservation Union (IUCN), primarily as a result of continuing threats from direct competition with humans for freshwater resources. Human population density is high in most Asian countries inhabited by river dolphins (ranging from 26 people/km^2 in Laos to 981 people/km^2 in Bangladesh) but low in South America (ranging from 8 people/km^2 in Boliva to 37 people/km^2 in Colombia)[2] (Wikipedia 2006). Community land rights in developing countries are generally insecure, and/or uncertain, with a lack of tenure in many areas. Uncertain land tenure, in combination with increasing human population growth, catalyses the 'tragedy of the commons' (Hardin 1968, Kay 1997). Weak, ineffective governance and corruption are major considerations in many developing countries, which further accentuate the difficulty of conservation (Kaufmann 1997, Davis 2004, Ferraro 2005, Katzner 2005). In many parts of poorer Asia, traditional subsistence fisheries are extensive, as are commercial fisheries in some regions (e.g. the Tonle Sap River and Great Lake of Cambodia) (Coates *et al.* 2003). Additionally, many river dolphin populations in South Asia are faced with serious threats caused by population fragmentation from large run-of-the-river dams, or reduction of water quantity through large-scale irrigation projects (Smith *et al.* 1998, Braulik 2006). Human persecution of dolphins as a result of direct competition with fishers appears minimal in most areas, possibly as a result of the small size of many river dolphin populations. Accidental catch in gillnet fisheries is a major threat. Freshwater dolphins are sympatric with many other mega-vertebrate species (see Chapter 3). As I discuss in Chapter 2, although most river dolphin populations are small and declining, there are few examples of on-the-ground conservation initiatives to conserve freshwater mega-vertebrate populations, and to subsequently develop urgently required management strategies.

1.1. THE IRRAWADDY DOLPHIN

The Irrawaddy dolphin (*Orcaella brevirostris*) (Owen in Gray, 1866) has recently received attention as an Asian facultative freshwater cetacean (*i.e.*, it inhabits both fresh and marine waters), which is subject to increasing human-induced threats as a result of its preference for riverine and coastal habitats (Smith and Jefferson 2002) (Chapter 2). Consequently, the

[1] The fransciscana (*Pontoporia blainvillei*) is considered one of the four 'obligate' or 'true' river dolphins. However, it is not considered further in my thesis, because of its coastal distribution.
[2] The list of countries by population density was accurate as of July 2005. A total of 193 countries were listed. The country with the highest population density was Monaco, with 16,620 individuals/km^2.

Irrawaddy dolphin requires increased conservation management (Perrin *et al.* 1996, Reeves *et al.* 2002, Reeves *et al.* 2003). The IUCN has listed most isolated sub-populations of *Orcaella* as *Critically Endangered*. The Mahakam River sub-population (Kalimantan, Indonesia) is listed in the 2000 Red List (Kreb and Smith 2000). The Songkhla Lake (Thailand); Ayeyarwady River (Myanmar); Malampaya Sound (Philippines); and Mekong River (Cambodia, Vietnam and the southern Lao Peoples' Democratic Republic - hereafter referred to as Laos) sub-populations are listed in the 2004 Red List (Smith 2004, Smith and Beasley 2004a, Smith and Beasley 2004b; c). Thus, conservation of Irrawaddy dolphins is a matter of significant concern throughout much of their range, particularly within major river systems (Smith *et al.* 2003a). Smith and Jefferson (2002) noted that numerous populations of Irrawaddy dolphins exist and called for a clarification of taxonomic and demographic relationships throughout the range of the species.

My study focused on the Irrawaddy dolphin population inhabiting the Mekong River of southern Laos, Cambodia and Vietnam (Figure 1.1). Prior to my study, very little information was available regarding the population dynamics, mortality rates and causes, biology, or ecology of this population. Chapters 2 and 4 provide a background to the previous knowledge of Irrawaddy dolphins in the Mekong River.

The Irrawaddy dolphin has been recorded in a wide range of coastal habitats, from the northwestern Bay of Bengal, east to southern Vietnam and south to the east coast of Suluwesi (Stacey and Leatherwood 1997). Riverine populations occur in the Mahakam, Ayeyarwady and Mekong Rivers of Southeast Asia. Lacustrine populations seemingly isolated from coastal waters occur in Songkhla Lake and Chilka Lake (India). A small population occurring in Malampaya Sound, southern Philippines, was only recently documented (Dolar *et al.* 2002, Smith *et al.* 2004). Knowledge of the distribution of Irrawaddy dolphins throughout their range is still incomplete.

It was once thought that Irrawaddy dolphins also occurred in Australian/Papua New Guinean (PNG) coastal waters (Stacey and Leatherwood 1997). The first *Orcaella* specimens from Australia were collected in 1948; however, their occurrence was documented (although incorrectly as the Irrawaddy dolphin) only in the 1960s (Johnson 1964, Mörzer-Bruyns 1966) with scattered records subsequently (Dawbin 1972, Whiting 1997, Paterson *et al.* 1998, Chatto and Warneke 2000, Parra *et al.* 2002)[3]. Through research conducted for my thesis, clear and consistent species-level differences between Asian and Australian/PNG specimens are evident

[3] Dawbin (1972) also recorded *Orcaella* from Papua New Guinea.

in colouration, cranial and external morphometrics, postcranial morphology and molecular data. The Asian and Australian/PNG stocks of *Orcaella* were thus designated as separate species and now named the Australian snubfin dolphin (*Orcaella heinsohni*) (Beasley *et al*. 2002a; 2005[4]: Appendix 1 and 2). Cranial morphological features from one specimen from PNG were consistent with those of *O. heinsohni* (Beasley *et al.* 2002a). However, further study is needed on *Orcaella* in PNG and neighbouring regions to confirm the distribution limits of both species (Beasley *et al.* 2005).

The species-level separation of *Orcaella brevirostris/heinsohni* has immediate conservation implications. Australia is a large, developed country, with a relatively small, environmentally-conscious human population, strict government regulations protecting biodiversity and habitats, and the financial capacity to assist management programs. Australia, therefore, has significant potential to conserve endangered species. As mentioned in Beasley *et al.* (2002b), the taxonomic findings confirm that a single geographic region, e.g. northern Australia, cannot conserve the genetic diversity of the genus *Orcaella*, since two species are now known to exist. Increased research and conservation efforts should be focused in both regions (Australia/PNG and Asia), where very little is currently known about basic biological and ecological aspects of either species. Based on recent research, most *Orcaella* populations are in rapid decline, with all known riverine populations facing potential extirpation in the near future (Smith *et al.* 2003a). As demonstrated by molecular data (Beasley *et al.* 2005), the potential for subspecies-level differences among the riverine sub-populations makes conservation efforts significant and urgent.

1.2. STUDY AREA

The study area for my research is the lower Mekong River of southern Laos, Cambodia and Vietnam (Figure 1.1. and 1.2; described in detail in Chapter 3). The Mekong River still retains much of its ecological integrity, particularly when compared with other major river systems that are degraded, such as the Nile in Egypt, the Ganges and Indus in South Asia, the Amu Dar'ya and Syr Dar'ya in Central Asia, the Yellow River in China, and the Colorado River in North America. These rivers are dammed, diverted and overused to the extent that for parts of the year, little or none of their freshwater reaches the ocean (Dudgeon 2000b; a; c; d).

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[4] These publications were a collaborative effort between myself (cranial morphology, external morphometrics and colouration), Dr. Kelly Robertson, Southwest Fisheries Science Center (genetics), the late Dr. Peter Arnold, Museum of Tropical Queensland (taxonomic treatment and significant contribution to the discussion) and Dr. George Heinsohn, James Cook University (taxonomic treatment).

Freshwater species and habitats are among the most threatened in the world. The three primary threats to freshwater ecosystems are land-use disturbances, altered hydrology, and introduction of non-native species (Saunders *et al.* 2002). An index of the health of the world's freshwater ecosystems showed a decline of 50% between 1970 and 1995 (Loh *et al.* 1998). The future extinction rate of freshwater animals is predicted to be almost five times greater than that for terrestrial animals and three times that of coastal marine animals (Ricciardi *et al.* 1999).

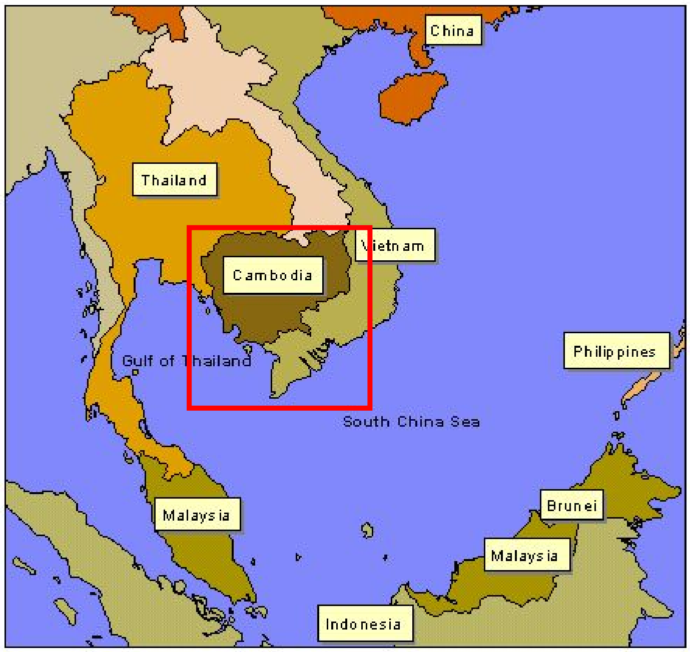


Figure 1.1. Location map of southern Laos, Cambodia and Vietnam, showing the research area where my study was undertaken.

Despite the alarming state of many freshwater systems, there is a notable lack of on-the-ground management strategies to conserve freshwater species and ecosystems. Saunders *et al*. (2002) provide a discussion of the potential benefits of freshwater protected areas for freshwater conservation. However, few other papers address on-the-ground freshwater conservation initiatives, particularly in developing countries. Although the lower Mekong River and Tonle Sap Great Lake support one of the most significant freshwater fisheries in the world (Coates *et al*. 2003), very little attention has been paid to conservation of its important areas, or species. Chapter 3 provides an overview on the history of the lower Mekong River and discussion of the importance of habitat preservation to species conservation.

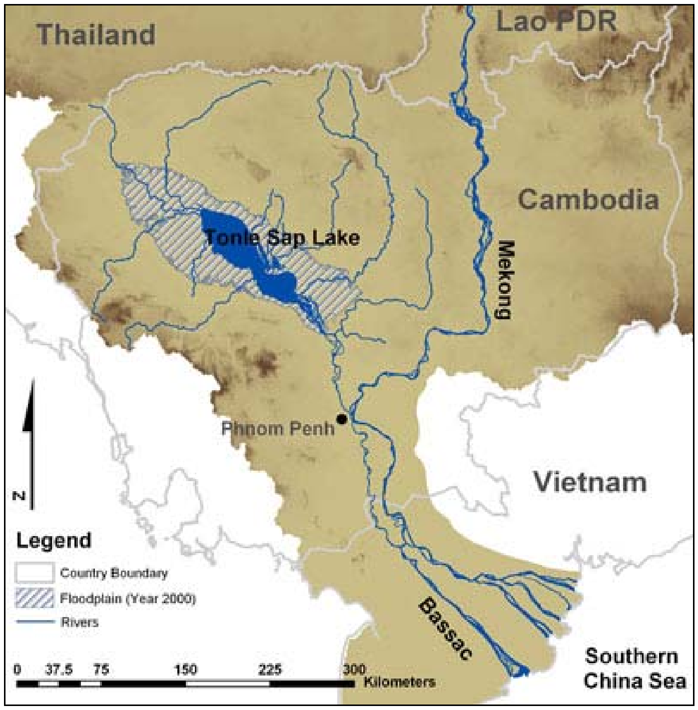


Figure 1.2. Location map of the lower Mekong River study area. The study area begins at the Laos/Cambodian border and extends south to the Vietnamese Delta (including Tonle Sap Lake). The light blue shading shows the floodplain area of Tonle Sap Lake. Map created by Matti Kummu (MRCS/WUP-FIN Lower Mekong Modeling Project) and reproduced with his permission.

1.3. ENDANGERED SPECIES CONSERVATION

Conservation biology is a crisis discipline aimed at saving biodiversity: limited information is applied in an uncertain environment, to make urgent decisions with sometimes irrevocable consequences (Soule 1986, Maguire 1992, Anthony and Blumstein 2000). An accepted approach to saving biodiversity has been to obtain information about biologically important areas for particular species and then to attempt to exclude local inhabitants and their activities from these important patches of habitat (Peres 1995, Kramer *et al.* 1997, Brandon *et al.* 1998, Terborgh 1999). It was believed that this method would reduce threats and maintain ecosystem level processes that, in turn, would preserve populations of species and habitats. However, this approach provoked protests from social advocates who argued that:

1. only initiatives related to poverty alleviation would lead to successful biodiversity conservation because only these initiatives address the root cause of environmental destruction (Duraiappah 1998, Ravnborg 2003);
2. protected areas take away the property rights of local peoples and compromise their present and future welfare (Ghimire and Pimbert 1997, Colchester 2004, Wilke *et al.* 2006); and

3. even if conservation areas generate economic value, the distribution of these benefits are so skewed against poor rural peoples that the role of parks in local development is negligible and protected areas neither compensate for lost property and rights nor contribute to poverty alleviation (Brockington 2003, McShane 2003).

It is now recognised that successful conservation biology requires the integration of biological, social, economic and political factors (McShane and Wells 2004b). As stated by Stankley and Shindler (2006),

> "*effective policies for management of rare and little-known species must not only be scientifically valid and cost-effective but also consistent with prevailing social beliefs and values. Failure to foster understanding and support will leave management dominated by conflict and continued species loss*".

The three countries of the lower Mekong region; Laos, Cambodia and Vietnam, are developing quickly and face burgeoning pressures from human over-population, excessive exploitation of resources, poverty, lack of basic services, and wide scale corruption at all social levels. When developing strategies to conserve and manage the Irrawaddy dolphin population in the Mekong River (as well as other flora and fauna), biological and social factors are of major importance.

1.4. THE IMPORTANCE OF BIOLOGICAL STUDIES IN SPECIES CONSERVATION

Applied population biology (the study of the biology of an organism) can contribute greatly to the management of a species (Primack 2002. When managing threats and impacts, it is vital to have a robust scientific understanding of a species ecology, its distinctive characteristics (*i.e.*, natural history), status of populations, and the dynamic processes that affect population size and distribution (Slooten and Lad 1991, Primack 2002). With such information, conservationists and land managers are able to minimise human impacts more effectively, identify factors that place species at risk of extinction, make mathematical predictions of the ability of species to persist in an area (typically a protected area) and evaluate the impact of alternative management options (Primack 2002).

Primack (2002) stressed that conservation biologists need to answer questions about a species' environment, distribution, biotic interactions, systematics and morphology, physiology and life history, demography, behaviour, and genetics, to implement effective population-level conservation efforts. Many of these questions fall under four main sub-disciplines relevant to conservation biology:

1. *population ecology* - incorporating measures of birth, death, immigration and emigration;
2. *behavioural ecology* - behavioural factors influencing survival and reproduction of individuals;
3. *population genetics* - using genetic variation and genetic population structure; and
4. *systematics* - relying on traditional and molecular techniques to reconstruct phylogenies.

There are numerous debates about the relative importance of these sub-disciplines in endangered species conservation, as well as about the value of systematic, ecological and evolutionary focuses for conservation (Franklin 1993, Forey *et al.* 1994, Wheeler and Cracraft 1996). Most of these factors, except population genetics, will be discussed extensively throughout this thesis, with reference to my study population.

To inform management and conservation of an endangered population, researchers ideally gain relevant information about its population biology, genetics, behavioural ecology, and systematics. With the usual lack of resources, information needs must be prioritised. Imperfect information should not be used as an excuse for delaying effective on-the-ground conservation (McShane and Wells 2004a). Very little biological information was available on the Irrawaddy dolphin population in the Mekong River prior to my study. Thus, all the above sub-disciplines were relevant to the design of my research.

1.5. THE IMPORTANCE OF COMBINING BIOLOGICAL AND SOCIAL STUDIES

Wildlife conservation generally necessitates managing people, rather than wildlife. Thus, because many problems facing endangered species are social, effective solutions require an understanding of human motivations, value systems and local knowledge (Meffe *et al.* 2000). To preserve natural resources, the social sciences must become central to conservation science and practice (Mascia *et al.* 2003). A socio-economic assessment provides information on the social, cultural, economic and political conditions of individuals, groups, communities and organisations. Such assessments may investigate resource use patterns, stakeholder characteristics, gender issues, stakeholder perceptions, organisation and resource governance, traditional knowledge, market attributes for extractive and non-extractive use, and non-market and non-use values (Bunce *et al.* 2000).

The processes required for a socio-economic assessment will vary depending on the assessment objectives, the stakeholder groups involved, and the resources available - especially the researchers available to conduct the assessment (Bunce *et al.* 2000). For project managers with little technical experience in socio-economic assessments, a wealth of literature is available to aid the design of effective monitoring projects (Bunce *et al.* 2000, Bunce and Pomeroy 2003). Although the techniques described in these documents are based on coral reef management, they have more generic application.

1.5.1. Stakeholder Involvement

There is growing support for developing management regimes that use citizen participation and empower traditional users (Johannes 1998, Johannes *et al.* 2000, Friedlander *et al.* 2003). Stakeholder involvement often increases compliance with policy and the capacity to design culturally sensitive regulations (Fiske 1992, Pollnac *et al.* 2001, Appeledoorn and Lindeman 2003, Friedlander *et al.* 2003). Indigenous peoples are frequently concerned about maintaining ecological processes and the species that mediate those processes because they rely on these resources for subsistence (Alcorn 1989; 1993). Thus, it is in Indigenous peoples' best interests to ensure that ecological processes are kept intact and large-scale destruction prevented. A variety of projects attempt to integrate local communities into conservation strategies through provision of various community benefits, such as integrated conservation development programmes (ICDPs) (Newmark and Hough 2000, McShane and Wells 2004a).

Energising local people to support conservation, while recognising and addressing the objections of those who oppose it, can be challenging. In many cases, improving the economic conditions of peoples' lives and helping them secure rights to their land is essential to preserving biological diversity in developing countries (Primack 2002). Although working with local people may be a desirable goal, in some cases this approach has been considered impossible, necessitating the exclusion of people from protected areas and rigorous patrol of their boundaries (Terborgh 2000). The success of community-based conservation programs has often been compromised when local communities have internal conflicts and poor leadership, making the community incapable of administering a successful conservation program (Primack 2002). Increasing human populations and outsiders moving into areas further exacerbate these concerns (Primack 2002). Successful conservation projects often build on and work with stable local communities, with effective leadership and competent government agencies (Barrett *et al.* 2001, Salafsky *et al.* 2001).

In Chapter 10, I argue that even in these difficult circumstances, managers should increase their efforts to develop solutions to increase community involvement, rather than placing the topic in the 'too-hard' basket. The potential interest and capacity of local communities to be involved in natural resource management results in my hypothesis that community-based management should not be the sole focus of a conservation program. I consider '*community conscious conservation*' a more appropriate approach.

1.5.2. Political Considerations

Conservation is a political process (Alcorn 1993). Initiatives are required to involve governments in conservation projects and to obtain their support. Many government agencies are ineffective or corrupt, preventing conservation programs from succeeding (Primack 2002). Although corruption can reduce environmental pressure by hindering development activity (Laurance 2004), corruption is a threat to sustainable development in various ways including demands for bribes for compliance, and the acceptance of bribes to overlook illegal activities (Davis 2004).

Corruption is most prevalent in developing countries with low government salaries, weak regulatory institutions, high political patronage and almost non-existent accountability (Kaufmann 1997, Laurance 2004). The positive and negative impacts of corruption on biodiversity conservation have only recently been debated in the scientific literature (Kaufmann 1997, Laurance 2004, Ferraro 2005, Katzner 2005, Smith and Walpole 2005, Walpole and Smith 2005). These discussions noted that the impact of corruption on conservation manifests in two ways:

1. reduced effectiveness of conservation programs through a reduction in available financial resources, law enforcement and political support; and
2. an incentive for the overexploitation of resources (Smith and Walpole 2005).

Among various examples, a study by Smith *et al.* (2003b) describes how pervasive corruption has promoted rampant illegal logging and destruction of tropical forests in Indonesian Borneo (Kalimantan).

International organisations such as Transparency International, are attempting to address corruption in various countries and have developed a 'Corruption Perception Index'. This index defines corruption as the '*abuse of public office for private gain*' and measures the degree to which corruption is perceived to exist among a country's public officials and politicians.

Cambodia is listed as 131 out of 159 countries, indicating that corruption is a major problem (the higher the value of the index the more corrupt the country).

1.6. MOUNTAIN GORILLA CONSERVATION – AN 'ON-THE-GROUND' EXAMPLE

Few projects have attempted to integrate biological and social considerations into conservation and management strategies (Friedlander *et al.* 2003). The efforts to conserve the mountain gorillas (*Gorilla gorilla beringei*), which inhabit the Parc de Virungas and Parc des Volcans National Parks on the borders of Rwanda, Uganda and the Democratic Republic of Congo (previously Zaire) is a relevant example. Biological research on mountain gorillas began in the late 1950s (Schaller 1963), followed by the legendary efforts of Diane Fossey from 1967-1985. Fossey investigated the behavioural ecology of the gorillas while undertaking significant on-the-ground conservation efforts (Fossey 1983). Detailed data are now available on the population parameters of the gorillas and how these parameters varied in space and time (Schaller 1963, Harcourt and Fossey 1981, Harcourt *et al.* 1981, Weber and Vedder 1983, Harcourt 1986, Sholly 1990), and on the gorillas' social structure, individual life histories, acoustics and behaviour (Schaller 1963, Fossey 1983, Stewart and Harcourt 1987). Recently, gorilla-watching tourism has become a booming industry, bringing thousands of international tourists into close proximity with gorillas (Oates 1996, Wilkie and Carpenter 1999) and creating another significant threat to their survival (Homsy 1999, Vaughan 2000). As a result of the potential for human-transmitted disease to gorilla populations, significant biological research has now been undertaken on disease transmissions and recommended strategies to mitigate these threats (Homsy 1999).

The Virunga gorilla population is one of the best known and longest studied populations of large mammals in the tropics (Hamilton *et al.* 2000). These data have allowed important quantitative assessments of the gorilla's conservation status (Harcourt 1995; 1996) as well as development and implementation of critical management recommendations, that would have been impossible if long-term data were not available.

The importance of social research relevant to gorilla conservation is demonstrated by events at Bwindi Impenetrable Forest, Uganda (Nowak 1995). Bwindi Impenetrable Forest was designated as a forest reserve in 1932. Illegal logging and other activities resulted in its being declared a protected area in 1991 (Hamilton *et al.* 1990). The forest contains about half the world's total of 620 mountain gorillas and many other rare or endemic species (Nowak 1995).

Bwindi Forest is surrounded by densely populated agricultural land and lies within a region of historical and contemporary political instability (Dunbar 1960, Turyagyenda 1964, Doornbos 1998). Designation of the forest as a protected area, without adequate consultation or concern about the local people’s loss of access to resources (e.g. people were not allowed to collect bark from an important medicinal tree that grew only in the park), resulted in local resentment of the protected area (Hamilton *et al.* 1990, Cunningham 1996). Fires were subsequently set in the forest by villagers and threats made against the gorillas (Wild and Mutebi 1996). As a result of the problems associated with this local resentment of the park regulations, three schemes to provide benefits to communities from the existence of the forest and to involve these communities in park management were instituted. These agreements included controlled harvesting of resources in the park (Cunningham 1996, Wild and Mutebi 1996); receipt of a percentage of the revenue from tourism (Wild and Mutebi 1996); and establishment of a trust fund partly for community development (described in more detail in Hamilton *et al*. 2000). Tension between people and park officials has apparently been reduced as a result of these measures (Harcourt 1986).

This case demonstrates the importance of community involvement in the development and maintenance of protected areas (Hart *et al.* 1997). The mountain gorilla case-study mirrors the critical conservation situation facing the Irrawaddy dolphin population that inhabits the Mekong River. Important lessons can therefore be learnt related to endangered species’ management from experiences gained through the mountain gorilla projects and other similar efforts world-wide. One of the most important lessons is the importance of community support for conservation, when resources available to park managers are limited and political instability pandemic. Further discussion on the integration of social and biological considerations relevant to conservation of the Irrawaddy dolphin population inhabiting the Mekong River is presented in Chapter 11.

1.7. BAIJI CONSERVATION – AN EXAMPLE OF UNSUCCESSFUL CONSERVATION

The Yangtze River dolphin or baiji (*Lipotes vexillifer*) is a freshwater cetacean found only in the Yangtze River of China. It is listed by the IUCN as *Critically Endangered* and is the world’s most endangered cetacean (Dudgeon 2005). Compared to the apparently successful efforts to conserve mountain gorillas outlined above, the baiji provides an example of unsuccessful conservation efforts, where biological and social factors were not adequately considered and management was ineffective.

The baiji is on the verge of extinction and has recently being considered *Effectively Extinct* after a large-scale survey throughout the Yangtze River failed to sight a single individual (Lovgren 2006). This unfortunate situation is largely as a result of extreme anthropogenic pressures (e.g., dam construction, agricultural and industrial pollution, riverine development, boat traffic, and fishing) associated with living in an exploited habitat, where the surrounding human population is equivant to as much as 5% of the world's total (Yang *et al*. 2006). Efforts to conserve baiji were initiated in the early 1980s and consisted of local awareness-raising activities, collection of carcasses, establishment of natural and semi-natural reserves, development of a conservation action plan and two international workshops (Braulik *et al.* 2005, Reeves and Gales 2006). Although conservation efforts have been evident, the commitment to baiji conservation efforts by international NGOs, the Chinese government and various stakeholders is debatable (Reeves and Gales 2006). A major impediment to baiji conservation is the severely degraded state of the Yangtze River, where there are no prospects for improvement in the near future (Dudgeon 2005, Reeves and Gales 2006). Recent debates regarding baiji conservation efforts are evident in the literature and unfortunately the future of the baiji looks bleak (Dudgeon 2005, Reeves and Gales 2006, Wang *et al*. 2006, Yang *et al.* 2006).

Regardless of the future directions of baiji conservation efforts (if any), it is imperative that lessons are learnt from the unsuccessful efforts to date. The problems of habitat destruction, high human population growth in the catchment and lack of stakeholder commitment need to be considered and appropriate solutions applied to conservation of the Irrawaddy dolphin population inhabiting the Mekong River, and other freshwater dolphin populations.

1.8. EFFECTIVE PLANNING FOR ENDANGERED SPECIES CONSERVATION

1.8.1. Principles of Conservation Management

Recognising that conservation planning needs to be effective within a scientific, social and political framework, various principles for the conservation of wild living resources, including aquatic mammals have been developed. For example, Meffe *et al*. (2000) developed a set of five principles for the conservation of marine mammals, which were modified and reorganised from the more detailed principles presented by Mangel *et al*. (1996), which in turn built on Holt and Talbot (1978). Additional comments and perspectives on Mangel *et al.* (1996) are provided in Folke (1996), Wagner (1996), Lovejoy (1996) and Hilborn (1996). The five principles for effective aquatic mammal conservation are:

Principle I: Maintenance of healthy populations of wild aquatic mammals in perpetuity is inconsistent with ever-growing human consumption of marine [aquatic] resources.

Principle II: Regulation of the use of aquatic mammals must be based on an understanding of the structure and dynamics of the ecosystems of which they are a part.

Principle III: The human species, with all its activities, needs and diverse values, affects every aquatic ecosystem and this fact must be addressed and accommodated in the management of any living marine resource. All stakeholders must be included in the process of determining optimal management strategies.

Principle IV: Assessment of the possible ecological, economic and social factors of using aquatic mammals as resources should precede proposed use and proposed restriction of ongoing use.

Principle V: Conservation requires communication and education that are interactive, reciprocal and continuous.

The basis for these five principles is comprehensively discussed in Meffe *et al*. (2000). Importantly, although conservation principles provide guidance for natural resource managers in their task of regulating human activity related to renewable living resources, I agree with Hilborn (1996, pg 364), that '*our state of knowledge is such that general principles cannot provide practical help to resource managers on what risks are entailed by different levels of resource-use*' and Wagner (1996, p365), that '*understanding, reconciling and even changing values are what is central to conservation – not biology*'. These situations result both from a lack of understanding of how ecosystems function and from different personal values, *i.e*., one person's acceptable level of change is another person's ecological catastrophe (Hilborn 1996). Although these principles provide an excellent basis for the process of managing conservation, further investigations are required to establish the trade offs between levels of resource use and consequences to ecosystems. These principles provided me with a theoretical basis to develop my thesis goals and objectives.

1.8.2. Conservation Process

The conservation principles provide a framework to guide conservation and management of biodiversity. Following from these principles, various processes need to be considered when developing and implementing management strategies and conducting post-implementation activities. Importantly, appropriate management models must be based on parameters that can be estimated readily; explicitly account for uncertainty; and be simple to understand and implement (Taylor *et al*. 2000). Margoluis and Salafsky (Margoluis and Salafsky 1998) developed a seven-step process for the conservation of biodiversity (Figure 1.3). All stages of this process are integral for effective management and achieving on-the-ground conservation. However, in reality, for many conservation programs, at least one or more stages are omitted from project activities as a result of time, personnel, funding, social and/or political constraints.

The conservation process developed by Margoluis and Salafsky (1998) (Figure 1.3) consists of:

1. clarifying the groups mission
2. developing a conceptual model
3. developing a management plan
4. developing a monitoring plan
5. implementing both plans
6. analysing data and communicating results, and
7. using the results to adapt and learn

From the onset, I attempted to integrate this conservation process into the design and implementation of my research.

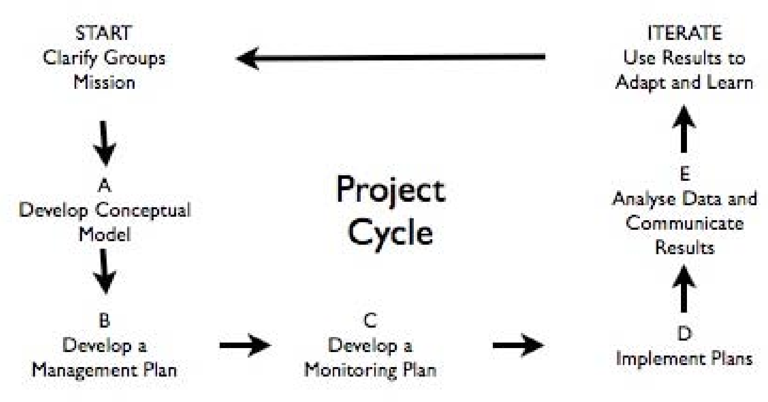


Figure 1.3. The seven components of an overall process for conserving biodiversity, as described by Margoluis and Salafsky (1998), pg 319.

1.8.2.1. **Clarifying Mission and Developing a Model**

My research priorities (objectives) aim to contribute to the effective conservation of the Irrawaddy dolphin population that inhabits the lower Mekong River (see '*1.8. Thesis Goals, Aims and Objectives*').

1.8.2.2. **Developing Plans**

The second stage of my research design involved the development of research and conservation strategies to achieve my objectives. These strategies attempted to encompass the full array of actions necessary to abate threats, or enhance the viability of the conservation targets (Nature Conservancy 2001).

As a result of limited funding and resources, once biological and social data are compiled to inform an appropriate management strategy, it is often necessary to prioritise conservation actions. Managers and decision makers are faced with the difficult task of not only choosing a management strategy but also convincing various parties that the choice is sensible (Ralls and Starfield 1995). It is difficult to make choices when there are significant uncertainties, conflicting objectives, and complex interactions (Maguire 1991). The use of an explicit framework to guide conservation decisions can help to choose strategies that are consistent with goals, data, and various social, economic and political considerations. Such a framework will assist to document the decision-making process and make it easier for managers to defend decisions (Ralls and Starfield 1995). Population viability analyses are often used to simulate models of small populations and the probable results of various management strategies (Soule 1987, Nunney and Campbell 1993). Multiple-criteria decision-making methods and risk analyses are also used to choose a management strategy based, at least in part, on modelling (Maguire and Lacy 1990, Maguire 1991, Maguire 1992, Ralls and Starfield 1995). For most endangered populations, few data are available to contribute to a reliable population viability analysis; however, even using a basic decision-making framework that indicates the consequences of action and inaction, will enhance a manager's ability to make consistent choices and defendable decisions (Maguire 1991). Chapter 11 illustrates my approach to prioritising strategies to contribute to the urgent conservation of Irrawaddy dolphins in the Mekong River.

1.8.2.3. **Implementing Plans**

An important component of the conservation process is implementation and on-the-ground project activities. Often recommendations are developed and published but not implemented. As an example, in December 2004 a workshop was conducted by the IUCN Mekong Wetlands Biodiversity and Sustainable Use Project (MWBP) to develop priorities for Irrawaddy dolphin conservation and community development at Chiteal Pool on the Laos/Cambodian border (Lopez 2004). The establishment of a '*joint committee to deal with issues affecting the trans-boundary population*' was the most immediate priority, plus eleven other recommendations to be dealt with by the joint committee. To my knowledge, the joint committee has not yet been established and none of the eleven priority activities have yet been conducted. Without implementation of recommendations, the development of strategies (no matter how technically robust and/or applicable) is a futile and worthless endeavour.

1.8.2.4. **Measuring Success - Project Evaluation**

Program evaluations determine how well a program has performed and assign responsibility and accountability for success or failure (Clark 1996). The evaluation of conservation programs is rare but increasingly important in improving program effectiveness and efficiency. The criteria for success must encompass both biological and social measures and include learning and the application of new knowledge to management (Kleiman *et al.* 2000). Monitoring and evaluation form the basis for improved decision-making and can:

1. provide information on public and internal accountability and help demonstrate impact, which is increasingly important with budgetary constraints (Sawhill and Williamson 2001, Hockings 2003);
2. identify the conditions under which a conservation action is likely to succeed or falter (Hatry 1999, Blann and Light 2000); and
3. provide an early warning system for potential problems and lead to ideas for potential remedial actions (Hatry 1999, Rigby *et al.* 2000).

Monitoring and evaluation assessments are unfortunately infrequent because of resistance by participants, lack of knowledge regarding monitoring techniques by researchers, and a lack of funding (Stem *et al.* 2005). Nonetheless, the results of evaluations at a variety of levels and time frames can permit the refinement of parts of conservation programs, the alteration of whole programs, or even a change in the entire approach to conservation problems (Kleiman *et al.* 2000).

Monitoring is a critical element in any natural resources management plan for conservation or sustainable use. A dysfunctional program organisation and process can cripple a conservation effort as well as cause a major biological catastrophe (Kleiman *et al.* 2000). However, the complexity of systems to be managed makes the selection of appropriate indicators challenging because the suite of indicators must encompass sufficient breadth to provide the information for feedback, without being too cumbersome or expensive to monitor effectively (Kremen *et al.* 1998). Development of further approaches to aid evaluation, such as threat reduction assessment, and reporting of evaluation efforts (whether successes or failures) (Salafsky and Margoluis 1999), will assist managers to develop standardised and cost-effective methods for defining and measuring conservation success.

A detailed evaluation of the success of my project was outside the scope of my research as a result of time restrictions. However, the necessity for project evaluation is discussed further in Chapters 10 and 11.

1.9. GOALS, AIMS AND OBJECTIVES OF MY RESEARCH

As stated above, the goal of my research was to *contribute to the effective conservation of the Irrawaddy dolphin population that inhabits the lower Mekong River*. My study had two main aims:

1. Contribute towards a comprehensive understanding of the population biology of the Mekong dolphin population.

2. Investigate social considerations directly relevant to the long-term conservation of the Mekong dolphin population.

To address each of these aims, my study had six specific objectives:

Objective 1. Determine the current status of freshwater populations of Irrawaddy dolphins at a global scale and investigate their susceptibility to threats (Chapter 2).

Objective 2. Provide information about the study area and justify why habitat conservation must be a major management priority (Chapter 3).

Objective 3. Investigate the historical status and local perceptions of the dolphin population relevant to conservation (Chapter 4).

Objective 4. Investigate the behavioural ecology of the Irrawaddy dolphin population in the Mekong River, to develop conservation strategies by providing baseline data on:

a. abundance (Chapters 5 and 6).
b. distribution and habitat preferences (Chapter 7).
c. school dynamics and social structure (Chapter 8).
d. mortality rates and causes (Chapter 9).

Objective 5. Investigate social considerations influencing conservation strategies and trial a ‘Dolphins for Development’ conservation initiative (Chapter 10).

Objective 6. Provide recommendations towards the effective conservation of Irrawaddy dolphins and their riverine habitat (Chapter 11).

1.10. THESIS FRAMEWORK AND OUTLINE

1.10.1. Conceptual Framework

The conceptual basis for my thesis was adapted from Groves' (2003), seven 'steps' of effective planning for biodiversity conservation. I also incorporated all elements of the conservation process (Figure 1.3), focusing on the first four components as a result of the lack of relevant information regarding the Irrawaddy dolphin population inhabiting the Mekong River.

The conceptual framework of my thesis therefore follow the following five steps (Figure 1.4):

1. identify conservation targets and assess existing management,
2. collect information and identify information gaps,
3. set conservation goals and priorities,
4. implement priority conservation goals,
5. review project activities and prioritise these accordingly.

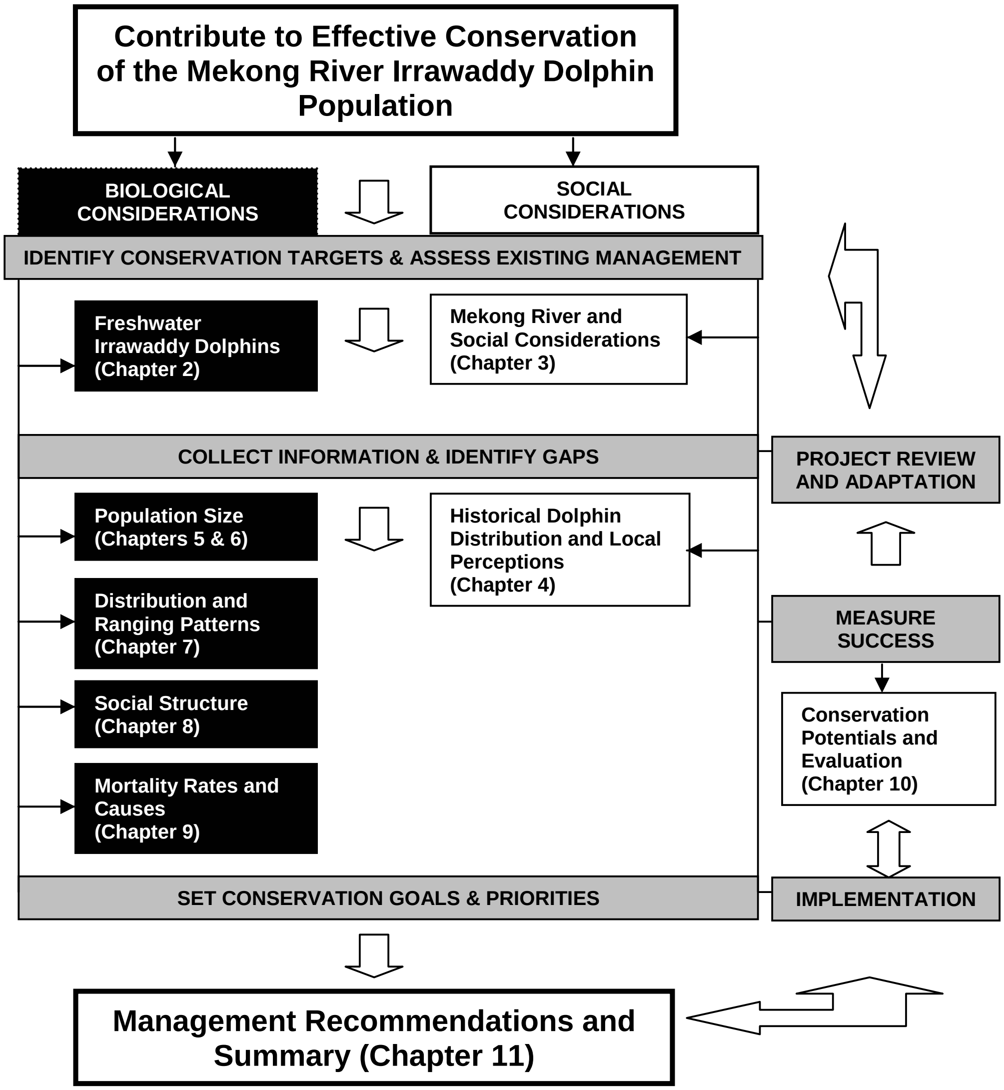


Figure 1.4. A conceptual framework of my thesis, as adapted from Groves (2003). My primary goal is to contribute to the effective conservation of the Irrawaddy dolphin population inhabiting the Mekong River, by considering both biological and social factors (shown by the black and white boxes respectively) of relevance to conservation and management.

1.10.2. Thesis Outline

My thesis consists of eleven chapters, arranged in four parts. The first part (Chapters 1-3) provides introductory material relevant to my study; the second part (Chapters 5-9) discusses my biological research; the third part (Chapters 4 and 10) discusses social considerations; and the fourth part (Chapter 11) provides the concluding management recommendations and discussion.

Chapter 2: *Freshwater dolphin populations at risk: Irrawaddy dolphins (Orcaella brevirostris) as a case study*. Comprehensive knowledge of the biological characteristics and ecological preferences of freshwater Irrawaddy dolphins is essential to design effective management strategies. In Chapter 2, I provide a comprehensive background on the status of freshwater Irrawaddy dolphins and their susceptibility to local extinction. I emphasise the importance of immediate and effective conservation initiatives to contribute to the populations' long-term survival and illustrate the significant value of freshwater dolphins as flagship species for conservation.

Chapter 3: *The Mekong River in peril: a history of the lower Mekong River and the importance of habitat preservation to species conservation*. Habitat preservation is an essential component of endangered species conservation. Of particular importance are habitats not yet significantly modified by human activities. The lower Mekong River is an example of a riverine habitat that remains relatively intact. Parts of this river stretch are still home to a wide variety of flora and fauna, many of which are now locally extinct in other countries. In Chapter 3, I provide an historical overview of the lower Mekong River, and a summary of the environmental and social factors that influence the design of my research. I outline the threats facing the river, the importance of community-based management and government support in successful conservation, and emphasise the importance of habitat preservation to species' conservation.

Chapter 4: *Evaluating the conservation status of Irrawaddy dolphins in the Mekong River using local knowledge*. Throughout the Mekong River, local subsistence fishers are integrally dependent on the river for their daily food requirements. Through long-term opportunistic observations, these fishers have significant knowledge of the patterns of occurrence of various species, their behaviours, life histories and the threats they face, particularly within areas the fishers commonly frequent. This local knowledge of flora and fauna can provide significant information relevant to the management of endangered species. Published scientific data are sparse concerning the historical distribution of Irrawaddy dolphins in the Mekong River. However, local communities have known of the dolphins' presence for many centuries (Chapter 4). In Chapter 4, I use local community knowledge to illustrate the historical distribution of the Irrawaddy dolphin in the Mekong River. I discuss local perceptions of the dolphins and fisheries conservation as well as factors perceived by local communities to threaten the dolphins, fisheries, and the integrity of the lower Mekong River.

Chapter 5: *Estimating abundance and assessing trends of Irrawaddy dolphin numbers in the Mekong River, based on capture-recapture analysis of photo-identified individuals*. Accurate and reliable estimates of total population size and trends in abundance are critical to formulating management initiatives for endangered species' conservation. Recent advances in analytical techniques using capture-recapture of photo-identified individuals have enabled researchers to obtain reliable abundance estimates from a wide range of species. However, as a result of the small size of endangered populations, it often remains difficult to assess trends in abundance, even with modern techniques. In Chapter 5, I estimate the population size of Irrawaddy dolphins in the Mekong River using closed population capture–recapture analyses of photographically-identified individuals. Based on the resulting estimates of precision, I estimate the statistical power necessary to detect a population change with ongoing surveys. I conclude this chapter by discussing the conservation and management implications of my results.

Chapter 6: *Population size estimates of freshwater Irrawaddy dolphins in the Mekong River, based on direct counts and distance sampling techniques*. Abundance surveys for Asian river dolphins have generally been conducted without rigorous or standardised survey design. As a result, many estimates of population size lack precision and are biased to an unknown degree. Reliable information on abundance is essential for monitoring trends in abundance and the development of management strategies for endangered species conservation. With limited resources available for endangered species conservation, it is imperative that available resources are used effectively to obtain the required information. In Chapter 6, I estimate the abundance of Irrawaddy dolphins that inhabit the Mekong River through direct counts and distance sampling techniques, investigate the statistical power necessary to detect a population change with ongoing surveys, and identify the survey methodology that provides the most reliable estimates of Irrawaddy dolphin population size in the Mekong River.

Chapter 7: *Distribution and habitat use of Irrawaddy dolphins in the Mekong River*. An understanding of the habitat preferences of Irrawaddy dolphins in the Mekong River, as well as identification of critical habitats, is fundamental to enhancing the conservation prospects of this population. In Chapter 7, I investigate the distribution and ranging patterns of Irrawaddy dolphins in the Mekong River and provide a discussion on observed changes in distribution based on previous occurrence records compared to my boat surveys and photo-identification of individuals.

Chapter 8: *School dynamics and social structure of Irrawaddy dolphins inhabiting the Mekong River*. An understanding of a population's social structure has important implications for conservation and management. In Chapter 8, I investigate the school dynamics and association patterns of the Irrawaddy dolphin population inhabiting the Mekong River. I assess the temporal variation in their association patterns and apply various models to determine the type of association that best describes their social structure. I compare the results of my study to other comparable studies of the genus *Orcaella* and discuss the implications of these findings towards the management of the Mekong dolphin population.

Chapter 9: *Mortality rates and causes affecting survival of the Irrawaddy dolphin population in the Mekong River*. Information obtained through a dedicated marine mammal carcass recovery programme can contribute to knowledge of trends in mortality rates and anthropogenic interactions, as well as provide information on stock identity, life history and contaminant levels. Such information is essential for developing effective management strategies for endangered populations. In Chapter 9, I provide significant new information on mortality rates of Irrawaddy dolphins in the Mekong River, based on results from a carcass recovery program that was undertaken throughout the duration of my study. I also discuss potential threats that may have an adverse impact on the dolphin population, other flora and fauna, and local communities that reside along the river.

Chapter 10: *Encouraging community support for Irrawaddy dolphin conservation: rural development, livelihood diversification and tourism*. Successful long-term conservation of endangered species and their habitats adjacent to human settlements requires the support and cooperation of local communities. In Chapter 10, I describe an integrated conservation development project, Dolphins for Development, that I trialled to increase the cooperation of local communities to conserve Irrawaddy dolphins in the Mekong River. I discuss the potential effectiveness of this project and introduce ‘community conscious conservation’ as a concept to guide species and habitat conservation in Cambodia.

Chapter 11: *Management recommendations for the conservation of Irrawaddy dolphins in the Mekong River:* Conservation and management of an endangered population requires a comprehensive adaptive long-term strategy that is developed and adopted by all stakeholders. In Chapter 11, I propose management and conservation recommendations to contribute to the long-term conservation of the Irrawaddy dolphin population inhabiting the Mekong River. These recommendations are based on all aspects of my research and conservation activities from 2001-2004.

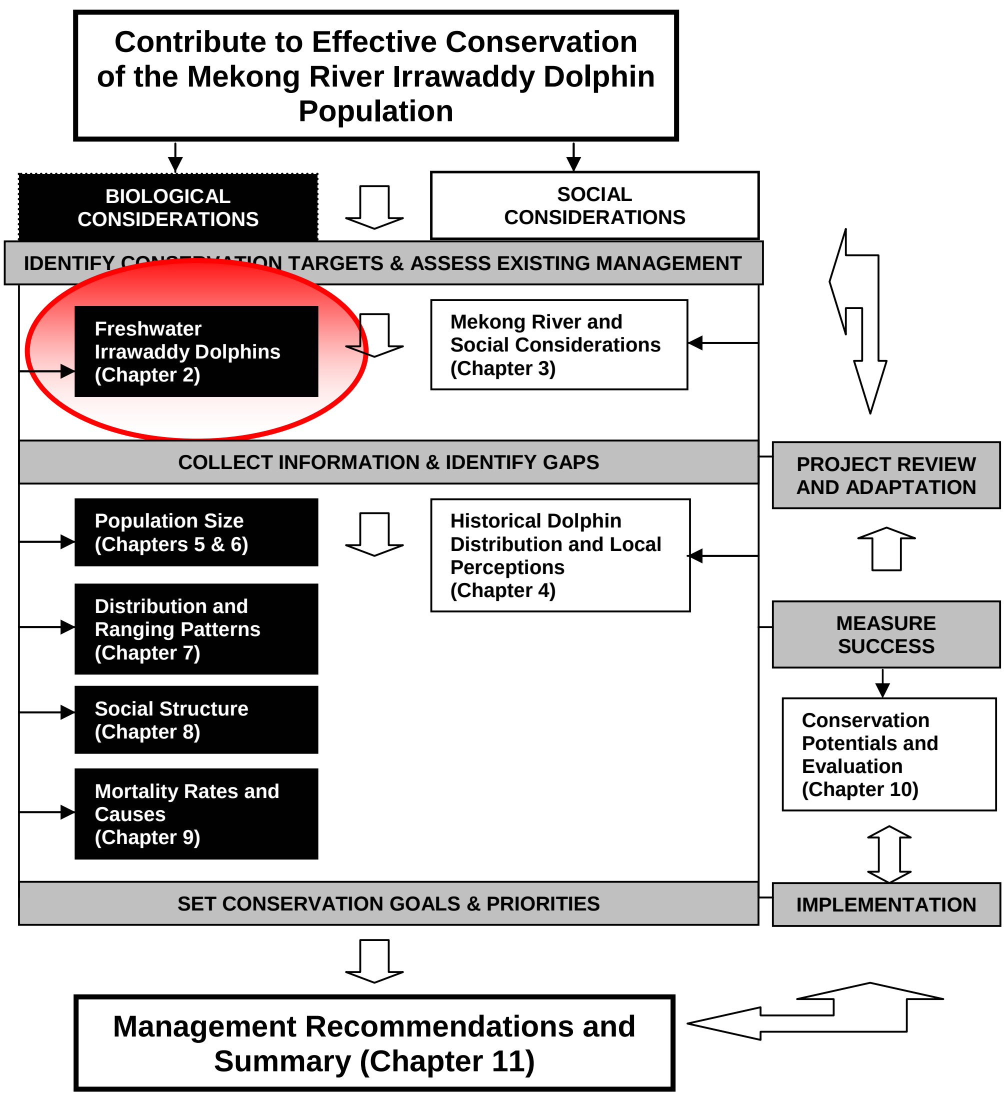
2. FRESHWATER DOLPHIN POPULATIONS AT RISK: IRRAWADDY DOLPHINS (*ORCAELLA BREVIROSTRIS*) AS A CASE STUDY

Freshwater Irrawaddy dolphins occur in three major river systems in Southeast Asia. Populations are reportedly small (each numbering no more than 200 individuals) and apparently declining. A comprehensive knowledge of the biological characteristics and ecological preferences of freshwater Irrawaddy dolphins is essential to design effective management strategies. In Chapter 2, I provide a comprehensive background on the status of freshwater Irrawaddy dolphins and their susceptibility to local extinction, emphasise the importance of immediate and effective conservation initiatives to the populations' long-term survival, and illustrate the significant value of freshwater dolphins as flagship species for conservation.

An Irrawaddy dolphin calf from the Mekong River, Cambodia

2. FRESHWATER DOLPHIN POPULATIONS AT RISK: IRRAWADDY DOLPHINS (*ORCAELLA BREVIROSTRIS*) AS A CASE STUDY

Chapter 2 provides a context for the biological considerations component of the '*identifying conservation targets and assessing existing management*' section of my conceptual framework. The aim of Chapter 2 is to determine the current status of freshwater populations of Irrawaddy dolphins at a global scale and investigate their susceptibility to threats (thesis objective 1: see Chapter 1).



2.1. INTRODUCTION

Freshwater habitats throughout the world are being subjected to unprecedented levels of human disturbance (Saunders *et al.* 2002). Increasing anthropogenic pressures that reduce water quality and quantity have led to significant degradation of freshwater systems. Species dependent of these freshwater habitats are in danger of disappearing (Saunders *et al.* 2002). Most of the world's river dolphins spend their entire lives in freshwater habitats. River dolphins are among the least known and most endangered of all cetaceans. They compete directly with humans for freshwater and fish, are subsequently facing many associated direct threats (Reeves and Leatherwood 1994). There are four species of obligate (true) river dolphins (three of which are only found in river systems): the Amazon River dolphin or boto (*Inia geoffrensis*), the Ganges River dolphin (*Platanista gangetica*), the Yangtze River dolphin or baiji, and the franciscana (*Pontoporia blainvillei*: which does not occur in freshwater and inhabits coastal/estuarine waters). Additionally, there are three species of facultative river dolphins (dolphins found in riverine, lacustrine and coastal waters but with separate populations/subspecies that occur only in river systems): the Yangtze River finless porpoise (*Neophocaena phocaenoides asiaeorientalis*); tucuxi (*Sotalia fluviatillis*); and the Irrawaddy dolphin. Obligate river dolphins are morphologically and phylogenetically distinct from facultative river dolphins and marine delphinids (Hamilton *et al.* 2001). With the exception of the boto and tucuxi, most river dolphin populations (hereafter referred to as freshwater dolphin populations to include those inhabiting lacustrine habitats) have received minimal dedicated study. Freshwater Irrawaddy dolphins are the focal species for my research. Recent studies throughout their range have increased knowledge of their biology and conservation status (Table 2.1).

The Irrawaddy dolphin was originally described as the short-snouted porpoise, from a specimen found in 1852 at the mouth of the Vishakhapatnam (Vizagapatam) River, along the east coast of India (Owen 1866). Irrawaddy dolphins reach lengths of 2.26 m (females) to 2.75 m (males) (Arnold and Heinsohn 1996, Beasley *et al.* 2002a), have a rounded forehead, small dorsal fin and disproportionately large paddle-like flippers (Figure 2.1).

Figure 2.1. An Irrawaddy dolphin photographed from the Mekong River, Cambodia. This image shows the characteristic slaty grey uniform colouration, rounded head and small rounded dorsal fin. Irrawaddy dolphins in the Mekong River rarely leap completely out of the water (as shown in this picture) and normally surface inconspicuously, with little of their body showing. Photograph by Yim Sak Sang.

It is only recently, as part of the work for this thesis (see Appendix I and II), that Irrawaddy dolphin stocks have been separated into two species: the Irrawaddy dolphin, which inhabits Asian waters, and the Australian snubfin dolphin which occurs in Australian and probably PNG waters (Arnold and Heinsohn 1996, LeDuc *et al.* 1999, Beasley *et al.* 2002a, 2005) (Figure 2.2). There are indications of further subspecies level differences within *O. brevirostris* based on habitat (e.g. freshwater and coastal); however, further study is required to elucidate these differences. Inclusion of further specimens from eastern Indonesia and Papua New Guinea in such studies will be particularly important (Beasley *et al.* 2005).

In this chapter, I review the biological and ecological aspects of freshwater Irrawaddy dolphin populations, to illustrate their susceptibility to threats and to demonstrate their status. I begin by outlining the demographic characteristics that accentuate their vulnerability and examine the range of human impacts that affect their long-term survival. I then provide examples of apparent population declines. Previous investigations into the socio-economic status and perceptions of local communities will be discussed, as well as current management and threat mitigation initiatives. I conclude by discussing the value of freshwater dolphins as a flagship species for freshwater habitat conservation.

Figure 2.2. Partial distributions of the Irrawaddy dolphin (black) and Australian snubfin dolphin (red). The species-level separation between the Irrawaddy and Australian Snubfin dolphin stocks appears to occur on either side of the deep-water straits of Indonesia.

2.1.1. Irrawaddy Dolphin Distribution

The Irrawaddy dolphin is distributed from the western Bay of Bengal, south to possibly Madras (Sathasivam 2002), east through Bangladesh, Myanmar, Thailand, Cambodia, southern Vietnam, southern Philippines (Palawan) and south through Malaysia, Brunei Darussalam, Singapore and Indonesia (including Kalimantan, Java and the east coast of Suluwesi) (Stacey and Leatherwood 1997) (Figure 2.2). Five freshwater Irrawaddy dolphin populations are recognised. Three populations occur in major river systems: the Mahakam (Kalimantan, Indonesia); Mekong (southern Laos, Cambodia and Vietnam); and Ayeyarwady (Myanmar) Rivers. Two populations occur in brackish/freshwater lakes: Songkhla Lake (Thailand) and Chilka Lake (India) (Figure 2.3).

Very little is known of the status of coastal Irrawaddy dolphin stocks and only one comprehensive study in Bangladesh has been undertaken on a coastal population to estimate abundance (Smith *et al.* 2005). Previous summaries of the status and distribution of Irrawaddy dolphins have been reported (Stacey 1996, Stacey and Leatherwood 1997, Stacey and Arnold 1999).

Figure 2.3. Locations of the five freshwater Irrawaddy dolphin populations, shown in red: Chilka and Songkhla Lakes (shown by red dots) and the Mahakam, Mekong and Ayeyarwady Rivers (shown by red lines).

2.1.2. Global Status

On a global scale, Irrawaddy dolphins are considered "Data Deficient" by the IUCN (CSG 1996). However, four of the five freshwater sub-populations have recently been classified as *Critically Endangered* by the IUCN (populations facing a high probability of extinction in the near future): the Makaham River (Kreb and Smith 2000); Mekong River (Smith and Beasley 2004b); Ayeyarwady River (Smith 2004); and Songkhla Lake (Smith and Beasley 2004c). Irrawaddy dolphins are currently listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which means that international trade of specimens is permitted only in exceptional circumstances, and any trade of live individuals is forbidden.

2.2. REVIEW OF FRESHWATER IRRAWADDY DOLPHIN POPULATIONS

Various summaries are provided on the ecology and status of freshwater dolphin populations (Perrin *et al.* 1989, Ridgway and Harrison 1989, Zhou and Zhang 1991, Perrin *et al.* 1996, Jefferson and Smith 2002, Perrin *et al.* 2005). In this section, I review the available information for freshwater populations of Irrawaddy dolphins. A summary of abundance estimates for each population is presented in Table 2.1.

2.2.1. Chilka Lake (India)

Chilka Lake is located adjacent to the Bay of Bengal in Orissa State, on the southeast coast of India (Figure 2.3). Chilka Lake is the largest brackish-water body in Asia, with an area of 1,100 km^2. The lake has historically been an important habitat for Irrawaddy dolphins, with sighting records dating back to 1875 (Stacey and Leatherwood 1997). Annandale (1915), was the first to provide detailed accounts of dolphins occurring in the lake, followed by occasional observations and carcass recovery nearly 80 years later (Dhandpani 1992, Sahu *et al.* 1998). Dedicated research and conservation work on this population was initiated by the Chilka Development Authority in 1999 and Dipani Sutaria (as part of her Ph.D with James Cook University, Australia), in 2004. Recent direct count surveys estimated a minimum of 89 dolphins inhabiting the lake (Table 2.1). Whether the dolphins from the lake are able to move out into coastal waters and vice-versa is uncertain, but recent data suggest that such movements are rare (D. Sutaira *pers comm*.).

2.2.2. Songkhla Lake (Thailand)

Songkhla Lake is located on the southwest coast of Thailand. The lake has a total area of 1,082 km^2 and is Asia's second largest freshwater lake (Beasley *et al.* 2002b). Few dedicated studies on dolphins have been conducted in Songkhla Lake, although dolphins have been known to occur there since the early work of Pilleri and Gihr (1974) (71 years after Irrawaddy dolphins were first recorded from Thailand) (Bonhote 1903).

In the late 1990s, the Songkhla Dolphin Conservation Group (SDCG), a group of local Thais worked to increase local awareness about dolphin conservation. They collected dolphin carcasses when reported by members of the public (Beasley *et al.* 2002b). Recent surveys indicate that the population of Irrawaddy dolphins inhabiting Songkhla Lake is very small, perhaps numbering no more than 20 individuals (Table 2.1). The Southern Marine and Coastal Resources Research Centre, Songkhla, reportedly continues research on Irrawaddy dolphins in the lake.

2.2.3. Ayeyarwady River (Myanmar)

The Ayeyarwady River flows through the entire length of Myanmar (approximately 2,200 km), before its reaches the Andaman Sea (Smith *et al.* 1997b). Irrawaddy dolphins were first reported in the Ayeyarwady River in 1871 by Anderson (1879) who described Irrawaddy dolphins in the Ayeyarwady River as distinct from *O. brevirostris* and classified them as a separate species, *Orcella* [sic] *fluminalis*. Subsequent authors reported no significant differences between Irrawaddy dolphin populations from various parts of Asia (Weber 1923, Lloze 1973, Pilleri and Gihr 1974), and concluded that all populations belonged to the same species. Recent taxonomic studies have also indicated a lack of difference between the Ayeyarwady River and other Irrawaddy dolphin populations (Beasley *et al.* 2002a, Beasley *et al.* 2005). However, limited skeletal material (cranial/postcranial) or tissue samples (genetic analyses) from the Ayeyarwady River population have been available for analyses.

In Myanmar, Irrawaddy dolphins have been reported along almost the entire navigable length of the Ayeyarwady River, from Prome (approximately 360 km from the sea), north, to just above Bhamo (1,500 km upstream) (Anderson 1879, Mörzer-Bruyns 1966, Pilleri and Gihr 1974, Smith *et al.* 1997b, Smith and Hobbs 2002). No dedicated surveys were undertaken until 1996 (Smith *et al.* 1997b) and recent research using direct counts has resulted in abundance estimates of 33-76 individuals (Table 2.1). The Myanmar Department of Fisheries now conducts research and conservation efforts.

2.2.4. Mahakam River (Indonesia)

The Mahakam River is located in East Kalimantan, Indonesia and measures 800 km from its origin to the river mouth. Irrawaddy dolphins in the Mahakam River are locally referred to as *pesut* and have been recorded up to 690 km upstream (Kreb 2004). Early studies on this population were conducted by Jaya Ancol Oceanarium, Jakarta, with the aim of live-capturing animals for display (Tas'an *et al.* 1980, Tas'an and Leatherwood 1984). Later studies focused on the dolphins' bioacoustics (Kamminga *et al.* 1983) and their distribution/daily movement patterns in Semayang-Melintang Lakes and the connecting Pela and Melintang tributaries (Priyono 1994). Recent research by Kreb (Kreb 1999; 2002, Kreb 2004) has contributed significantly towards an understanding of this freshwater Irrawaddy dolphin population and resulted in total population estimates of 33-55 individuals (95% C.L. 31-76) (Table 2.1). A local Non Government Organisation (NGO), Yayasan Konservasi RASI (Conservation Foundation for Rare Aquatic Species of Indonesia) continues conservation and research efforts.

2.2.5. Mekong River (southern Laos, Cambodia and Vietnam)

The Mekong River has a total length of 4,800 km and flows from Tibet south to the Vietnam Delta. Irrawaddy dolphins from the Mekong River were first reported in the literature in the mid 1960s (Mouhot 1966). The Khone Falls on the Laos/Cambodian border (located 560 km upstream from the river mouth) form a barrier to dolphin movement up-stream. Lloze (1973) conducted limited distributional and biological studies in 1968/69.

In the early 1990s, field research confirmed the presence of Irrawaddy dolphins in southern Laos and to a lesser extent in northeast Cambodia. Baird and Mounsouphom (1994, 1997) conducted studies on distribution and feeding and investigated mortality rates and causes at Chiteal Pool on the Laos/Cambodian border from 1992-1997. Daily observations to assess surface intervals and behaviour patterns were conducted by Stacey (1996) and Stacey and Hvenegaard (2002), and acoustic and visual studies were undertaken in March/April 1998 by Borsani (1999). Baird and Beasley (2005) conducted interviews with local fishers in the Sekong River and its tributaries in Laos (which converges with the Mekong River at Stung Treng, Cambodia: 500 km from the river mouth), which confirmed that dolphins historically ascended approximately 280 km up the Sekong River, to the Sekong tributary of Kaleum District in southern Laos.

Tana (1995) outlined the status of Irrawaddy dolphins in the Mekong River of Cambodia in a report submitted to Perrin *et al*. (1996), in which he concluded that the species was rare in riverine waters as a result of human activities, including direct persecution for oil extraction in Tonle Sap Great Lake during the mid 1970s. Baird and Beasley (2005) combined boat surveys and interviews in 1996, to assess abundance and distribution of dolphins in the upper Cambodian Mekong River. My study expands on these studies and further investigates historical dolphin distribution (Chapter 4).

There are three recently confirmed reports of Irrawaddy dolphins from the Vietnamese Mekong River. The first dolphin was reported as being captured in fishing gear near the Vietnamese/Cambodian border in 1997. I confirmed this report after observing a photograph of the dolphin being buried in a dedicated ceremony. In March 2002, a second Irrawaddy dolphin carcass was found by local fishers in Tien River (a branch of the Mekong River) in An Giang Province, Vietnam (near the Cambodian border) (Chung and Ho 2002). A third dolphin was reportedly found in November 2005, again near the Vietnamese/Cambodian border. These three dolphins are the only recently confirmed records known from the Vietnamese Mekong River.

Previous to the 1997 record, the last known reports were apparently in the 1920s (Krempf 1924-25, Gruvel 1925, Lloze 1973)[5]. Irrawaddy dolphin specimens have also been discovered in various whale temples in Vung Tau and Binh Thang, which are situated near the Mekong River Delta, Vietnam (Smith *et al.* 1997a, Beasley *et al.* 2002a). However, based on local reports of Irrawaddy dolphins occurring along the Vietnamese coast (Chapter 4), it is likely that these specimens were from coastal populations.

Prior to my study, only one attempt was made to estimate the population size of Irrawaddy dolphins in the Mekong River (Baird and Beasley 2005; Table 2.1). This study resulted in estimates of no more than 200 individuals remaining in the river. My research has resulted in robust estimates of total population size, to assist with monitoring and prioritisation of management strategies (Chapters 5 and 6). The World Wildlife Fund – Cambodia Program continue research and conservation efforts in Cambodia.

[5] I was not able to locate Krempf (1924-25) or Gruvel (1925).

Table 2.1. A summary of previous attempts to estimate abundance of freshwater Irrawaddy dolphin populations.

Population	Date of survey	Reported abundance	Survey methodology	Reliability of estimate[1]	Reference
Chilka Lake	1990s	Min. 20 individuals	Opportunistic	Best guess only	(Dhandpani 1992)
	Feb 2002	45 groups sighted, with a best estimate of 89 dolphins	Direct counts covering major portion of lake (422 km over 27 hrs)	Provides minimum estimate but no estimate on proportion of dolphins missed or potential for double counting provided	(Chilka Development Authority 2002)
Songkhla Lake	1990s	Estimate of 100 dolphins	Opportunistic	Best guess only	(Anderson and Kinze 1994)
	2000	Min. 20 individuals	Standardised distance sampling	No reliable estimate possible as a result of low sightings (4 groups after 545.2 km boat survey and 204.4 km aerial survey)	(Beasley *et al.* 2002b)
Ayeyarwady River	1996-2004	Range of 33-72 individuals (best estimate) from eight surveys	Direct counts, direct counts with independent observer and two independent teams	Provides minimum estimates No evidence of population size resulting from the use of direct counts	(Smith *et al.* 1997b, Smith and Hobbs 2002, Smith and al. 2002, Smith 2004)
Mahakam River	mid 1980s	100-150 individuals	No surveys undertaken	Best guess only	Indonesian Nature Conservation Office (Tas'an and Leatherwood 1984)
	1990s	68 individuals	Opportunistic	Best guess only	(Priyono 1994)
	1999-2002	33 to 55 individuals (95% C.L. 31-76)	Direct counts, distance sampling (strip and line-transect) and mark-recapture using photo-identification	Reliable with estimates of precision (co-efficient of variation: CV) provided	(Kreb 2004)
Mekong River	1997	40 sighted (200 individuals total estimated)	Direct counts	Provides minimum estimate (only best guess at total population)	(Baird and Beasley 2005)
	2001 - 2005	136 – 178 individuals	Direct counts, distance sampling and mark-recapture using photo-identification	Reliable with associated CV provided	As part of this study: Chapters 5-6

[1]. My estimate of reliability is based on the survey technique used and the inclusion, if any, of associated estimates of precision.

2.3. NATURAL SUSCEPTIBILITY TO ANTHROPOGENIC IMPACTS

Many species currently under threat are large-bodied and/or specialised, two characteristics that usually lead to low population densities (Shaffer 1981). As a result of these factors and additional biological considerations (outlined below), freshwater dolphin populations are naturally susceptible to anthropogenic impacts.

2.3.1. Risks Associated with Small Populations

It is estimated that no more than 200 Irrawaddy dolphins remain in either the Mekong River (Chapters 5 and 6) and Chilka Lake (Chilka Development Authority 2002) and less than 100 dolphins in each of the other areas: Ayeyarwady River (Smith 2004), Mahakam River (Kreb 2004) and Songkhla Lake (Beasley *et al.* 2002b) (Table 2.1). Based on current population estimates, mortality rates and habitat reductions, there is clear evidence that populations are small and declining. Although further research is needed to obtain accurate and precise estimates of abundance for these populations, small population sizes further accentuate the difficulty of obtaining accurate abundance estimates (Smith *et al.* 2003a). The recent listing of four of the five freshwater populations as *Critically Endangered* by the IUCN (Smith 2004, Smith and Beasley 2004a, Smith and Beasley 2004b; c), provides clear justification for concern regarding all freshwater Irrawaddy dolphin populations.

Very small populations are at risk, simply because of their size (Soule *et al.* 1988, Berger 1990, Caughley and Gunn 1996, Reed *et al.* 2003). Small populations are particularly susceptible to threats such as:

1. *demographic stochasticity* (e.g. the effect of chance on whether a population of a few animals increases, or decreases over a year, rather than depending on the age-specific probabilities of survival and reproduction (May 1973, Roughgarden 1975, Shaffer 1981, Caughley and Gunn 1996);
2. *environmental stochasticity and natural catastrophes* (e.g. temporal variation of habitat parameters and the populations competitors, predators, parasites and diseases (May 1973, Roughgarden 1975); and floods, fires, droughts etc., which may occur at random intervals through time: (Shaffer 1981)); and
3. *genetic stochasticity* (e.g. loss of the natural genetic variation common in large populations, resulting from changes in gene frequencies as a result of the founder effect, random fixing or inbreeding (Berry 1971, Roughgarden 1975).

The effects of small population sizes on social structure are also potentially important. Many species have elaborate social breeding systems, or feed and move in schools and swarms for reasons of defence, or feeding efficiency (the social structure of the Mekong River Irrawaddy dolphin sub-population is investigated in Chapter 8). There is minimal information available on the consequence of reduced population size and the functioning of social behaviours. Some researchers believe that the collapse and extinction of the huge flocks of passenger pigeons (*Ectopistes migratorius*) once estimated to have a total population of 3-5 billion individuals (Ellsworth and McComb 2003), was catalysed when numbers decreased to the point that the birds were increasingly susceptible to slaughter and social systems were degraded. This degradation of social systems reportedly caused decreased reproductive and foraging success (Greenway 1967, Halliday 1978, Reed 1999), therefore accelerating extinction (Schorger 1955).

The minimum viable population (MVP) size (*i.e.*, the smallest size required for a population of a species to have a predetermined probability of persistence for a given length of time (Shaffer 1981), is not known for small cetaceans, or any other species, although many have attempted to answer this question (Franklin 1980, Lande and Barrowclough 1987, Reed *et al.* 2003). Importantly, a MVP is not one that can simply maintain itself under average conditions but one that is of sufficient size to endure the calamities of various perturbations and do so within its particular biogeographic context (Shaffer 1981, Thomas 1990). Reed *et al*. (2003) used population viability analysis to estimate MVPs (99% probability of persistence for 40 generations) for 102 vertebrate species and concluded that to ensure long-term persistence, at least 7000 breeding age adults were required (with sufficient habitat). However, genetic studies conducted on the New Zealand Chatham Island black robin (*Petroica traversi*), where the entire current population of ~200 individuals is derived from a single breeding pair, suggests that the population is viable under existing conditions, thus illustrating that significant levels of genetic variation are not a necessary prerequisite for endangered species survival (Ardern and Lambert 1997). As Caughley and Gunn (1996) state, '*common-sense tells us that there is no single number that tips a species into the small, or minimum viable population categories*'. There are various examples of small populations, such as the black footed ferret (*Mustela nigripes*) (May 1986, Seal *et al.* 1989, Russell *et al.* 1994), Californian condor (*Gymnogyps californianus*) (Sarrazin and Barbault 1996) and northern elephant seal (*Mirounga angustirostris*) (Hoelzel *et al.* 2002, Weber *et al.* 2004), that have been brought back successfully from the brink of extinction. However, many species (such as the dodo *Raphus cucullatus*), have not been as fortunate and are now extinct (Quammen 1996). Recent studies have focused more on estimating risk and identifying risk factors and threatening processes, rather than attempting to estimate MVPs (Maquire and Lacy 1990, Maquire 1991, Maguire 1992, Ralls and Starfield 1995, Slooten *et al*. 2000).

2.3.2. Habitat Preferences

The close proximity of freshwater dolphins to human activities, makes them particularly susceptible to the detrimental effects of anthropogenic threats, including accidental catch in fisheries, agricultural activities and pollution (see '*2.5. Threatening Processes*'). As a result, all freshwater Irrawaddy dolphin populations are currently vulnerable to human disturbance and local extinction.

Unlike more ecologically flexible dolphin species, such as bottlenose dolphins (*Tursiops* sp.) (Leatherwood and Reeves 1990), freshwater dolphins have adapted to relatively rare and restricted ecological conditions within freshwater systems. In major river systems, Irrawaddy dolphins commonly prefer deep, slow-moving water areas. These areas are also preferred habitats of many migratory and sedentary fish species, often attracting high levels of human fishing activity (Kreb 2004). In the upper Cambodian Mekong River (including the Laos/Cambodian border), Irrawaddy dolphins are commonly found in deep pool areas, normally at the confluences of rivers, above or below mid-channel islands, or below rapid systems, especially during the dry season (Baird and Mounsouphom 1994, Stacey 1996, Stacey and Hvenegaard 2002, Baird and Beasley 2005). Irrawaddy dolphins in the Ayeyarwady River are found in the deep-water reaches of the river, where the depth is 40-60 fathoms (73-110m: Anderson 1879) and prefer areas of slow-moving water, such as those sheltered by mid-channel islands (Smith *et al.* 1997b). In the Mahakam River, Indonesia, the dolphins' main habitat includes areas of confluence between the main river and tributaries or lakes, in which dolphins use small areas intensively (including confluences), moving upstream and downstream daily over an average length of 10 km of river and within 1.1 km^2 area. These areas are also primary fishing grounds and subject to intensive motorised traffic (Kreb 2004). In Songkhla Lake, the few recent sightings have been in Thale Luang, the deepest section (2-4 m) of the freshwater portion of the lake (Beasley *et al.* 2002b). In Chilka Lake, dolphins are found primarily in the deeper channels (3-4 m) near the lake mouth (Chilka Development Authority 2002).

During the flood season, riverine Irrawaddy dolphins were known to undertake seasonal large-scale migrations of up to 300-400 km up tributaries to follow fish migrations and into large lakes where fish congregate to spawn (Coates *et al.* 2003) (e.g. Tonle Sap Great Lake, Cambodia: Baird and Beasley 2005 and Semayang Lake, Mahakam River: Kreb 2004). These large-scale migrations may now occur only infrequently as a result of a reduced dolphin population and increased human activity along the river (Baird and Beasley 2005).

2.3.3. Survival and Life History

Although there is a reasonably good understanding of the life-history of many freshwater dolphin species (Brownell 1984, Perrin *et al.* 1989), there is virtually nothing known about Irrawaddy dolphin populations (coastal and freshwater).

Based on observations between February 1999 and August 2002, Kreb (2004) reported that Mahakam River Irrawaddy dolphin birth and mortality rates were similar, *i.e*., 13.6% and 11.4% respectively. No changes in abundance >8% were detected over 2.5 years (see Kreb 2004). There is no detailed information on the maximum age, or age of sexual maturity of the Irrawaddy dolphin. What is currently known at the generic level has come from studies conducted on the Australian snubfin dolphin (Heinsohn 1979, Marsh *et al.* 1989), the closest relative of the Irrawaddy dolphin. The maximum age of the snubfin dolphin is estimated to be 30 years, with age at sexual maturity being reached at 4-6 years (Heinsohn 1979, Marsh *et al.* 1989).

Previous information on freshwater Irrawaddy dolphin life history has come from studies of captive animals and necropsy descriptions of Irrawaddy dolphins from the Mekong River (Lloze 1973). Anecdotal information was gathered from dolphins held in captivity in Indonesia, live-captured from the Mahakam River. A female dolphin was born in captivity in Jakarta after a gestation period estimated (from the time between the last observed mating and parturition) to be 14 months (although a gestation period of 11 months is more likely: see Appendix VI). The calf started suckling 12 hours after birth and began eating dead fishes at the age of 6 months. It was fully weaned by two years of age (Tas'an *et al.* 1980, Marsh *et al.* 1989).

Predicting the viability of Irrawaddy dolphin populations in freshwater systems with continued anthropogenic-caused mortalities is difficult as a result of minimal available data on Irrawaddy dolphin life-history. However, Kreb (2004) estimated various parameters based on Marsh *et al*. (1989) and results from Kreb (2004). Based on studies of other small cetaceans (Perrin and Reilly 1984, Pichler *et al.* 2003), Irrawaddy dolphins are likely to exhibit late onset of maturity; a minimum 10 month gestation period; long calving intervals of two to four years; and a lactation period from one to two years. With a probable population growth of 2% per annum under ideal circumstances (based on studies conducted on other small cetaceans (Slooten and Lad 1991), I predict that Irrawaddy dolphins will not recover quickly from population decline.

2.4. EVIDENCE OF POPULATION DECLINES

Of critical importance to the development of effective management strategies for freshwater dolphins is an understanding of population size and degree of change over time. There is significant anecdotal evidence of population declines from nearly all freshwater Irrawaddy dolphin populations. However, in the absence of previous dedicated research (with many previous estimates being no more than educated guesses), conclusions about the degree of these declines are limited. Table 2.2 provides a comparison of reported occurrence and abundance for freshwater Irrawaddy dolphin populations.

As a result of the small population sizes of the remaining populations, it will be difficult to detect a statistically significant declining trend (Taylor and Gerrodette 1993). By the time a trend is detected with a high level of statistical confidence, the population will be approaching local extinction. Scientists and managers have emphasised the need for a precautionary approach towards management of seemingly small and declining populations (Mayer and Simmonds 1996, Thompson *et al.* 2000, Pichler *et al.* 2003).

2.5. THREATENING PROCESSES

Threats facing cetaceans have changed through time. Many species were previously directly hunted for food or oil, or because of perceived competition with fisheries. Additional serious threats have recently been recognised: accidental catch in fisheries, habitat degradation, and pollution (Reeves *et al.* 2003). Increasing human populations and rapid economic development, particularly throughout Asia, cause additional threats (Dudgeon 2000a; b; c; d). Freshwater dolphins are often in direct competition with humans for space. As a result, many freshwater dolphin populations are facing threats that coastal or oceanic cetaceans do not encounter. Historical and contemporary threats to freshwater Irrawaddy dolphin populations include: direct take, live-capture for display, dolphin-watching tourism, fisheries related impacts, and habitat degradation, as detailed in Smith and Smith (1998).

Table 2.2. Comparisons of previous and current freshwater Irrawaddy dolphin abundance estimates and historical distribution. Many of the previous estimates are anecdotal reports, or best guesses, as a result of a lack of detailed study.

Population	Previous estimates/range	Current estimates/range
Songkhla Lake	100 dolphins estimated in 1992 (Andersen and Kinze 1993).	Less than 15 dolphins in 2001 (Beasley *et al.* 2002a).
	Commonly sighted from shore (Beasley *et al*. 2002a, anecdotal reports from local residents).	Never sighted from shore (Beasley *et al*. 2002, anecdotal reports from local residents).
Mekong River	Ranged from Khone Falls (Laos/Cambodian border) south into the Vietnamese Mekong (incl. Tonle Sap Great Lake) (Lloze 1973)	Boat and interview surveys of the entire Cambodian Mekong River (incl. Tonle Sap Great Lake) sighted and received reports of dolphins only in a 190 km section from Kratie north to Khone Falls (Laos/Cambodian border) (Baird and Beasley 2005, Chapters 5, 6 and 7).
	Local people reported commonly seeing dolphins all along the Cambodian Mekong River (incl. Tonle Sap Great Lake (Beasley *et al.* 2003).	Local people south of Kratie now rarely see dolphins, if at all (Baird and Beasley 2005, Chapter 4).
	Approximately 30-35 dolphins sighted by Beasley *et al*. (2003) in 1997 in Chiteal Pool.	Estimates of 8-10 dolphins in Chiteal Pool by Borsani (1999) and 9-10 by my research (Chapter 5).
	Dolphins previously reported to be very common within a 200-km section of the Sekong River (Baird and Mounsouphom 1994).	Dolphins now not reported to occur in the Sekong River (Baird and Beasley 2005).
Mahakam River	Dolphins previously occurred 60 km upstream from the river mouth (Kreb 2004).	Based on interviews and personal observations by Kreb (2004) a range decline occurred, with dolphins now not being found below 120 km upstream from the river mouth.
	Previously sighted in Semayang and Jempang Lakes (Tas'an and Leatherwood 1984).	Dolphins no longer sighted in the Lakes (Kreb 2004).
Ayeyarwady River	Reported along the Ayeyarwady River (Anderson 1879).	Absence of dolphins downstream of Mingun – a potential range decline of 488 km in river length (60% of previous distribution) compared with historical distribution (Smith 2004).
Chilka Lake	Previous estimates of 20 individuals (Dhandapani 1992).	Recent estimates of a minimum of 89 individuals (CDA 2002).

2.5.1. Direct Take

Historical reports of dolphins killed by hand harpoons for their oil and other body parts are known from Chilka Lake (Annandale 1915, Dhandpani 1992), the Ayeyarwady River (Smith *et al.* 1997b) and the Mekong River (Tana 1995, Perrin *et al.* 1996). The most devastating direct take was that in Tonle Sap Great Lake, Cambodia, by the Khmer Rouge[6] from 1975-1979. Large numbers of dolphins (at least three to four dolphins a day over certain seasons) were reportedly killed for their oil, for use in lamps and motorbikes (Perrin *et al.* 1996, Chapter 4). This slaughter was followed by indiscriminate killing for target practice by soldiers after the Khmer Rouge regime (1979-late 1980s) (Baird and Mounsouphom 1994).

The current level of direct take of freshwater Irrawaddy dolphins is likely low. However, in areas where numbers of Irrawaddy dolphins are greatly reduced, any directed takes will have significant damaging impacts (Stacey and Leatherwood 1997). Direct take now occasionally occurs in only two known countries: Cambodia and Indonesia (Kalimantan). In Cambodia, dolphins move downstream from the upper Cambodian Mekong River when the river floods and there are recent reports of Khmer-Islam fishers catching the dolphins in seine nets and killing them for food (Beasley *et al.* 2003, Baird and Beasley 2005). Direct captures have also been reported from the Mahakam River, where 10% of deaths resulted from deliberate kills, often in isolated areas where dolphins rarely occurred (Kreb 2004).

2.5.2. Live- Capture for Display

Twenty-two Irrawaddy dolphins were captured from the Mahakam River by Jaya Ancol Oceanarium, Jakarta, in 1974 (6 dolphins), 1978 (10 dolphins) and 1984 (6 dolphins) (Tas'an *et al.* 1980, Tas'an and Leatherwood 1984, Wirawan 1989). All have since died. A further seven were reported to have been illegally captured in 1997 and 1998 (D. Kreb *pers comm*.); however, the fate of these dolphins remains unknown. Irrawaddy dolphins inhabiting the Mahakam River are now protected by law against further live-capture. There is no known live capture from other freshwater Irrawaddy dolphin populations, although coastal Irrawaddy dolphins have been captured from Thai and Cambodian waters (Perrin *et al*. 2005, Figure 2.4).

[6] The Khmer Rouge regime followed the cessation of the Vietnam War from 1975-1979. It was estimated that over 1 million Cambodians lost their lives during this regime.

Figure 2.4. Irrawaddy dolphins live-captured from coastal Thai waters and held for public display at Oasis Sea World, Chantaburi Province, Thailand, near the Thai/Cambodian border.

2.5.3. Dolphin-Watching Tourism

Dolphin-watching for Irrawaddy dolphins is only known from three areas: Chiteal Pool on the Laos/Cambodian border (Figure 2.5); Kampi Pool, Cambodia; and Chilka Lake, India. The effects of these dolphin-watching tourism operations on dolphins are unquantified. However, such activities are potentially a threat to the dolphins' natural behaviours (e.g. feeding, resting, socialising) through daily harassment by boats, increased noise pollution from boat engines and water pollution from garbage (including plastics). Fatal collisions between tourism boats, and dolphins have been reported from Chilka Lake (Chilka Development Authority 2002).

Few communities are receiving direct financial benefit from this tourism. Baird (2004) reviewed dolphin-watching tourism at Chiteal Pool and concluded that the government authorities and villagers need to work together to establish new regulations to reduce the impact of dolphin-watching on the dolphins, and ways need to be found to increase dolphin tourism benefits to adjacent villagers, in order to provide these communities with additional incentives to protect dolphins.

Figure 2.5. An example of the dolphin-watching boats now used at Chiteal Pool to observe dolphins. The area is very small (1 km^2) and this photograph shows the main habitat for the dolphins.

2.5.4. Fisheries-Related Impacts

In common with other freshwater dolphin species and almost all cetacean species around the world, incidental catch in gillnet fisheries is a significant threat to Irrawaddy dolphins (Stacey and Leatherwood 1997). Incidental catch in gillnets (particularly large mesh gillnets) affects all freshwater populations of Irrawaddy dolphins and is reported for Songkhla Lake (Andersen and Kinze 1993, Beasley *et al.* 2002b), Chilka Lake (Mohan 1994, Chilka Development Authority 2002), the Ayeyarwady River (Smith *et al.* 2003a), the Mahakam River (Kreb 2004) and the Mekong River (Baird and Mounsouphom 1994, Perrin *et al.* 1996, Baird and Mounsouphom 1997, Beasley *et al.* 2003, Baird and Beasley 2005) (Figure 2.6). Thus, incidental capture in gillnets is currently one of the major causes of mortality for freshwater Irrawaddy dolphins and, given the small size of populations, is likely leading to population declines.

Destructive fishing methods, such as electric and dynamite fishing have taken their toll on many freshwater Irrawaddy dolphin populations (Stacey and Leatherwood 1997), especially in the Mekong River (Baird 1994, Perrin *et al.* 1996, Baird and Mounsouphom 1997). A dolphin was killed by explosives in the Srepok River, Mondulkiri Province, Cambodia in 2005 because of local concern over potential restricted access to fishing rights if the dolphins occurred in the area (AFP 2005).

Figure 2.6. An Irrawaddy dolphin captured by a large mesh gillnet in the Mekong River, Cambodia in February 2001. The indentations from the net can be viewed just behind the flippers and neck region (indicated by the arrow).

2.5.5. Habitat Degradation

To conserve freshwater Irrawaddy dolphins in the long-term, their habitat must be protected. The current sources of habitat degradation that affect freshwater Irrawaddy dolphins include: dams, declining food sources, pollution, deforestation, and sedimentation of lakes (Stacey and Leatherwood 1997). Examples of these pressures are illustrated by:

1. declining fish stocks in the Mekong River as a result of increased fishing effort and upstream activities, such as dam construction and the use of pesticides (Roberts 1993);
2. loss of habitat in the Mahakam River through increased industrial activity (Tas'an *et al.* 1980, Tas'an and Leatherwood 1984);
3. skin disease in the Mahakam River population thought to be caused by water chemistry changes (Wirawan 1989);
4. sedimentation in Chilka Lake, which caused the lake opening to close for a time and increase salinity (Dhandpani 1992), before it was re-opened by the Chilka Development Authority in 2001 (Chilka Development Authority 2002); and

5. significant habitat degradation through over-fishing, eutrophication and pesticides being used near the lake margins in Songkhla Lake and the use of extensive fixed fishing gears near the lake entrance (Beasley *et al.* 2002b).

Levels of persistent organic pollutants including organochlorine pesticides, polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers, were measured in tissues of Irrawaddy dolphins collected from Chilka Lake (Kannan *et al.* 2005). The concentrations of organochlorine pesticides and PCBs in Irrawaddy dolphins were lower than the concentrations reported for coastal and riverine dolphins collected in Asia. However, Kannan *et al*. (2005) recommended that efforts should be made to decrease the sources of contamination of dichlorodiphenyltrichloroethane (DDTs) and hexachlorocyclohexanes (HCHs) in Chilka Lake, to minimise the potential for reduced fitness and additional anthropogenic mortalities.

Freshwater Irrawaddy dolphin populations are not currently facing immediate water development threats, which can result in fragmentation of dolphin populations, reduction in water quantity, habitat degradation, and ecosystem decay. However, it is likely that as development proceeds throughout Asia, these will be additional concerns for the future. In order to conserve freshwater dolphins, it is essential that their habitat is preserved as a matter of priority (Chapter 3).

2.6. SOCIO-ECONOMIC STATUS AND LOCAL PERCEPTIONS OF VILLAGERS

Social factors and local perceptions significantly influence the potential success of conservation and management programs (Bunce *et al.* 2000). There has been little effort to assess the socio-economic status of local people living adjacent to freshwater dolphin habitats and their relation to dolphin/fisheries conservation. There are only two published investigations into local perceptions and knowledge concerning status, conservation and protection of freshwater Irrawaddy dolphins, and no studies of other freshwater dolphin populations. The studies relevant to freshwater Irrawaddy dolphins were conducted in southern Laos and the upper Cambodian Mekong River in 1996 (Baird and Beasley 2005) and Mahakam River in 1999-2002 (Kreb 2004). Kreb (2004) assessed the attitudes of local villagers towards conservation of Irrawaddy dolphins in the Mahakam River. Of 258 respondents, 75% believed dolphins were advantageous to them (e.g. indicating good fishing areas, enjoyable to observe); 99% believed the dolphins need to be protected (e.g. rare mammals, indicator of good fish seasons, tourism value); 74% agreed to establishing protected areas (e.g. under certain conditions); 64% stated they would feel regret if the dolphins became extinct (e.g. pride of Kalimantan, rare species, indicator of good fish seasons). Local residents adjacent to the Mekong River reported positive perceptions towards dolphins and an eagerness to assist with conservation programs (Baird and Beasley 2005).

2.7. CONSERVATION, MANAGEMENT AND THREAT MITIGATION

Despite the critical situation facing freshwater dolphin populations, there has been a notable absence in long-term, on-the-ground conservation measures, which are integrated into an overall management plan for each population. Such a coordinated management approach is essential if freshwater dolphin populations are to survive. The following section outlines the various conservation, management and threat mitigation activities that have been implemented to protect freshwater Irrawaddy dolphin populations

2.7.1. Cultural Protection

Freshwater Irrawaddy dolphin populations are generally revered by local people (Stacey and Leatherwood 1997). The Ayeyarwady population receives customary protection from direct killing, or intentional disturbance, as a result of positive interactions with local fishers. Thein (1977) reported that Irrawaddy dolphins in the Ayeyarwady River were venerated by the Myanmar people and he recounted second-hand observations of a cooperative fishing practice between local fishermen and Irrawaddy dolphins. This fishing method has since been confirmed and observed by Smith *et al.* (1997b) and Tun (2004). In the Mekong River, fishermen regard Irrawaddy dolphins as sacred animals resulting from a well-known folklore in the region (although folklores differ between southern Laos, Cambodia and Vietnam) and try to release dolphins alive if they become entangled in nets. However, as mentioned previously, in contrast, Khmer-Islam fishermen of Cambodia still kill dolphins for food (Lloze 1973, Marsh *et al.* 1989). The generally positive attitude of local residents towards the conservation of Irrawaddy dolphins in the Mahakam River may further enhance prospects for conservation success (Kreb 2004). This local reverence for freshwater dolphins is likely to have contributed towards preventing local extinction of Irrawaddy dolphins in freshwater river systems. Other species inhabiting similar habitats that are not a revered by local peoples, such as the *Critically Endangered* Siamese Crocodile (*Crocodylus siamensis*), are now locally extinct in many parts of their former range, primarily as a result of direct persecution (Platt and Van Tri 2000).

2.7.2. Awareness Raising Programs and Community Involvement

Local people are more likely to appreciate and play a role in conserving river dolphins if they understand their cultural and ecological values (Smith and Smith 1998). Education and community awareness-raising initiatives have been developed and implemented to varying degrees in all areas frequented by freshwater Irrawaddy dolphins (Table 2.3). However, most efforts have been minimal, of short duration, and are not encompassed into an integrated management plan.

Table 2.3. Various awareness-raising conservation initiatives implemented to conserve freshwater Irrawaddy dolphin populations

Conservation Initiative	Ayeyarwady River	Chilka Lake	Mahakam River	Mekong River	Songkhla Lake
Nationally Adopted Management Plan				X	
Conservation Posters	X	X	X	X	
Conservation Leaflets			X	X	
Children's Books		X		X	X
School Visits			X	X	
Colouring Competitions					X
Village Workshops	X		X	X	
Fisherman Workshops			X		
Tourism Operator Workshops		X		X	
Signs and Billboards			X	X	
Visitors' Centre		X	X	X	X
Fun Run					X
Project Website			X[1]	X[2]	
References	Tint Tun (*pers. comm.* 2005)	Pattnaik (*pers comm.* 2005)	Kreb 2004	Beasley *et al*. 2003	Beasley *et al*. 2002

[1]http://www.geocities .com /yayasan_ konservasi_rasi. [2]http://www.mekongdolphin.org

2.7.3. Net-Compensation Packages

Net-compensation packages reimburse fishers for replacement costs of having to cut their nets to free dolphins, or other aquatic mega-vertebrates. Between 1993–1997, the Lao Community Fisheries and Dolphin Protection Project (LCFDP) worked with Laos communities to manage aquatic resources in a sustainable manner, and to reduce illegal fishing (e.g. electric fishing) and incidental catches of dolphins in gillnets (Baird and Mounsouphom 1994; 1997, Perrin *et al*. 1996). The LCFDP project established a fund so that fishermen who found dolphins entangled in their nets and cut them free would be compensated for damages (Baird *et al*. 1994). Throughout the duration of the project, only one fisher requested compensation for cutting a dolphin from his net, as no other entangled dolphins were reported during that time, or the dolphins had already died upon arrival of the fisher (Baird and Mounsphom 1997). Such net compensation packages may be an appropriate incentive for fishers to cut their nets to release dolphins alive. However, an important component of the program should be to ensure the goals and specifics of payment are adequately disseminated to villagers, and local communities are included in the initial design and implementation of such programs.

2.7.4. Integrated Conservation Development Projects

Integrated Conservation and Development Projects (ICDPs) aim to achieve conservation of endangered species and/or habitats, while simultaneously providing benefits to local communities (McShane and Wells 2004b). Although potentially contributing towards conservation, questions have been raised regarding the contribution of ICDPs to biodiversity conservation from both ecological (Robinson 1993) and social perspectives (Ghimire and Pimbert 1997, McShane and Wells 2004b). Conceptual flaws in ICDPs have become evident, such as local people being more likely to incorporate new sources of income as complements to existing activities, rather than as substitutes for them (Ferraro and Kiss 2002). A critical evaluation of community-based management and ICDPs is outlined in Chapter 10.

As part of my research, the Mekong Dolphin Conservation Project (MDCP), initiated the first known (ICDP) aimed at conserving a freshwater dolphin species in mid 2004 (Beasley 2005a). This project, named Dolphins for Development, was undertaken in collaboration with a local Cambodian Non-government Organisation (NGO), the Cambodian Rural Development Team (CRDT) in three villages adjacent to critical dolphin habitats. The focus of the project was to improve basic village hygiene (*i.e.*, provide toilets and access to freshwater through wells (Figure 2.7) and rainwater collectors); and assist to diversify local livelihoods and reduce fishing pressure in the river by provision of small livestock (pigs, ducks and chickens), bio-digesters (which produce methane gas) and initiation of land-based fish culture using native herbivorous fish. Importantly, intensive training of local villagers by CRDT team members regarding all project aspects, from construction of wells/toilets to small livestock disease control, were incorporated as a major component to this project. All project components were undertaken in parallel to MDCP awareness raising and conservation activities, which assisted to strengthen the villagers’ commitment to dolphin conservation (Chapter 10).

Preliminary indications of project success are encouraging, such as villagers requesting assistance to organise community patrols of the area to reduce illegal fishing, and the continued use of infrastructure such as toilets and wells. However, it will be essential that a formal project evaluation is conducted, to establish if the ICDP's aims are being achieved and are sustainable in the long-term.

Figure 2.7. One of the many wells that were constructed by the Cambodian Rural Development Team to provide access to freshwater, in rural villages adjacent to critical dolphin habitats. Photograph by Brendan Boucher.

2.7.5. Dolphin-Watching Tourism

Small-scale dolphin-watching tourism operations are outlined above (see '*2.6.3. Dolphin-Watching Tourism*'). Although listed as a threat, these operations present a significant opportunity to provide local villages with revenue from the dolphins and assist with gaining local support for dolphin conservation (Baird 2004). If dolphin-watching activities are well managed and regulated, local community involvement in such ventures should significantly assist with long-term conservation efforts (see Chapter 10 for further discussion).

2.7.6. Protected Areas

There are currently no known protected areas established specifically for freshwater Irrawaddy dolphins, although the Myanmar Government recently issued an Order (28 December 2005) for a protected area to be developed between the Hsithe and Mandalay segment of the Ayeyarwady River (Tint Tun *pers. comm.*). In other countries, protected areas are established but offer no protection for dolphins as a result of inadequate regulations with little community consultation (*i.e.*, Mekong Dolphin Royal Decree), or dolphins not occurring in the site (*i.e.*, Stung Treng Ramsar Site) (Table 2.4).

Protected areas should be an important component of any effective conservation strategy towards freshwater Irrawaddy dolphins (Stacey and Leatherwood, 1997). However, when developing protected areas, it is essential that conservation objectives are defined, and areas selected are biologically significant and scientifically valid with regards to the species/habitat to be protected (*i.e.*, considering size, shape and connections between reserves). It is essential to have adequate enforcement capabilities and full involvement of, and co-operation with, local communities living in, or adjacent to the protected area (Caughley and Gunn 1996).

2.7.7. Legislation

Legislation provides an essential basis for the development of conservation and management programs. Legislation to protect freshwater Irrawaddy dolphins is available, or being developed, for all populations (Table 2.5). However, enforcement of regulations is not logistically, or politically possible in many developing countries.

2.8. THE VALUE OF FRESHWATER DOLPHINS AS A FLAGSHIP SPECIES

The validity of continuing efforts to conserve small marine and terrestrial populations, often referred to as species ‘triage’, has been debated on numerous occasions (Vane-Wright *et al.* 1991, McIntyre *et al.* 1992, Beever 2000). A recent example of such a debate concerns the Yangtze River dolphin, or baiji, which is considered to be the rarest large mammal on earth and facing imminent extinction (Dudgeon 2005, Kleiman 2006, Reeves and Gales 2006, Wang *et al.* 2006, Yang *et al.* 2006)[7].

[7] A six-week survey of the entire lower Yangtze River in 2005 failed to site a single baiji. The species is now considered functionally extinct (www.baiji.org).

Table 2.4. Known, proposed, or recommended protected areas for freshwater Irrawaddy dolphins

Country	Name	Status	Comments
Cambodia	Stung Treng Ramsar Site	Established. Declared as a Ramsar site in 1999. Site extends 37 km along the Mekong River from 6 km north of Stung Treng town to 3 km south of the Lao border	The Irrawaddy dolphin was part of the rationale for protection (Hoyt 2004). However, the site does not contain dolphins and lies a few kilometres short of encompassing the Laos / Cambodian border group of dolphins
	Mekong Dolphin Royal Decree	Proposed	The Mekong Dolphin Royal Decree proposes establishment of up to nine dolphin conservation areas in the Mekong River
India	Chilka Lake	Established. Declared as a Ramsar site in 1981	Although Chilka Lake is a RAMSAR site, threats to dolphins continue primarily through boat collision, tourist boat harassment and accidental catch in fisheries gear (CDA 2002)
Indonesia	Semayang Lake National Park	Previously officially proposed (now no longer being considered; Kreb *pers comm.*)	Areas around Semayang Lake, Kalimantan were proposed as National Park status, for reasons including the protection of dolphin (Wirawan 1989) but this park has not yet been established (Hoyt 2005)
	Muara Pahu and Kedang Pahu tributary until Bolowan, Muara Kaman (Kreb 2004)	Recommended by researchers – no formal proposal (Kreb 2004)	These areas were recommended by Kreb (2004), after dedicated research on the Mahakam population from February 1999 until August 2002
Laos	Community Fisheries Conservation Zones (FCZ) of Muang-Khong District, Laos (Lao/Cambodian border)	Proposed by researchers and the community (Baird and Mounsouphom 1997). FCZs have significant potential to assist with dolphin conservation efforts (Hoyt 2005)	In Laos, between 1993 and 1999, the Lao Community Fisheries and Dolphin Protection Project (LCFDPP) assisted with establishing 73 village-managed Fish Conservation Zones (FCZs) in the mainstream Mekong None of these areas include dolphins as a result of difficulties at the time with trans-boundary conservation issues with Cambodia (Hoyt 2005)
Myanmar	Upper reaches of the Ayeyarwady River in Histle to Mandalay river section	Order confirmed on 28 December 2005	Order confirmed to conserve the traditional cooperative fishing practices between local villagers and dolphins.
Thailand	Thale Noi Ramsar Site	Established. Thale Noi Waterbird Sanctuary declared as Ramsar site in 1995	Thale Sap is located in the northern portion of Songkhla Lake (Hoyt 2005). However, dolphins do not occur in this portion of the lake and unless extended south to include Thale Luang (the dolphin habitat), would be ineffective in conserving dolphins

Table 2.5. Legislation relevant to freshwater populations of Irrawaddy dolphins

Population	Country	Status	Legislation
Ayeyarwady River	MYANMAR	The Irrawaddy dolphin is described under the "Completely Protected Animals" category in the list of protected animals, issued by the Forest Department, Ministry of Forestry, Union of Myanmar's notification No 583/94, Dated 26 October 1994.	*Protection of Wildlife and Protected Areas Law* (the State Law and Order Restoration Council Law No 6/94) 8th June 1994; Chapter V, Protected Wildlife and Wild Plants; Article 15 (A). Tint Tun (pers comm. 2005)
Chilka Lake	INDIA	The consequences for killing or harming a dolphin is two months imprisonment and/or a fine of Rs. 2000 (US$83).	*Schedule I* of the 1972 Indian Wildlife Act. Stacey and Leatherwood (1997), Mohan (1994)
Mahakam River	INDONESIA	Live-captures (of Irrawaddy dolphins in the Mahakam River) not allowed Punishment applies to whoever keeps, possesses, raises, transports and trades in protected species, such as *Orcaella brevirostris.*	*Law Republic Indonesia No. 5, 1990. Conservation of Flora and Fauna Act No. 7. 1999*
Mekong River	CAMBODIA	Currently no legislation. With the revised Fisheries Law 2005, live-capture of cetaceans will be strictly prohibited and subject to permit. Mekong Dolphin Royal Decree on the protection of dolphin habitat passed by the Ministry of Agriculture, Forestry and Fisheries and sent to Council of Ministers for final approval.	Fisheries Law 2005
Mekong River	LAOS	Live-captures not allowed. Refers to the Mekong Irrawaddy dolphin population only. The hunting, capture and trading of dolphins is illegal.	*Decree 118/MCC*
Mekong River	VIETNAM	All cetaceans are protected by a decree of the National Assembly but this is not generally enforced.	Decree of National Assembly
Songkhla Lake	THAILAND	Live-capture not allowed. Captive facilities must obtain a valid licence for operations (Section 29) and must report any change in numbers held (Section 30).	*Protection and Conservation of Wild Animals Law 1992. Act No. 16 – prohibition of hunting or catching protected animals. Act No. 19 – prohibition of possessing protected animals or their carcasses, and Act No. 20 – prohibition of trade in protected animals.*

The potential for an endangered species to influence ecosystem conservation is an important consideration when evaluating the appropriateness of continuing conservation efforts. Like many other mega-vertebrates (e.g. carnivores, with low total biomass and primary productivity), dolphins are top predators. Recent studies illustrate the importance of top predators for ecosystem functioning, such as the commonly cited examples of sea otters (*Enhydra lutris*), that have an important role in facilitating biodiversity within coastal kelp forest communities along the North Pacific Rim (Fanshawe *et al.* 2003), and killer whale (*Orcinus orca*) predation on sea otters that affects kelp forest biodiversity in western Alaska (Estes *et al.* 1998, Kaiser 1998). Some researchers have argued that the absence of top predators may not necessarily affect the rest of the ecosystem (resulting from a potential lack of impacts from their activities that support many other species), with such reduced impacts being particularly the case for freshwater systems which are dynamic and constantly changing (Moss 2000). Based on recent studies of the importance of top predators (Estes *et al.* 1998, Kaiser 1998, Fanshawe *et al.* 2003), it is likely that species such as dolphins (*i.e.*, uncommon and/or transient species), are under-appreciated in their role in controlling community structure and promoting linkage across ecosystems (Estes *et al.* 1998). Scientific studies to test this assumption for river dolphins, and most cetaceans, are logistically and ethically difficult.

Species which may indirectly assist with ecosystem conservation (*i.e.*, surrogate species), are often referred to as:

1. *indicators* (sentinels) (*i.e.*, indicators of the quality of health of the freshwater system (Aguirre and Lutz 2004, Aguirre and Tabor 2004, Bonde *et al.* 2004, Burger and Gochfeld 2004, Jessup *et al.* 2004, Tabor and Aguirre 2004, Wells *et al.* 2004b);
2. *umbrellas* (*i.e.*, species requiring such large areas of habitat that their protection might automatically protect other species (Lambeck 1997, Andelman and Fagan 2000, Roberge and Angelstam 2004); and
3. *flagship* species (*i.e.*, charismatic species that attract and garner public support for ecosystem protection (Andelman and Fagan 2000, Zacharias and Roff 2001, Caro *et al.* 2004) (Figure 2.8).

In addition to the role of dolphins as top predators, the potential value of using freshwater dolphin populations as flagship species is significant[8]. The surrogate species approach has been

[8] It is not immediately obvious that Irrawaddy dolphins are functionally crucial to a suite of other species to be considered a 'keystone species' (Simberloff 1998), resulting from a lack of impacts from their activities that obviously support many other species. Examples of keystone species include the gopher tortoise (*Gopherus polyphemus*), whose burrows are also home to at least 332 other species (Jackson and Milstrey 1989), and beavers (*Castor canadensis*) that change the pysical structure of the environment

most commonly applied to terrestrial taxa with large home ranges, or species that significantly affect their environment (Naiman *et al*. 1986, Jackson and Milstrey 1989, Noss 1996, Caro 2003, Hitt and Frissell 2004). Only recently is the approach been applied to marine conservation and management (NRC 1995, Zacharias and Roff 2000, Zacharias and Roff 2001), with even fewer published examples existing for riverine conservation and management. Threatened or endemic species of fish have been identified in marine and freshwater ecosystems as important surrogate species (Whitfield 1997, Creed 2000, Xie 2003).

Various proposals have been put forward to conserve endangered species or landscapes. These include:

1. the use of a single-species (*i.e*., flagship, umbrella and keystone species: Simberloff 1998);
2. a suite of 'focal species' to define appropriate management areas (Lambeck 1997, Lindenmayer *et al.* 2002); and
3. ecosystem management approaches (Grumbine 1994, Simberloff 1998).

However, it has been acknowledged that neither single-species approaches, nor investigations of landscape pattern and process, can when considered alone, quantify the requirements necessary for the retention of biota at a landscape scale (Lambeck 1997). In considering various approaches, it is important to reiterate that freshwater ecosystems differ significantly from terrestrial systems. Terrestrial systems have long periods of minimal disturbance, with organisms such as trees dominating the system, enabling high levels of niche differentiation. In contrast, in freshwater systems the medium, rather than the organisms, determine ecosystem structure, resulting from the dynamic and constantly changing freshwater environment (Moss 2000). Associated with the need for multi-level approaches, there is little evidence to support the statement and subsequent conclusions by Moss (2000) that "*in freshwater systems, maintenance of particular species, as opposed to general life forms, is probably not important. The system is more crucial…the whole system is a more tangible commodity to 'sell' to policymakers*'. Without at least one 'flagship' species to catalyse conservation efforts, it is unlikely that political and public support will be strong enough to elicit positive conservation action, particularly in developing countries where there is limited local education and/or understanding about the importance of ecosystem structure and function.

Although there are numerous debates as to the usefulness of the single-species approach (Andelman and Fagan 2000, Caro *et al.* 2003), the value of flagship species for ecosystem

with their dams to benefit other species (Naiman *et al.* 1986). However, no studies have been conducted on small delphinids to test the 'keystone species' hypothesis.

conservation has been illustrated extensively (Dudgeon 2000b; d; 2005). I propose that freshwater dolphins possess the spatial, compositional and functional requirements for persistence that encapsulate an array, if not the majority, of additional species within the system (Lambeck 1997). In the absence of any other highly visible charismatic mega-vertebrates in river systems and the dolphins' requirements for a relatively intact and functional ecosystem to survive (including catchments), freshwater dolphins are an obvious focal candidate for focusing conservation efforts[9], rather than simply relying on an ecosystem management approach alone.

Ideally, a precautionary management approach should be taken for all freshwater dolphin populations. Additionally, significantly more effort should be invested into socio-economic studies in Asia in parallel with biological studies, if conservation of freshwater dolphins is to be effective.

Figure 2.8. A Mekong River giant stingray (*Himantura chaophraya*) that was captured by a large hook in Kampi Pool in January 2004. Conservation efforts directed at the *Critically Endangered* Irrawaddy dolphin population would also benefit other fauna and flora in the river system.

[9] The Mekong River giant catfish (*Pangasianodon gigas*) would be another potential candidate for flagship species status in the Mekong River. However, it is rarely sighted, highly endangered and does not hold the same reverence by the majority of local communities (Chapter 4).

2.9. CONCLUSIONS

Chapter 2 aimed to determine the current status of freshwater populations of Irrawaddy dolphins at a global scale and to investigate their susceptibility to threats (thesis objective 1). A summary of the main conclusions from Chapter 2 are listed below:

- Freshwater habitats throughout the world are being subjected to significant levels of human disturbance. Species dependent on these freshwater habitats, such as dolphins, are subsequently in danger of local extinction (see Chapter 3).
- Irrawaddy dolphins are naturally susceptible to anthropogenic impacts resulting from their small population sizes, strict habitat preferences, apparent high site fidelity, slow maturation rate, long calving intervals and most importantly, close proximity to human activities in freshwater ecosystems.
- Very little is known about Irrawaddy dolphin life-history (Appendix VI).
- Freshwater dolphins compete directly with humans for freshwater and are subsequently facing many associated direct threats. It is therefore essential that these threats (e.g. anthropogenic threats, disease, competition and predation) are identified and effectively mitigated, as a matter of urgency.
- There has been a notable lack of on-the-ground conservation measures to conserve and manage freshwater dolphin populations (Chapter 10).
- Other flora and fauna along the river, as well as local subsistence communities are facing similar threats to those faced by freshwater Irrawaddy dolphins. Irrawaddy dolphins' should therefore be considered a flagship species for freshwater biodiversity conservation.
- A precautionary management approach should be taken for all freshwater dolphin populations.
- Chapter 11: Table 11.1 summarises the main research and conservation implications from this chapter.

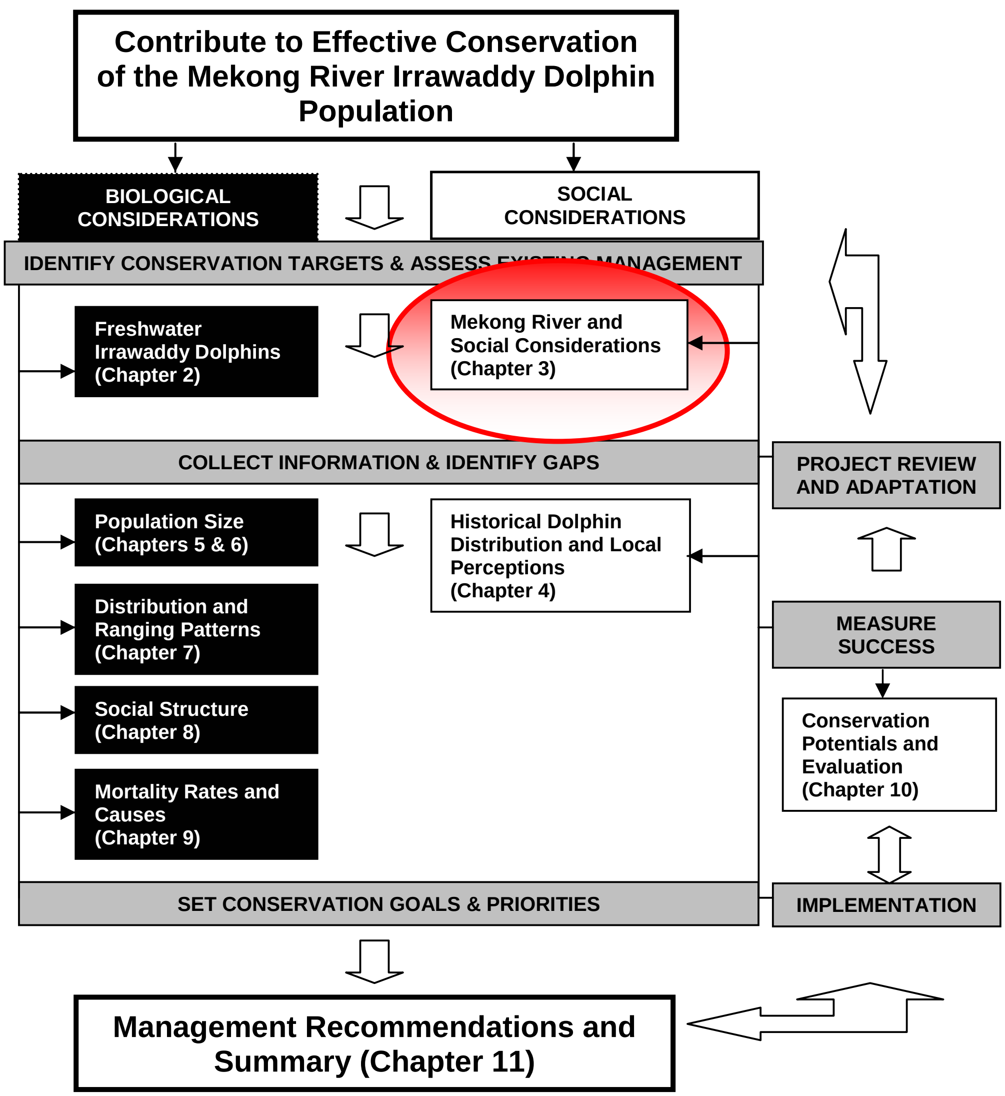
3. THE MEKONG RIVER IN PERIL: A HISTORY OF THE LOWER MEKONG RIVER AND THE IMPORTANCE OF HABITAT PRESERVATION TO SPECIES CONSERVATION

Habitat preservation is an essential component of endangered species conservation, particularly habitats not yet significantly modified by human activities. The lower Mekong River is an example of a riverine habitat that remains relatively intact and home to a wide variety of flora and fauna, many of which are now locally extinct in other countries. This chapter provides a historical overview of the lower Mekong River, including the environmental and social factors that influenced the design of my research. I outline the threats facing the river, the importance of community-based management and government support in successful conservation, and emphasise the importance of habitat preservation for species conservation.

Mekong giant stingray: Photograph by Dr. Zeb Hogan

3. THE MEKONG RIVER IN PERIL: A HISTORY OF THE LOWER MEKONG RIVER AND THE IMPORTANCE OF HABITAT PRESERVATION TO SPECIES CONSERVATION

Chapter 3 investigates social considerations in the context of the '*identifying conservation-targets and assessing existing management*' section of my conceptual framework. The aim of Chapter 3 is to provide information about the study area and justify why habitat conservation should be a major management priority (thesis objective 2: Chapter 1).



3.1. INTRODUCTION

The last two centuries have witnessed human-induced environmental change on an unprecedented scale in Asia. At the heart of this process has been the integration of the region into a globalising capitalist economy, that has promoted Asia's emergence as one of the key natural resource regions in the world (Bryant and Parnwell 1996). Dudgeon (2000a) states,

> "*Asia is the most populous region of the planet, both in terms of absolute abundance (over 50% of the global total) and densities (in 13% of the world's land area). More people live in poverty in Asia, than Africa and Latin America combined. Poverty – with its pressures to survive – and affluence – with its pressures to consume – drive and have driven environmental degradation in Asia, contributing to a situation where economic growth takes precedence over other considerations*".

Asia is drained by several great rivers; however, none remains in a pristine condition and many are degraded. An extensive background on Asian river ecosystems, threats to freshwater biodiversity, and the potential for future conservation are discussed in Dudgeon (2000b, 2000a, 2000c, 2000d, 2005).

The Mekong River is the largest river in Southeast Asia (4,800 km) and the twelfth longest river in the world (Welcomme and Vidthayanom 2003). The Mekong originates in the eastern Tibetan highlands, at an altitude of 4,970 m above mean sea level. From Tibet, the river crosses the Chinese provinces of Qinghai and Yunnan, flowing through narrow gorges in a landscape of very steep topography for most of its upper course (MRC 2003). After leaving China, the Mekong marks the border between Myanmar and Laos. Further downstream, the river flows through Laos, Thailand, Cambodia and Vietnam to the South China Sea (Coates *et al.* 2003) (**Figure 3.1**). The Mekong River catchment is approximately 795,000 km^2 in area and the river's mean discharge is 15,000 m^3/s (Hortle *et al.* 2004). The fisheries of the Mekong River support most of the human population within the basin.

The Mekong River is divided into three distinct, but inter-connected, geographical regions:

1. the upper Mekong section: which includes headwaters in Yunnan Province in China, as far south as the Myanmar/Laos border
2. the middle Mekong section: from the Myanmar/Laos border south to Khone Falls (southern Laos)
3. the lower Mekong section: from Khone Falls, south to the river mouth in southern Vietnam (including Tonle Sap Lake) (Welcomme and Vidthayanom 2003)

Irrawaddy dolphins from the Mekong River occur only in the lower Mekong section. The lower Mekong section is therefore the focal geographic region for this study (Figure 3.1). This region (which includes southern Laos, Cambodia and Vietnam), has experienced a very turbulent past, including war and civil upheaval. As a result of this political instability and lack of development, much of the natural integrity of the river has remained intact. However, recent developments in response to an increasing human population are proceeding quickly. This accelerated pace of change threatens the continued survival of flora and fauna, as well as local human communities that rely on the river ecosystem.

In this chapter, I provide a brief history of the lower Mekong River, as the context to the field survey methodology I developed for this thesis. Successful conservation of Irrawaddy dolphins in the Mekong River and their habitat is integrally dependant on fluctuating social and political considerations within the region (see Chapter 1). To provide a background to these considerations, I discuss factors of major conservation concern in the river, stressing the importance of local community and government support for management strategies. I conclude by emphasising the importance of habitat preservation for species conservation.

3.2. GEOLOGICAL HISTORY OF AREA

The complex geological history of river basins in Southeast Asia and the biogeography of the associated flora and fauna have been shaped primarily by extensive tectonic activity. This activity has significantly altered river courses over time (McConnell 2004). Pleistocene (1.6-0.1 million years ago) glaciations and interglacial periods caused sea-levels to rise and fall by up to 120 m in the region (Rainboth 1996, Voris 2000), repeatedly exposing and inundating the Sunda shelf, the extended continental shelf that connects the islands of West Indonesia (Sumatra, Borneo and Java) to the Southeast Asian mainland. During glacial maxima, many of the currently recognised major river systems in the region extended onto the Sunda Shelf and drained into common basins (McConnell 2004), for example the Chao Phraya River (Thailand) and North Sunda River. The Mekong River Basin did not extend significantly past its present range, nor previously connect with these other major river systems (Voris 2000).

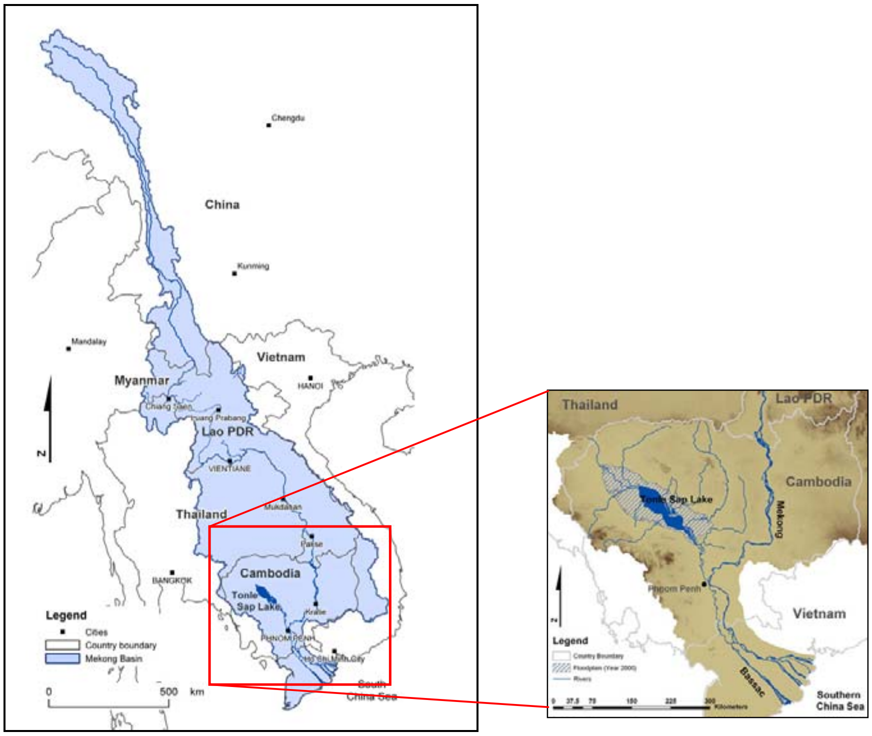


Figure 3.1. The Mekong River from its origin in Tibet to the South China Sea (left). The inset on the right shows the study area of the lower Mekong River section. A large expanse of waterfalls, named Khone Falls, is situated across the Laos/Cambodian border. These falls prevent dolphin movement north. My surveys cover nearly the entire known historical distribution of dolphins in the Mekong River, apart from the Sekong River of southern Laos. Both maps were produced by Matti Kummu (MRCS/WUP-FIN Lower Mekong Modelling Project) and reproduced with his permission.

The lower Mekong Basin covers an area of approximately 611,000 km^2 and includes most of Laos (202,400 km^2), the northern tip and the northeast area of Thailand (180,240 km^2), 90% of Cambodia (154,000 km^2) and the western flank and southern tip of Vietnam (including the Mekong Delta) (65,200 km^2). The complex geological history of the basin has resulted in five physiographic units: the Northern Highlands, Annamite Chain, Southern Uplands (upper Mekong section), Korat Plateau (middle Mekong section), and the Mekong Plain (lower Mekong section) (Fedra *et al.* 1991). The Mekong Plain unit (comprising the lower Mekong River section) is most relevant to this study. Most of the plain lies below 100 m and was formed by erosion and sedimentation (Fedra *et al.* 1991).

The Tonle Sap Lake (commonly called Tonle Sap Great Lake) in northwest Cambodia is the centre of Cambodian fishery production. Tonle Sap Lake, was formed by subsidence about 5,700 years ago (Tsukawaki 1997). Cambodia's history revolves around Tonle Sap Lake and the Mekong River and it is no coincidence that Angkor, one of the greatest ancient civilizations in Asia, developed in proximity to the lake (Sarkkula *et al.* 2003). A study of clay mineral deposits, depositional settings and sedimentation rates by Okawara and Tsukawaki (2000), concluded that the water from the Mekong River did not flow into Tonle Sap Lake before about 5000 years ago and only rivers and streams from the surrounding areas of the lake flowed into and supplied sediments to the lake.

The Mekong River has two major distributary channels into the Vietnamese Delta. The positions of these channels are estimated to have been relatively stable over the last 2000-3000 years, based on the distribution of the beach ridges, which indicate inter-distributary plains (Fedra *et al.* 1991). The Mekong Delta was formed in the period extending from the old-Tertiary Period of the Cenozoic (tens of millions of years ago) to the Pleistocene[10]. In the Recent (or mid Holocene Epoch) Quaternary Period, the Indochina region (*i.e.*, Laos, Cambodia and Vietnam) was affected by the global rise in sea-level and most of the present Mekong Delta was submerged. Sea-level maximum height was recorded at 2.5-4.5 m above the present sea level about 4,000 to 6,000 years ago (Nguyen *et al.* 2000) The coastal shoreline at that time (which nearly coincides with the maximum flooding surface) was located in Cambodia. Most of the present Mekong Delta plain in Vietnam was shallow sea. Since then, the delta has moved southeast toward the South China Sea at an average rate of about 9 km^2/year (Saito 2001).

3.3. COUNTRIES OF THE LOWER MEKONG RIVER

Modern Cambodia and Laos emerged from many ancient tribes and small states that rose along the Mekong River valley of Southeast Asia. The peoples of both countries originally came from the mountains of southern China (Issacs *et al.* 1987). The Vietnamese also originated from China, although through another valley to the Red River Delta. Although peoples from Cambodia (also referred to as Khmer) and Laos borrowed much of their culture from India, the Vietnamese of the Red River were dominated by Imperialist China. As mentioned by Issacs *et al.* (1987), '*the difference in their cultural roots marks a profound separation between Vietnam and Cambodia/Laos and contributes to their long-standing hostility*'.

By A.D. 635, Khmer control extended throughout the Cambodian Plain and surrounding areas. In the early 1000s, King Suryavarman II began construction of the temple system of Angkor Wat (Issacs *et al.* 1987). Various regional conflicts between Laos, Thailand, Cambodia and Vietnam have ensued since that time, as the countries progressed towards the 1800s.

In 1859, the Vietnamese city of Saigon was attacked and then later controlled by the French. By 1884, the entire nation of Vietnam was under French control. France then went on to control

[10] http:/www.cantho.cool.ne – Geology of the Mekong Delta

Cambodian foreign policy from 1863 and Laos in 1893. Japan invaded Vietnam through China in September 1940 and by 1941 the remainder of Indochina was ruled by an uneasy French/Japanese joint control (Issacs *et al*. 1987). In 1945, after the Japanese were defeated in World War II, the French once more regained some control of Indochina (Osborne 2000).

Anti-colonial sentiment led to the creation of the Vietminh (ethnic Vietnamese and small bands of Khmer Communists in eastern Cambodia) in 1942 and to continued revolution in the region, particularly in Vietnam. The first Indochina War began in 1946 (Osborne 2000), as a result of France's continued attempts to control Indochina under the guise of '*a fight against international communism*', a movement which was subsequently backed by the United States (communist China and the Soviet Union backed Vietnam). In 1954, a meeting in Geneva between the major countries involved in the Indochina conflict, resulted in the 'Geneva Accords'. The Geneva Accords resulted in the removal of foreign forces from Laos, Cambodia and Vietnam, but also the partitioning of Vietnam into north and south Vietnam, with the promise of democratic election to reunite the country (Issacs *et al*. 1987).

After a period of relative stability but continued unrest, fighting began in Laos in the 1960s., and the country experienced another decade of war (Issacs *et al.* 1987). This fighting then grew into the Second Indochina War, or Vietnam War (1965-75), after the United States began large-scale bombing of northern and southern Laos in 1964, as part of the even larger United States/North Vietnam conflict in South Vietnam. In the late 1960s, Cambodia became involved in fighting and aligned with the South Vietnamese and Americans (although America continued to secretly bomb Cambodia's borders), while the Communist Khmer Rouge aligned with the North Vietnamese.

Following the end of the war in 1975, communist governments came to power in Vietnam, Laos and Cambodia. However, in Cambodia, the Pol Pot regime embarked on a reign of terror, which resulted in mass genocide of approximately one million Cambodians. Since 1978-79, after Vietnam invaded Cambodia and overthrew the Pol Pot regime (the Third Indochina War), each of the three countries has progressed independently and relative stability has finally been achieved.

To provide an insight into the current economic status of the lower Mekong countries, current statistics (2003 data) for the three countries are compared with comparative statistics for Australia (Table 3.1). These statistics are based on the Human Development Index (HDI), which is a composite index measuring *average achievement* in three basic dimensions of human development: a long and healthy life, knowledge, and a decent standard of living (UNDP 2004).

The Human Poverty Index (HPI) is also listed. The HPI is a composite index measuring *deprivations* in the three basic dimensions captured in the human development index, which are listed above but also capture social exclusion (UNDP 2004).

Despite recent economic developments in the lower Mekong countries, levels of education, health, gender equality and life expectancy remain relatively low (Table 3.1). Many people continue to live in poverty and are unable to access basic services, such as clean freshwater (Hook *et al.* 2003). Cambodia and Laos remain significantly underdeveloped compared to other countries, although Vietnam fares slightly better. Poverty, illiteracy and poor health in these countries results in the need for innovative strategies that may not be applicable in developed countries, when attempting endangered species conservation.

Table 3.1. The 2003 Human Development Index and Human Poverty Index statistics for Laos, Cambodia and Vietnam, compared with Australia (UNDP 2004)

Statistic	Laos	Cambodia	Vietnam	Australia
HDI Index (out of 177 countries)	135	130	112	3
Human Poverty Index (out of 95 countries)	66	74	41	--
Total population (millions)	5.5	13.8	80.3	19.5
Life expectancy (years)	54.3	57.4	69	79.1
Population growth rate (%)	2.2	2.5	1.9	1.3
% population with income below US$2 day	73.2	77.7	63.7	0
% population below national poverty line	38.6	36.1	50.9	--
Adult illiteracy rate (% aged 15 and above)	33.6	30.6	9.7	--
Under 5 mortality / 1,000 live births	100	138	39	6
Children underweight for age (% under 5)	40	45	33	--
Population without access to sustainable fresh water (%)	63	70	23	--

Small-scale semi-subsistence farming and fishing in rural communities remains the dominant way of life in all three lower Mekong countries. Laos has a pivotal role in the conservation of the biodiversity of the Mekong. Most of the Mekong River runs through Laos and along its border. Additionally, more of the drainage that feeds the river originates in Laos than in any other country in the basin (Robichaud *et al.* 2001). Cambodia relies on inland fisheries, perhaps more than any other country in the world (Hortle *et al*. 2004). Cambodia’s inland fisheries produce about 400,000 metric tonnes per year, the world’s fourth-largest, after countries which have much larger populations, such as China, India and Bangladesh (Coates *et al*. 2003). However, the actual yield is probably much higher because most of the rural population rely on subsistence fisheries, which are not officially recorded.

Vietnam is one of the most densely populated countries in Southeast Asia. As a result of the flat terrain, agriculture is now an important livelihood and comprised 23.6% of the total national Gross Domestic Product in 2001 (UNDP 2004). Fisheries in Vietnam previously provided the main livelihoods for Vietnamese living along the Mekong Delta. However, fish production has fallen gradually, as a result of over-fishing and the use of destructive fishing methods such as electric shock, small mesh size net, chemicals and explosives (Coates *et al.* 2003, Sultana *et al.* 2003).

3.4. DESCRIPTION OF THE LOWER MEKONG RIVER SECTION

My study focuses on the lower section of the Mekong River. However, it is important to emphasise that river use in the middle and upper river sections greatly influences downstream river use. In particular, the construction of dams and waterways significantly influences downstream water-flow and ecosystem integrity.

3.4.1. Climate

A monsoon rainfall pattern predominates throughout the lower Mekong, causing the river to undergo great cyclical changes in flow (Rainboth 1996). The dry season is from late October to the end of May. The lowest low water is normally at the start of April. During this time, water levels can reach a minimum of 1–2 m in many areas. The wet season commences around the last week in May. The water rises very quickly and currents become treacherous. Because of the rapid changes in the Mekong flow, the current slows greatly, or even reverses, in some small tributary streams (Coates *et al*. 2003).

3.4.2. Khone Falls

As the Mekong passes from Laos into Cambodia, it flows over Khone Falls, an elevation drop of 21 m (Rainboth 1996: Figure 3.2). Khone Falls are situated on the border between Cambodia and Laos and demarcate the ‘border’ between the lower and middle Mekong River sections. The falls are the only major waterfalls on the mainstream Mekong River south of China and are especially important fishing grounds for the Khong District (Siphandone Wetlands, southern Laos), adjacent to Cambodia. The falls include tens of channels, rapids and waterfalls (Baird 1996). Although the falls represent a barrier to dolphin movement upstream, they are not a barrier to all fish migration. Large-scale fish migrations involving many species have been documented through intensive sampling programs over the last decade (Roberts 1993, Baird 1996, Poulsen *et al.* 2002).

Figure 3.2. The Mekong River narrowing to the bottom of Khone Falls (left). The right photo is of a representative section of Khone Falls, showing the extensive small waterfall system

3.4.3. Khone Falls to Kratie Township River Section

Downstream from Khone Falls, the river enters Cambodia from Laos as a large upland river with alternating rapids, deep pools (see '*3.5.4. Deep Pools*') and scattered sandbars. At Stung Treng (56 km south of Khone Falls), the Mekong meets the major Sekong tributary (which further branches into the Sekong, Sesan and Srepok Rivers), which carries water draining from as far away as southern Laos and the central highlands of Vietnam. The Mekong maintains its fast upland form (alternating rapids, deep pools and scattered sandbars) until it reaches just north of Kratie Township (170 km south of Khone Falls), where it begins to slow (Rainboth 1996).

3.4.4. Deep Pools

In the Kratie Township to Khone Falls river section (190 km) of northern Cambodia, many deep pool habitats have been recorded (Figure 3.3). Chan *et al*. (2003) define a deep pool as,

> "*an area in the river significantly deeper than surrounding areas which holds water in the dry season, during which it may become disconnected from the main river*".

Until recently, very little was known about the deep pool areas in the Mekong River. However, recent information suggests that these pools are an essential component of the river system, critical for sustaining fisheries within Cambodia and the Mekong Delta in Vietnam. Deep pools are normally no larger than 2 km^2 and range in depth from 10-90 m. During a recent survey in Cambodia, 97 deep pools were identified by interviewing local fisher-folk (Chan *et al.* 2003), with a further 70 reported on the Laotian side of the border (Poulsen *et al*. 2002). A total of 53 fish species were reported to stay in deep pools for at least part of their life cycles (Poulsen *et al.* 2002). Fish begin to spawn in these pools at the onset of the rainy season (late May–July), when the first floodwaters arrive and water levels start to rise. Large numbers of fish eggs and fry are carried downstream by the currents and swept into the floodplain areas during their annual inundation (van Zalinge *et al.* 2003). Viravong *et al*. (2005) concludes that '*there was no doubt that deep pools constitute very important fish habitats both in the dry and wet seasons*'. These deep pools have also been identified as primary habitats for dolphins during the dry season (Beasley 2001, Vannaren and Kin 2001).

Figure 3.3. Chiteal Pool situated on the Laos/Cambodian border is one of hundreds of deep pool areas in the Mekong River. Dolphins preferentially use only 10-12 deep pool areas in the upper Cambodian Mekong River (including Chiteal Pool).

3.4.5. Kratie Township to Phnom Penh River Stretch

The transition from a deep pool/shallow rapid river section to a lowland river form is completed below Kratie Township and the Mekong transforms into a broad meandering channel with numerous oxbows (Rainboth 1996). The river drops only 20 m between Kratie Township and the sea, a distance of some 500 km (Hortle *et al*. 2004). At Phnom Penh (approximately 370 km south of Khone Falls), the Mekong River meets the Tonle Sap River, which runs northwest approximately 140 km and enters Tonle Sap Lake, the largest freshwater lake in Southeast Asia.

3.4.6. Tonle Sap Great Lake

Tonle Sap is a seasonally inundated lake surrounded by a broad belt of freshwater swamp forest about 25–65 km wide (Kosal 2002). These inundated forests and fields become a vast productive habitat for fish and other aquatic life (Hortle *et al*. 2004), particularly during the wet season. In 1997, Tonle Sap Lake was nominated as a Biosphere Reserve under the Man and the Biosphere Program of UNESCO (Hortle *et al*. 2004).

There is a seasonal relationship between the Tonle Sap Lake and the Mekong River; the lake expands and contracts in response to rainfall and the flow of the Mekong. Tonle Sap Lake thereby acts as a storage reservoir, which regulates flooding (Hortle *et al*. 2004). Between June and early October (wet season), the southwest monsoon brings rain to the Mekong River catchment. As the river levels begin to rise, the 120 km long Tonle Sap River, which connects the river and lake, reverses direction (Penny *et al.* 2005). Each year, approximately 51,000 million m^3 of the Mekong's floodwaters are naturally regulated in this way and the lake increases in area more than five-fold (Puy *et al*. 1999). The dry season (late October to late May) depth of 1-2 m increases to approximately 10 m at the peak of the flood. The lake expands from 2,500-3,000 km^2 in the dry season to 10,000-14,000 km^2 during the flood season, when it covers about 5 to 8% of Cambodia's land area (MRC 2003).

Tonle Sap Lake is a vital resource for the people who live around the lake. Fish resources yield 65,000–75,000 tonnes/annum (Puy *et al.* 1999). Fish migration from Tonle Sap Lake to the Mekong River provides a crucial re-stocking for the river as far north as Yunnan Province in southwest China (Kaosa-ared *et al.* 1995). The long term sustainability of the lake system is reportedly threatened by logging, over-fishing and pollution (Kaosa-ared *et al.* 1995, Bonheu and Lane 2002). Sedimentation has previously been reported as a threat (Bonheu and Lane 2002); however, recent studies reported that sedimentation in the lake basin proper should not threaten the short, or medium-term viability of the lake (Penny *et al.* 2005). Penny *et al*. (2005) however caution that changes in channel morphology where Tonle Sap River joins the lake, must be monitored carefully (these areas are very narrow and shallow) and infilling of these channels may represent a real threat to the viability of the lake and associated migratory fish species.

3.4.7. Lower Cambodian Mekong River and Vietnamese Delta

Near Phnom Penh, at the head of the delta, the river divides into a larger eastern branch (the Mekong River) and a smaller western branch (Bassac River), which flow southeast into the Mekong Delta of Vietnam. The Bassac River (Hau River in Vietnam) continues flowing a further 140 km as a single channel and empties into the South China Sea. The mainstream Mekong also enters Vietnam as a single channel (the Tien River in Vietnam). This channel subsequently branches into seven channels, all of which empty into the South China Sea.

The Mekong Delta is a large estuarine system that is highly modified in Vietnam by complex man-made canal networks. Saline water intrudes up the system during the dry season, the extent of which depends on the opposing river-flow and tidal height. Saline water does not reach Cambodia (Hortle *et al*. 2004).

3.5. FISH AND FISHERIES

Fish and fisheries are essential for the daily requirements of most human communities and other animals living along the river. The diversity of fish and freshwater river fauna in the Mekong River is second only to the Amazon River (Welcomme and Vidthayanom 2003). Seven hundred fish species have been formally described in the Mekong River and diversity in the basin is currently estimated at 1,200 species – although it could be as high as 1,700 species (Welcomme and Vidthayanom 2003).

The Mekong River fish fauna includes numerous threatened fish species. The Mekong Giant catfish (*Pangasianodon gigas*: Figure 3.4) is listed by the Guinness Book of World Records as the earth’s largest freshwater fish, measuring up to 3 m in length and 300 kg in weight (Hogan 2004). This catfish is endemic to the Mekong Basin and was recently classified as *Critically Endangered* by the IUCN (Hogan 2003), as a result of declining catches and a declining population (*i.e*., fisheries biologists estimating that the total population has decreased by approximately 90 percent in the past two decades) (Hogan 2003, Hogan 2004). Other large fish species, such as the *Endangered* Giant freshwater stingray (*Himantura chaophraya*) (SSG 2000) (measuring up to 5 m in length) and the Mekong giant carp (*Catlacarpio siamensis*) (measuring up to 2.5 m in length), also inhabit the lower Mekong River.

Water levels start dropping when the floods recede and the Tonle Sap River changes direction and flows again towards the Mekong River. This change in water direction is a signal for most fish to migrate to deeper water. Many migratory fish species will undertake long migrations from the lake to the Mekong River, probably moving mainly upstream and staying in the deep pools of the Kratie to Khone Falls river section during the dry season.

Figure 3.4. A Mekong giant catfish captured in the Dai fisheries situated along Tonle Sap River, Cambodia, at the end of the 2003 rainy season. Photograph by Dr. Zeb Hogan.

The Mekong River supports significant biodiversity, with complex inter-relationships between the people and the resources. Coates *et al*. (2003) states,

> "*the river is an integral part of the everyday life for almost the entire population of the basin (currently about 90 million people from the six range countries). Political and economic history, including a long period of military conflict, has shielded large areas of the river system from fast-track development. These attributes, coupled with the very high demand for fisheries products, result in what remains as perhaps one of the most productive freshwater fisheries in the world*".

3.6. NON-FISH FAUNA AND FLORA

In addition to fish, many other animals are associated with the Mekong River. Various reptiles include the *Critically Endangered* Siamese crocodile (*Crocodilius siamensis*) and river terrapin (*Batagur baska*), and the *Endangered* Asian giant soft-shell turtle (*Pelochelys cantorii*: Figure 3.5).

Figure 3.5. A large Asian Giant softshell turtle found dead during my surveys in the upper Cambodian Mekong River, near Sambor village, on 10 April 2005.

There is little published information regarding the status of riverine birds along the lower Mekong River. However, Indochina holds regionally-important populations of many bird species. These include the *Critically Endangered* Giant Ibis (*Pseudibis gigantean*); the *Endangered* sarus crane (*Grus antigone*) greater adjutant (*Leptoptilos dubius*); and white-shouldered ibis (*Pseudibis davisoni*). Additionally, a new species of wagtail, named the Mekong wagtail (*Motacilla samveasnae*) was recently described from the lower Mekong catchment of northeast Cambodia, southern Laos and marginally northeast Thailand (Duckworth *et al.* 2001). The Kratie to Khone Falls river section is particularly important for many of these species (Robson 2005).

The Mekong River is potentially an important permanent habitat for four globally threatened species of otter, the *Threatened* Eurasian otter (*Lutra lutra*) and Oriental small-clawed otter (*Aonyx cinerea*); the *Vulnerable* smooth-coated otter (*Lutrogale perspicillata*); and the *Data*

Deficient hairy-nosed otter (*Lutra sumatrana*). Virtually no information is available on the otter species present, or status of species within the lower Mekong River. Additionally, nominally terrestrial mammal species, such as monkeys, wild water buffalo (*Bubalus arnee*) and deer (e.g. sambar deer: *Cervus unicolor*), are associated with the Mekong wetlands for part, or all of the year.

3.7. THREATS TO THE MEKONG RIVER

As a result of on-going threats, riverine ecosystem integrity has often been undermined to such an extent that systems fail to support adequate levels of aquatic life (Coates *et al.* 2003). Although local factors (over-exploitation and destructive fishing gears) threaten the integrity of the Mekong River, environmental degradation from outside sectors is clearly the major long-term threat. Human activities have promoted extensive loss of habitat, ecosystem simplification and reduced water quality and quantity (Coates *et al.* 2003). The following threats to the Mekong River are adapted primarily from Coates *et al.* (2003), and include direct threats from *within* the fisheries sector, and direct threats from *outside* the fisheries sector. For further information, comprehensive accounts of the perilous state of Asian rivers have been previously summarised by Dudgeon (2000b, 2000a, 2000c, 2000d, 2001).

3.7.1. Direct Impacts from *Within* the Fisheries Sector

1. *Destructive fishing practices* include: (a) explosives, (b) poisons, and (c) electric fishing. These fishing practices often cause large amounts of by-catch (including dolphin deaths) and habitat degradation.
2. *Unsustainable fishing practices* include: (a) exploitation of vulnerable life history stages, (b) fishing activities in sensitive areas (e.g. spawning periods), and (c) commercialised or high capture gear types (e.g. trawling, dai fishery, small and large mesh size gillnets).
3. *Introductions and transfers of living aquatic organisms* to, or within, the basin through two major activities: (a) inter- and intra-drainage transfers of water, and (b) transfers primarily through aquaculture-related activities (including ornamental fisheries/aquaria).
4. *Aquaculture* threatens the integrity of the river through: (a) inputs of lower grade fish from the capture fishery, and (b) negative environmental effects associated with wetland destruction and pollution.

3.7.2. Direct Impacts from *Outside* the Fisheries Sector

1. *Habitat degradation and alteration* occur primarily through: (a) destruction of local spawning grounds or dry season refuges by habitat alteration (e.g. dredging, removal or alteration of aquatic, emergent and riparian vegetation cover), and (b) near-river logging, causing increased levels of sedimentation.
2. *Reduction in water quality* occurs through: (a) agricultural run-off, (b) household and industrial garbage and sewage, and (c) mining operations.
3. *Reduction in water quantity* occurs primarily through: (a) irrigation schemes, and (b) construction of barriers. The construction of barriers (dams, weirs, diversions etc) is a major threat to the integrity of the Mekong River. The effects can include: (i) over-fishing in important habitats and loss of recruitment (e.g. catches in small river mouths); (ii) physical barriers to migrations; and (iii) loss of ecological function of the river (e.g. large dam projects). At least three large-scale dams have been constructed on the mainstream Mekong in China. No dams currently exist on the mainstream Mekong River below China, although numerous dams exist on the Laos and Vietnamese branches of the river (Poulsen *et al.* 2002).

Fishery management in the Mekong is urgently required. The overriding threat to the future of the Mekong's fish and fisheries is the impact of water management schemes, for purposes such as irrigation; hydroelectricity; and flood control (Poulsen *et al.* 2004). Poulsen *et al*. (2004) provide evidence on, "*the essential need for flooding as a trigger for spawning, the importance of fish access to flooded areas and the need for fish to migrate between widely separated habitats*".

The construction of water management schemes detrimentally affects fish stocks (Poulsen *et al.* 2002) and the integrity of the river system (Roberts 1993). A further problem associated with dam building is that the impact (e.g. elimination or dramatic reduction of fisheries) is felt locally by the rural riparian communities, whereas most of the benefits of dams are accrued in urban centres. An example of the negative effects of a dam on local communities is construction of the Pak Mun Dam (completed in 1994), located near the mouth of the Mun River, which is a major Mekong tributary running through Ubon Rachathari, Thailand (Roberts 1993; 1995). As a direct result of the dam, more than 20,000 people were affected by drastic reductions in fish populations upstream of the dam site and other changes to their livelihoods. The dam blocked the migration of fish and a fish ladder, promoted by the World Bank's fisheries experts as a mitigation measure, has proved useless (Roberts 1993).

Although threats to riverine ecosystems are significant, in Asia, as in other regions, there is often little pressure from the public to protect aquatic biodiversity. There is scant evidence that biodiversity conservation, or environmental protection, are priorities of government or legislators (Dudgeon 2000a). In addition, as stated by Dudgeon (2000d),

> "*non-government organisations promulgating conservation projects typically work within the political constraints set by governments, where these constraints include corruption and weak or inconsistent enforcement of legislation, leading to conservation goals that are compromised or unattainable*".

The catalyst for most of the above listed threats and the major obstacle to riverine conservation is the large and ever-growing human population's in Asia, high levels of poverty, and local people's reliance on freshwater resources. As Poulsen *et al*. (2004) report, '*the challenge is to improve environmental management of the Mekong fisheries, to ensure maintenance of ecosystems for flora and fauna that depend on the system and sustainability for future generations*'.

3.8. INSTITUTIONAL, LEGAL AND POLICY FRAMEWORKS

An international body that operates throughout most of the Mekong River and is responsible for implementing international agreements that have implications for wetland management in the lower Mekong River (Table 3.2) is the Mekong River Commission (MRC). Vietnam, Cambodia, Laos and Thailand are members of the MRC. China stills declines membership, although in 2002, China and Myanmar became dialogue partners of the MRC, with the aim of working together within a cooperative framework (MRC 2005).

Regional, national and international government support for conservation and management of species and habitats is essential. However, as Dudgeon (2000c) appropriately states:

> "*government corruption or incompetence is an addition impediment for conservation. Country leaders are often more concerned with maintaining a hold on power and enjoying the benefits of office. Initiation of conservation policies (especially where they might limit the freedom of sponsors of cronies to clear forests or pollute rivers) are unlikely to have high priority*".

Such issues will continue to hinder management of natural resources in many developing and developed countries. The challenge in such circumstances will be for managers and conservationists to work within legal boundaries to promote appropriate management initiatives and elicit public support for conservation.

Table 3.2. International agreements that pertain directly, or indirectly, to conservation and management of the lower Mekong River.

International Agreements	Specifics Regarding International Agreement	Laos	Cambodia	Vietnam
Convention on Biological Diversity	• Signed by 150 government leaders at the 1992 Rio Earth Summit. • The Convention on Biological Diversity is dedicated to promoting sustainable development. • Member countries are expected to develop and implement national plans to ensure that biological diversity is conserved.	20/09/1999 (acs)[1]	09/02/1999 (acs)[1]	28/05/1993 (signed) 16/11/1994 (rtf)[1]
The Ramsar Convention on Wetlands	• The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.	Not yet a contracting party	23/10/99; 3 sites totalling 54,600 ha. Two sites of relevant in the Mekong River.	20/01/89; 2 sites totaling 25,759 ha. No sites of relevance in the Mekong River
UNESCO Man and Biosphere Programme	• Biosphere reserves develop the basis, within the natural and the social sciences, for the sustainable use and conservation of biological diversity, and for the improvement of the relationship between people and their environment globally (UNESCO 2005).	No reserves	1997; Tonle Sap Lake	Four reserves established but none of relevance to the Mekong River/Delta
Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)	• CITES is an international agreement between governments, with the aim of ensuring that international trade in specimens of wild animals and plants does not threaten their survival.	Date of entry[2]: 30/05/04	Date of entry: 02/10/97	Date of entry: 20/04/94
Convention on the Conservation of Migratory Species of Wild Animals (CMS)	• CMS (also known as the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their ranges.	Not a party member of CMS and does not participate	Participates in CMS agreements and Memorandums of Understanding (MOUs) but not yet a party to CMS.	Participates in CMS agreements and MOUs but not yet a party to CMS

[1]The terms that signify the consent of a state to be bound by a treaty: "ratification" (rtf), "accession" (acs)
[2]The date that the country became a full signatory to CITES.

3.9. IMPORTANCE OF COMMUNITY-BASED CO-MANAGEMENT SYSTEMS

Community-based management systems have the potential to be implemented much more successfully than government driven top-down approaches to conserve riverine habitats. As Coates *et al*. (2003) state,

> "*in terms of fisheries regulations and legislation, the picture in the Mekong is much the same as elsewhere, top-down government approaches generally fail to be effective – especially so for the majority of fishing effort (smaller gears)*".

Studies on local knowledge in the study of river fish biology in the Mekong River (Bao *et al*. 2001) concluded that "*by accessing local knowledge it is possible to obtain vital information that could not have been revealed using conventional biological techniques*". The study also affirmed the value of Indigenous knowledge to contribute to basin-wide planning and development strategies. It was concluded that such intimate knowledge of the fisheries is essential for conservation and management strategies to be effective (Bao *et al*. 2001, Poulsen *et al*. 2002). The contribution of local knowledge to conservation is discussed further in Chapter 4. As mentioned by Cunningham (1998),

> "*many of the factors which will ultimately determine the future of the Mekong's hugely productive, biologically diverse fisheries depend on regional government policies. However, the survival of the Mekong's valuable fish species can only be secured with the full participation of fishing communities in fisheries management. The active support of local fishers is vital*".

The importance of community-based management of important aquatic areas is now accepted by many managers worldwide, particularly in coastal areas (Ruddle *et al.* 1992, Russ and Alcala 1999, Pollnac *et al.* 2001, Marschke and Nong 2003) and has recently been acknowledged by governments in both Laos and Cambodia, through decentralisation schemes and the creation of community-focused government departments.

An example of the potential success of community-based fisheries in the lower Mekong River is evident is southern Laos. With increasing anecdotal reports of a decline of fish, local Laos administrative authorities were empowered by the national government to play a major role in managing their own local natural resources, within a co-management framework. With assistance from the LCFDPP (1993-1997), followed by the Environmental Conservation and Community Development and Siphandone Wetland Project (ECCDSWP) (1997-1999), a total of 72 Fishery Conservation Zones (FCZs) were established by local communities in the Siphandone area (Baird 2000a). Various evaluations have now been undertaken to judge the effectiveness of the FCZs in meeting their intended objectives (Meusch 1997, Dacanto 1999, Chomchanta *et al.* 2000). The main conclusions from the most recent independent assessment conducted by Chomchanta *et al*. (2000), are that:

1. FCZs represent a good example of co-management and have been established democratically, with each village deciding on its own operating rules and regulations;
2. the FCZs have widespread support from the majority of the villagers in the communities in which they were established;
3. the FCZs have created some intra- and inter- village conflicts and disagreements, but these do not appear to be very serious; and
4. the sense of ownership created by the bottom-up management has been fundamental to the FCZs successes.

3.10. IMPORTANCE OF HABITAT PRESERVATION TO SPECIES CONSERVATION

Habitat degradation and loss is the most common threat to birds, mammals and other flora and fauna (Groombridge 1992, Mace and Balmford 2000, Sodhi 2002, Sodhi *et al.* 2004). Habitat degradation is catalysed by burgeoning human population's, with the associated need for increased utilisation of resources.

The *Critically Endangered* baiji is a stark reminder of the consequences of habitat degradation to a large mammal species. The baiji is restricted to the Yangtze River of China and considered the rarest large mammal on earth (with only few tens of individuals remaining). Since it belongs to a monotypic family, extinction of the baiji would mean the loss of an evolutionary lineage (Dudgeon 2005). Numerous threats to the baiji exist through overfishing, accidental catch in fishing gear such as gillnets and rolling hooks, clearing of land for agriculture adjacent to the river, intensive boat traffic, pollution, and water development projects.

Water development projects have had extensive deleterious effects on the entire river system (Liu *et al.* 2000). The Gezhouba and Three Gorges dams are located on the mainstem of the Yangtze (1100 km upstream from the river mouth) and now prevent any dolphin movement further upstream (Liu *et al.* 1996). In addition, numerous smaller dams along tributaries of the Yangtze and its appended lakes have dramatically reduced the availability of migratory fish. The baiji once occurred in the Qiantang River, a tributary of the Yangtze River, but apparently were extirpated after the construction of a high dam in 1957 on the Xinan River (Liu *et al.* 2000). Baiji conservation efforts have been underway since the mid 1980s (Kaiya 1986, Brautigam 2003, Zhang *et al.* 2003, Braulik *et al.* 2005). There are numerous debates about the appropriate conservation approach (*i.e.*, to leave baiji in the river, transfer them to semi-natural reserves, or transfer to a captive facility). However, whatever approach is implemented, the baiji population is now so small that it is highly unlikely that the species will continue to persist naturally in the Yangtze River. Dudgeon (2005) concludes '*the baiji is certain to become extinct if left to languish in the Yangtze*'. There are now fears for the Yangtze finless porpoise; an endemic sub-species of a widespread east Asian cetacean that also inhabits the Yangtze River (Reeves *et al.* 2002, Reeves *et al.* 2003). Although it is reported that up to 2000 finless porpoise inhabit the Yangtze River, this sub-species is now reportedly facing a population decline mirroring that of the baiji (Wang *et al.* 2000).

One of the primary threats to riverine ecology related to habitat degradation is dam and water-way construction. The top five dam-building countries account for nearly 80% of all large dams worldwide. China (with a population exceeding one billion people), has now built around 22,000 large dams (higher than 15 m), or close to half the world's total (Figure 3.6). India (which occupies only 2.4% of the world's land area but supports over 15% of the world's population) ranks third in the world (behind the US) with a comparatively modest total of slightly more than 4,000 (WCD 2000). The World Commission on Dams (WCD) (2000) and McCully (2001) provide comprehensive overviews on the construction and effects of dams worldwide.

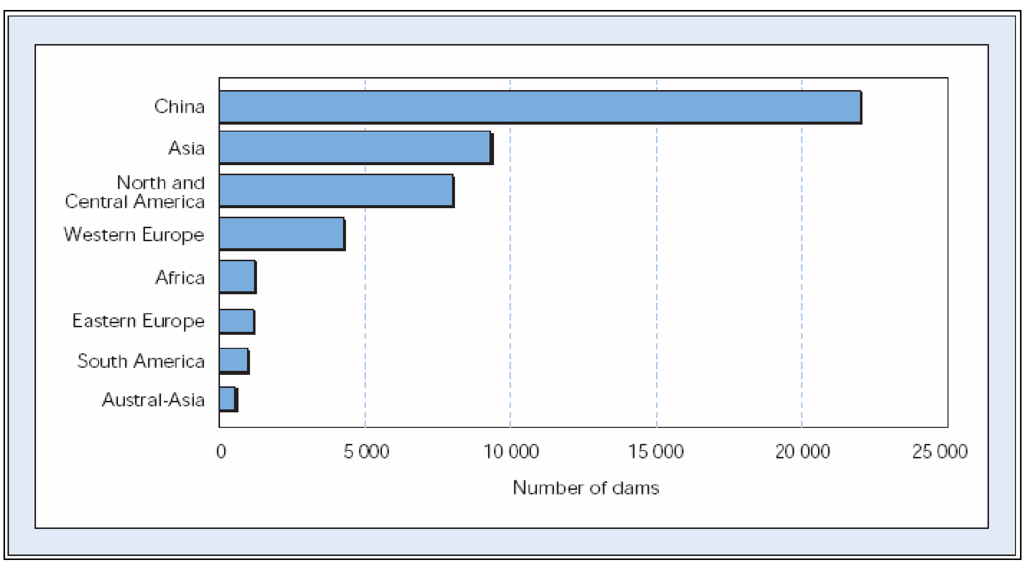


Figure 3.6. Regional distribution of large dams at the end of the 20th century. Excerpt from WCD (2000).

Dam and waterway construction pose significant problems to freshwater dolphin populations, particularly those in Asia. The Ganges River dolphin is an *Endangered* river dolphin which consists of two subspecies:

1. the Ganges River dolphin (*Platanista gangetica gangetica*), which occurs in Nepal, India and Bangladesh (Mohan *et al.* 1997, Smith *et al.* 1998, Ahmed 2000, Smith *et al.* 2001, Sinha and Sharma 2003); and
2. the Indus River dolphin (*Platanista gangetica minor*), which occurs in the Indus River of Pakistan (Braulik *et al.* 2004).

Dam and waterway construction throughout these species' ranges are fragmenting populations, preventing fish migrations and reducing water quantity through large-scale irrigation projects. In both the Ganges and Indus Rivers, dolphins also regularly enter irrigation canals, or channels downstream of dams, where they often perish when water-levels fall during the dry season (Dudgeon 2000d).

The precarious state of many fish species and the contribution of hydrological alterations to their decline is exemplified by the *Acipenseriformes* (sturgeons and paddlefish) of southern China, especially in the Yangtze River (Dudgeon 2000d). Spawning migrations of the anadromous[11] Chinese sturgeon (*Acipenser sinensis*) were blocked by the Chang Jiang (Yangtze) Low Dam at Gezhouba in 1981 and fish passages were not provided. This dam also fragmented populations of the endemic potamodromous[12] Yangtze (or Dabry's) sturgeon (*Acipenser dabryanus*). Sturgeons stranded below the dam are unable to spawn successfully because their breeding is associated with an upstream migration. As a result, the Yangtze sturgeon is now virtually extinct downstream of the dam (Wei *et al.* 1997, Zhuang *et al.* 1997). Of particular concern is the anadromous Chinese paddlefish (*Psephurus gladius*: Polydontidae) that declined drastically in the Yangtze after the Gezhouba Dam blocked access to its upstream spawning sites. Because it occurs nowhere else, this fish will almost certainly dwindle to extinction (Wei *et al.* 1997).

The construction of dams and waterways also affects local human communities. The recently constructed Yali Dam on the Sesan tributary in Vietnam, which flows into the mainstem Mekong River at Stung Treng Township, has impacted more than 55,000 people in Cambodia and Vietnam, causing displacement, deaths of humans and livestock and declining fish stocks (IRN 2002). The benefits of the dam have predominately been accrued in urban centres and by international consultancies related to the dam construction. Similarly, it is estimated that the

[11] Aquatic animals that live their lives in the sea and migrate to a freshwater river to spawn
[12] Aquatic animals that migrate within river systems

large dams of India and China together have displaced 26-58 million people between 1950 and 1990 (WCD 2000). Since 1994, construction of the Three Gorges Dam in China has already caused the displacement of over 1 million people, with an estimated 1.9 million to be displaced once the dam is operational (IRN 2005). Construction of further dams on the Mekong, or its tributaries, is likely to further decrease fish stocks and alter ecosystem functioning. These adverse effects will certainly be much more long-term and significant than the cumulative impacts of subsistence fishers.

There are clear lessons to be learnt from the precarious situation facing the Asian freshwater dolphin populations, as well as other large megafauna inhabiting Asian river systems. Without adequate habitat and ecosystem functioning, these species will almost certainly become extinct in the wild. The Mekong River is still relatively intact and the ecosystem, associated species and riparian human communities could still be sustained in the long-term. However, it is essential that dam and water-way projects are prohibited, wherever possible, for the integrity of the river to be adequately maintained. The impacts of dams, pollution, land clearance, deforestation and other threats are predictable and given the right political will, can often be ameliorated, or avoided. However, such actions require dedication and commitment from all sectors to work cooperatively towards a common goal (Dudgeon 2000a). Such cooperation is challenging, irrespective of increasing human populations, continued poverty and widespread corruption. Although challenging, habitat preservation is imperative for species conservation. Few species, or riparian human communities, will be able to survive in the long-term without having access to functioning ecosystems.

3.11. CONCLUSIONS

Chapter 3 aimed to provide information about the study area and justification for why habitat conservation should be a major management priority (thesis objective 2). A summary of the main conclusions from Chapter 3 are listed below:

- The lower Mekong River countries have experienced years of war and internal conflict and therefore their natural environments have been shielded from major development. All the lower Mekong countries are now developing quickly and are experiencing significant human population growth.
- Major threats are often linked with poverty and human overpopulation. It is essential that threats are mitigated and future large-scale destructive projects prohibited.
- Conservation lessons need to be learned from experiences in other countries.
- Based on lessons learned elsewhere, positive community involvement in conservation is imperative.
- Preservation of habitat is essential to endangered species conservation as well as to subsistence rural human communities and other flora and fauna that rely on the river system.
- Chapter 11: Table 11.2 summarises the main research and conservation implications from Chapter 3.

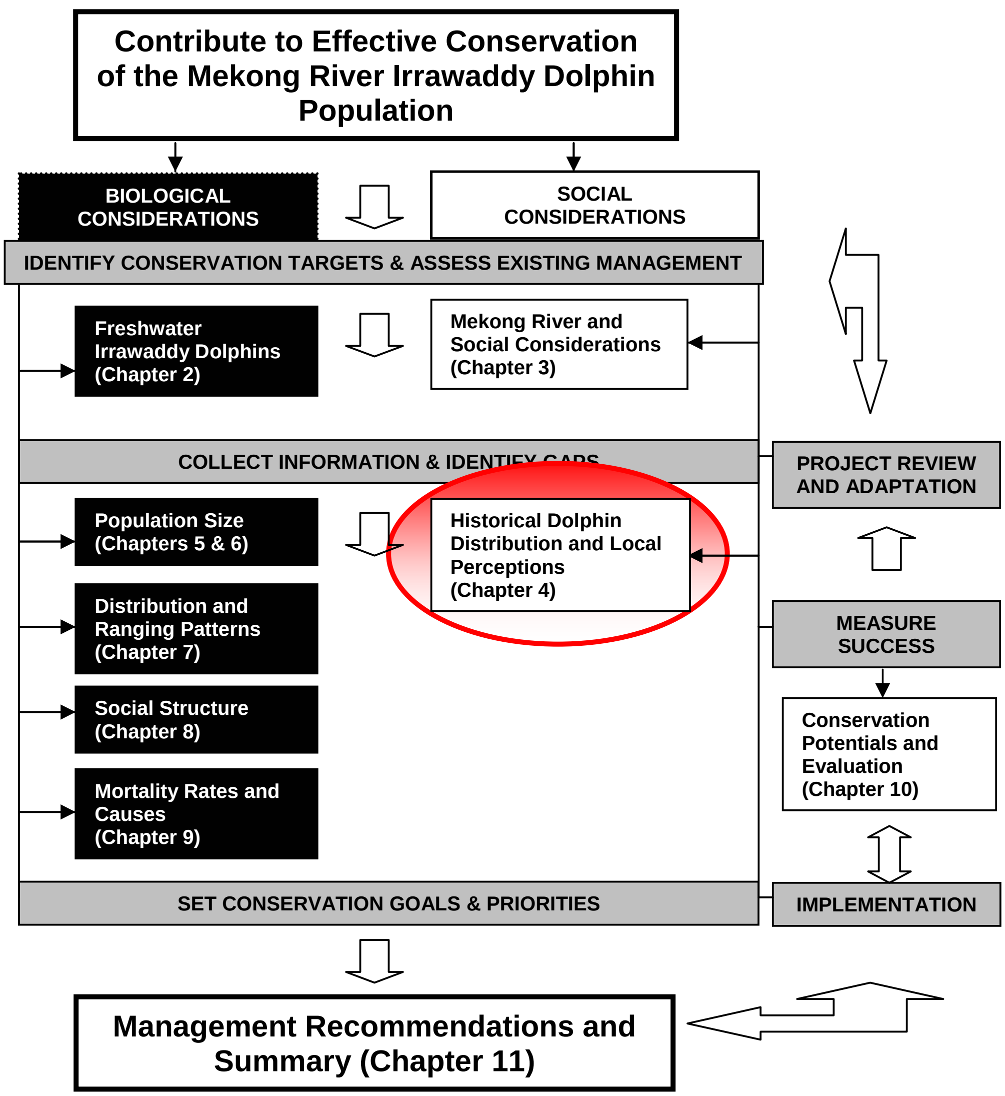
4. EVALUATING THE CONSERVATION STATUS OF IRRAWADDY DOLPHINS IN THE MEKONG RIVER USING LOCAL KNOWLEDGE

Local subsistence fishers throughout the Mekong River are highly dependent on the river for their daily food requirements. Through long-term opportunistic observations, these fishers have significant knowledge of the occurrence patterns, behaviour and life history of various species, particularly in areas commonly frequented by the individual informant. This local knowledge of flora and fauna can provide significant information relevant to management of endangered species. Published scientific data concerning the historical distribution of Irrawaddy dolphins in the Mekong River are sparse. However, local communities have known of the dolphin's presence for many centuries. In this chapter, I use local community knowledge to describe the historical distribution of Irrawaddy dolphins inhabiting the Mekong River. In addition, I discuss local perceptions of dolphins, fisheries conservation and the factors threatening the dolphins, fisheries and the integrity of the lower Mekong River.

MDCP team members with a local fisher (second from left) who is showing a poster that was distributed by MDCP for awareness purposes

4. EVALUATING THE CONSERVATION STATUS OF IRRAWADDY DOLPHINS IN THE MEKONG RIVER USING LOCAL KNOWLEDGE

Chapter 4 investigates a social consideration in the context of the ‘’*collecting information and identifying gaps*’ section of my conceptual framework. The aim of Chapter 4 is to investigate the historical status of the Irrawaddy dolphin population in the Mekong River and local perceptions and knowledge relevant to the dolphins’ conservation (thesis objective 3: Chapter 1).



4.1. INTRODUCTION

Endangered species are often characterised by small populations and restricted distributions. It is usually difficult to establish if populations are naturally small and limited in geographic range, or if other factors have caused these conditions. The IUCN Red List Categories and Criteria use, among other things, information on change in area of occupancy when evaluating the conservation status of a species (IUCN 2000). Although scientific study is often necessary to obtain robust estimates of population size (Criteria A, C and D of the Red Listing process), quantified local knowledge may contribute to estimates of geographic range changes (Criteria B), in the absence of historical scientific study, or when other data are not available.

Increasingly, studies of Indigenous knowledge are convincing researchers that many unschooled – but far from uneducated – rural people possess invaluable knowledge about the environments in which they live and the natural resources on which they depend (Johannes 1978; 1981; 1982, Gill 1994, Johannes 2002a; b). Local knowledge is often able to provide detailed information on historical species distributions, particularly when no scientific data exist. Local knowledge that has been relevant for research and management of endangered animal populations includes:

1. Inuit knowledge of the distribution and calving of beluga (*Delphinapterus leucas*) in Hudson Bay (McDonald *et al.* 1997, Johannes *et al.* 2000) ;
2. Iňupiat whalers' knowledge of the abundance, distribution and movements of Alaskan bowhead whales (*Balaena mysticetus*) (Freeman 1968, Johannes *et al.* 2000); and
3. local knowledge of the substantial decline in the spawning runs of bonefish (*Albula glossodonta*) in Kiribati, equatorial Pacific (Johannes *et al.* 2000, Johannes and Yeeting 2001).

Local knowledge and perceptions of species are also important in areas where conservation programs are being implemented (Johannes *et al.* 2000, Cinner *et al.* 2005). Thus, a major challenge is for conservation managers to incorporate local knowledge and perceptions into effective conservation and management strategies.

Development and human populations are now increasing dramatically along the lower Mekong River (Coates *et al.* 2003). An understanding of local knowledge and perceptions is critical to the integration of the local communities into conservation and management strategies. Such integration can be expected to improve management by (1) allowing management to be sensitive to the concerns of local users, adding legitimacy to the management process; (2) developing a sense of community stewardship and responsibility for the resource that should discourage abuse; (3) enabling management to be based on watershed specific data; and (4) increasing public awareness of management problems (Sutton 2000).

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Experience demonstrates that the processes used for collecting local knowledge data are as important as the information obtained. The usefulness of surveys in developing countries has been debated on numerous occasions (Chambers 1983, Gill 1994). Chambers (1983) and Gill (1994) provide comprehensive critiques of the inadequacy of survey data in developing countries, or ‘survey slavery’, where Chambers (1983) states that

> “*The costs and inefficiencies of rural surveys are often high: human costs for the researchers, opportunity costs for research capacity that may have been better used, inefficiencies in misleading findings*”

and time costs for respondents if data are not analysed and the resultant information not appropriately reported. Aragones *et al*. (1997) provide a discussion on the use and constraints of interview surveys to obtain data on marine mammal broad scale distribution/abundance, trends and habitat use.

In this study, I quantify local community knowledge of historical dolphin distribution in the Mekong River, investigate local perceptions towards dolphins and riverine conservation, and discuss how this local knowledge and perceptions can contribute towards effective conservation and management.

4.2. BACKGROUND SCIENTIFIC KNOWLEDGE OF IRRAWADDY DOLPHINS IN THE MEKONG RIVER

The Irrawaddy dolphins that inhabit the Mekong River have been locally known to occur in the river for centuries (locally named '*phsout Tonle Mekong*', or 'Mekong River dolphin' in Cambodian and '*ga nouc*', or 'Sir' in Vietnamese). However, dolphins were first recorded in the scientific literature only in the mid 1860s, after sightings near Cambodia's capital city, Phnom Penh (Mouhot 1966). There has been very little previous research on this freshwater dolphin population as a result of decades of war and a lack of local and international interest. Historical data on dolphin distribution and abundance are sparse. Dolphin specimens from the Mekong River were recovered in the late 1880s by two French military doctors and sent to the Laboratoire d'Anatomie, Paris, France. Beneden and Gervais (1880) were unable to ascribe these specimens to species and so described them as the 'Dolphin of Cochinchine'. Lloze (1973) conducted a three-year (1967-1969) study investigating the distribution, biology and behaviour of dolphins in the Cambodian Mekong River. Lloze (1973) provides the most comprehensive historical account of this Irrawaddy dolphin population, although virtually none of this Frenchman's work has been published in English. As part of Lloze's (1973) biological studies, he captured two female dolphins (the first on 28 February 1968 and the second on 18 February 1969), from near Kratie Township (northeast Cambodia). I was based at this township throughout my study.

In addition to their anatomical and histological studies, Lloze (1973) and his team observed numerous dolphins throughout the Cambodian Mekong River. These observations provide the only known historical reports of dolphins inhabiting Tonle Sap Lake. Lloze (1973) observed dolphins to occur frequently in Tonle Sap Lake in the wet season, when

> "*these lakes then turn into an inland sea, often subjected to strong storms which the dolphins cross in all directions. However, dolphins like to stay near the mouth of the main tributary of the lakes, the Stung Sen, the Stung Staung and the Stung Pursa, on the opposite side*".

Lloze (1973) notes that he was informed that at least one dolphin was sighted in the western Baray (a large artificial lake created in the 11th century in the basin of the Angkor temples) in 1955–1957. This vast rectangle water storage facility (8 km by 2 km and a depth of 4 m) is linked to the Siem Riep River by a system of canals (Lloze 1973). Lloze (1973) reported that dolphins often left certain flooded lakes (such as Tonle Sap) and rivers when water levels began to lower, '*to avoid being surprised by a sudden and rapid lowering of the water*'. Dolphins apparently left these areas at the same time as the large fish (*i.e*., Mekong giant catfish and giant carp) that fled Tonle Sap Lake before the shallowness of the water prevented them from crossing the threshold of Chhnoc Thru and the Tonle Sap River, which would have closed off their exit from the lake. Lloze (1973) observed that

> "*dolphins then swam along the Tonle Sap River and once at the Mekong, most individuals continued north up the Mekong towards Kratie and Stung Treng. However, some individuals apparently followed the lowering water levels and descended to the delta region of the Mekong*".

During the months of January and February 1968 and 1969, Lloze (1973) followed the movement of dolphins out of Tonle Sap River from the region of Dey Eth, south to Banam, which is close to the Vietnamese border (50.8 km south of Phnom Penh and 49.6 km north of the Vietnamese border: Figure 4.1). A report by Professor Fontaine from the Paris Natural History Museum also reported observing a pod of eight dolphins frolicking near Banam, at the end of January 1969 (Lloze 1973). Lloze (1973) observed many young dolphins in the Kratie to Stung Treng river stretch, whereas none was sighted in Tonle Sap Lake, or near the Vietnamese border. Lloze (1973) hypothesised that after a gestation period of 10–12 months, very pregnant females may go to the Kratie to Stung Treng region to find refuge and the necessary calm waters in order to give birth to their calves.

Lloze (1973) observed a close relationship between local Cambodian and Vietnamese fishers and the dolphins, and he believed that dolphins were not harmed by Khmer or Vietnamese fishermen as they were considered sacred. However, Khmer-Islam (Muslim) fishermen do not revere dolphins and killed them to eat. Local fishers told Lloze (1973) that dolphins would often fearlessly go into the nets of the Khmer and Vietnamese, but would stay away from the nets of the Khmer–Islam fishers. During Lloze's (1973) research, he observed

> "*a dialogue between the Vietnamese wife of the owner of a local fishing boat and a young dolphin, which lasted 15 minutes and during which the dolphin often approached in order to be caressed by the woman*".

Lloze (1973) also reported a female dolphin that was trapped in a net of large mesh-size in the region of Banam. The fisherman apparently opened the net to set her free as he did not want to capture her for fear of 'water spirits'.

The legend of the dolphin in Cambodia refers to beliefs and Gods from the Indian Brahamic civilization, which left a strong mark on the Khmer civilization (Lloze 1973). According to the legend, as quoted from Lloze (1973):

There was once, near a Khmer village, a banian tree inhabited by a spirit. A young girl came to the tree one day to make an offering to the spirit, who, highly moved, recognised in her the woman that he had loved during one of his previous lives. In order to live once again with her, as he was still in love with her, he asked for the help of the powerful god Indra, who gave the spirit the power to change into a python so that he could go and see the young girl without being recognised by the people of the village. The spirit was therefore able, each night, to go and pay a loving visit to his beloved, to whom he had, of course, made it known who he was.

To complete the happiness of his lover, and to reward her parents for their co-operation, the spirit revealed to them the location of a treasure hidden in the forest that made the family very rich. This story spread and made the simple people very envious. In a neighbouring village, a peasant couple thought that it would be enough to marry their daughter off to a python in order to acquire a great fortune. The peasant therefore went to the forest and soon found an enormous python that was half dead of starvation. He brought the python home and the preparations for the big ceremony began immediately. That night, the young bride was delivered to her starving husband, who, famished, started to devour her from the feet upwards. The cries of the poor bride made no difference as the parents were determined that this marriage be consummated.

The calm that descended again on the married couple's room raised the suspicions of the mother, who went to investigate. She went into the room and immediately understood the cause and effect between the disappearance of her daughter and the distended stomach of the full husband, and raised the alarm in the household. The father immediately opened the stomach of the animal and freed the girl, who was still alive but covered in foul-smelling mucus. Try as they might, washing her in warm water had no effect and the smell remained. The young girl decided to take a bucket and to go and wash herself with the water of the Mekong River. No result. Confused, shamed and desperate, she decided to throw herself into the river, after putting the wooden bowl on her head. Touched by her beauty and her youth, the spirit of the river took pity on her and turned her into a dolphin. This is how the legend of the dolphin came about, this extraordinary animal with the body of a woman, and the rounded and bald head, as if covered by a receptacle with a rounded base.

There are no other scientific observations of dolphins known from the Mekong River before the 1990s. Baird and Mounsouphom (1994) conducted interview surveys to assess dolphin distribution, seasonal migratory behaviour and feeding in northeast Cambodia and southern Laos intermittently from December 1991 to March 1994 and in southern Laos (including the Sekong River sub-basin), south to Kratie Township in 1996. The interviews documented the dolphin's distribution patterns, mortality rates and causes and provided anecdotal reports on the historical distribution of Irrawaddy dolphins in the Mekong River, which allegedly had been reduced significantly since the Vietnam War (Baird and Beasley 2005).

There are no known historical observations of dolphins from the Vietnamese Mekong River. The Vietnam War prohibited any investigations by Lloze (1973) beyond the Cambodian border into the Mekong Delta and his assertion that dolphins continue downstream to the South China Sea cannot be confirmed. Lloze (1973) instead relied on reports of Irrawaddy dolphins in the Vietnamese Mekong made by Krempf (1924-1925) and Gruvel (1925) (which I was not able to locate). Irrawaddy dolphin specimens collected by local Vietnamese fishers and residents over many years have also been located in various whale temples in Vung Tau and Binh Thang, which are situated near the Mekong River Delta, Vietnam (Smith *et al*. 1997; Beasley *et al*. 2002). However, the temples' close proximity to the ocean suggest that these specimens are from coastal populations that inhabit the Vietnamese Delta resulting from. This historical data indicate that dolphins previously occurred throughout the lower Mekong River, from southern Laos, south to at least the Cambodia/Vietnam border. However historical data, or information from Vietnam, remains limited.

4.3. SURVEY AREA AND TIMING

Interviews were conducted throughout the entire Cambodian Mekong River (including Tonle Sap Lake) from April 2001 to December 2003 (Figure 4.1). Interviews were normally undertaken during boat surveys along the study area (see Chapter 6).

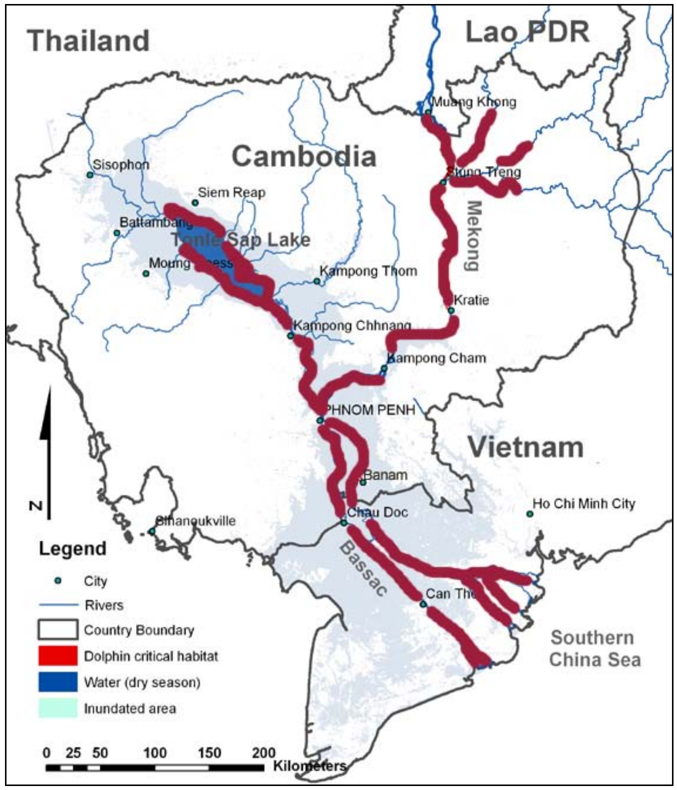

Figure 4.1. Location map of the lower Mekong River showing where interview surveys were conducted (as shown by the dark red line). No surveys were conducted north of Khone Falls (Muang Khong on map).

To overcome the logistical constraints of personnel, weather and finances associated with surveying the lake by boat, my team members travelled by motor-bike around the circumference of Tonle Sap Lake conducting interviews during November 2003. We surveyed by boat during May 2004. Interview surveys were undertaken throughout most of the Vietnamese Mekong in association with boat surveys, from 5-13 May 2005 (Figure 4.1). No interviews were conducted in southern Laos, as a result of language difficulties and our inability to obtain the required government permissions.

4.4. INTERVIEW METHODOLOGY

To assess local knowledge and perceptions towards dolphins and conservation, I developed a questionnaire and interviewed local people living along the lower Mekong River using semi-structured interviews. I initially found that local communities were wary of authorities or government departments in Cambodia. Therefore, to facilitate interviews, I created an independent local organisation called the Mekong Dolphin Conservation Project (MDCP) in 2002 (see Chapter 10). As a result of our neutral status and a non-government organization, this arrangement greatly improved the community's willingness to cooperate with my project and to freely discuss matters concerning conservation.

4.4.1. Questionnaire Development

The questionnaire was designed to be simple and to record basic information. When developing the questionnaire, considerations on how to improve data quality were implemented where possible, based on questionnaire concerns reported in Gill (1994) (Table 4.1).

The initial dolphin distribution questionnaire consisted of 30 short answer questions and was pre-tested on 34 individuals, to ensure respondents could understand the questions; and ensure additional questions were not necessary. During the pre-testing phase, both males and females from different ages and occupations were interviewed, to examine whether differences existed in levels of knowledge between age and gender. These data were not included in the final analyses. The questionnaire was then revised based on the responses of the initial interviewees and a final questionnaire produced. The final questionnaire consisted of 26 questions and was used throughout the remainder of the interview survey period.

The questions were designed to gather the following information from each interviewee:

1. the location and time the interviewee had spent in area (five questions);
2. previous and current distribution of dolphins in this and other areas (four questions);
3. current knowledge about the dolphins (five questions);
4. perceptions on dolphin/fish conservation (four questions);
5. dolphin mortality rates and causes (three questions); and
6. demographic data about the interviewee (five questions).

4.4.2. Methodology

All interviews followed the James Cook University (JCU) guidelines for interviewing Indigenous Peoples. Human ethics approval was obtained from JCU (under approval reference H1356). It was inappropriate to request that the interviewee sign the questionnaire to acknowledge that their consent had been given for the following reasons:

1. previous war and internal conflict in the country, which resulted in local distrust about signing anything – particular if people were unable to read what they were signing;
2. the current government regime and local distrust of government officials, as a result of common-place corruption; and

3. the illiteracy amongst many local villages along the Cambodian/Vietnamese Mekong River, which caused embarrassment if they were unable to write, or sign their name.

I regarded a completed questionnaire as indicative of the interviewee giving their verbal consent to be interviewed.

As a result of the pre-test phase (see '*4.4.1. Questionnaire Development*'), elderly male fishermen were the target group for interviews, because of their knowledge of the river and high probability of previously sighting dolphins while fishing. Females living along the river mostly spend their days at the home, bathing at the riverside in the early morning and late evening. Information that females provided on dolphin distribution was therefore less likely to be representative of actual distribution patterns. Children younger than 15 years often did not know that dolphins existed. Thus, children and women were not targeted for interviews. Photographs were taken of all interviewees to verify that the interviews did take place.

The potential success of the questionnaire depended on several factors:

1. local staff had been working with MDCP for a significant period of time (*i.e.*, up to 5 years);
2. local staff were involved in the development and translation of the questionnaires, which minimised confusion with questions;
3. I was present at most interviews, to ensure that data were collected accurately and any queries regarding the interviews could be quickly resolved;
4. I am moderately fluent in Khmer language and so was able to double-check that questions were asked appropriately and respondents' answers were accurately recorded;
5. the objectives of the survey were clearly explained to each respondent, which assisted in obtaining good quality responses; and
6. the questionnaires were short (*i.e.*, no more than 20 minutes) reducing respondent fatigue.

The interview procedure differed slightly for interviews in Cambodia and Vietnam (see '*4.4.2.1. Cambodia*' and '*4.4.2.2. Vietnam*'). Many of the factors that assisted the success of the questionnaire were not addressed as successfully for the Vietnamese surveys, as a result of my short time working in Vietnam and a lack of dedicated research assistants. Therefore, the quality of data obtained was potentially problematic in Vietnam (Table 4.1).

Table 4.1. Summary of the differences between developed and developing countries with respect to the conditions under which surveys are designed and deployed. The identified differences are arranged in ascending order of importance to undertaking a questionnaire survey regarding natural resource management issues. The third column describes the methods by which I addressed these concerns in my study. The last column summarises the potential for problems to occur during data collection/analyses based on my final questionnaire design.

***Developed* country design (based on Gill 1994)**	***Developing* country design (based on Gill 1994)**	**Mekong dolphin questionnaire (this study)**	**Potential for problem (this study)**
Questionnaire generally designed by specialist with appropriate training.	Questionnaire often designed by persons with no specialist training in questionnaire design.	I have previous experience in questionnaire design through a Masters course but no specialist training.	**Some**: but questionnaire was designed to be very simple
Questionnaire written in language in which it will be administered.	Questionnaire normally written in another language and translated, either beforehand or during the interview.	Questionnaire written in English and translated to Khmer and Vietnamese Khmer translation staff competent but competency of Vietnamese staff questionable.	**Unlikely confusion**: Khmer translations **Likely confusion:** Vietnamese translations
Respondents normally familiar with general purpose of surveys.	Respondents unfamiliar with rationale behind surveys and often apprehensive as to the use of the data.	At the start of every interview respondents were briefed extensively about the purpose of the questionnaire and use of the data.	**Unlikely**: respondents were explained the purpose of interviews
Restricted scope, simple issues addressed, short questions, usually 'opinion type' surveys.	Complex issues, information often sensitive, long questionnaires, wide scope and need for many open-ended questions.	Simple questionnaire regarding non-sensitive issues.	**Unlikely**: questionnaire designed to be simple
Built-in reliability checks.	Often little scope to check the reliability of findings.	Scope to check the reliability of findings through historical data available and multiple questioning in one area.	**Unlikely**: ability to check reliability of answers
Repeat surveys routine if trend information required.	One-shot, cross-sectional, trend estimation difficult.	No trend data required.	**Unlikely**: no trend data required
Respondents tend either to give a flat refusal or else cooperate fully.	'Conspiracy of courtesy', tendency to give answers that respondent thinks are wanted.	Simple questionnaire, however, some tendency for respondents to provide inaccurate answers for perception questions.	**Some**: but questionnaire designed to be simple
Little if any systematic gender bias.	Enumerators usually men, often severe problems in interviewing woman respondents.	Enumerators were men. Little problem interviewing females; however females had little experience on the river.	**Likely**: Gender bias occurred
Literate respondents.	Respondents either non-literate or unrepresentative.	Majority of respondents' non-literate. Simple questionnaire assisted interviews significantly.	**Likely**: but questionnaire designed to be very simple
Enumerators from roughly the same background as respondents.	Enumerators often from very different socio-economic background from respondents.	Enumerators either from same rural background or were respectful of villagers.	**Some**: but only with older enumerators from Phnom Penh
Respondents can understand what enumerator is writing and can correct errors.	Non-literate respondents cannot correct any mistakes or misunderstandings.	Respondents non-literate but enumerators re-checked answers verbally once written down.	**Some**: but respondents double checked answers verbally

4.4.2.1. Cambodia

I chose interviewees opportunistically during boat surveys in Cambodia. Interviewees were encountered while they were fishing, at the riverside, or transiting close to an area where we had stopped our survey boat. The chosen interviewee was asked if s/he was willing to participate in the survey and the survey objectives were explained. If the person did not want to be interviewed, another person was chosen.

All interviews took place away from a group situation (e.g. on a boat, or on the riverside) and only the responses of the target interviewee were recorded (Figure 4.2). Once the interviewee agreed to participate in the interview, one MDCP team member was responsible for asking all questions. One other team member recorded notes, if required. Questions were pre-determined (as explained in '*4.2.2. Questionnaire Development*') and recorded on a standardised data sheet. All interviews were conducted in Khmer. The responses were also recorded in Khmer and English later when necessary (most questions required only a tick in a box to indicate the interviewee's choices). To ensure all questions were asked correctly and to clarify any confusion, I listened to the questions and answers, which was enabled by my proficiency in Khmer.

4.4.2.2. Vietnam

Interview surveys along the Vietnamese Mekong were undertaken in parallel with boat surveys used to assess dolphin distribution. After an hour of boat survey (approximately 10 km), survey effort was stopped and interviews were conducted. Whenever possible, at least one JCU representative conducted the interviews together with a Cantho University researcher/Vietnam Department of Fisheries official (the cooperating agencies in Vietnam). As a result of working in Vietnam for only two weeks, this arrangement ensured that all questions were asked and no confusion with questions or answers arose. All interviews were conducted in Vietnamese by the Cantho University researchers and/or Department of Fishery officials.

Figure 4.2. MDCP team conducting interviews with a local Cambodian fisher. All Cambodian interviews were conducted by Khmer staff, in Khmer language. Photograph by Yim Sak Sang.

4.5. RESULTS

A total of 497 interviews were conducted: 413 interviews in Cambodia (180 in the Kratie to Khone Falls section of the lower Mekong River (see Chapter 3), 72 south of Kratie to the Vietnamese/Cambodian border, 161 in Tonle Sap River and Great Lake), and 84 in Vietnam.

4.5.1. Demographics of Respondents

The average age of respondents from Cambodia was 46.6 years ± s.d. 14.5 (range 15-81, n = 413). The average age of respondents in Vietnam was 53 years ± s.d. 16 (range 22-92 years, n = 84).

Most respondents from Cambodia and Vietnam had lived in the area where they were interviewed for more than 20 years (average 32.1 years ± s.d. 20.7 (1–81) and 42.3 years ± s.d. 20.5 (range 1–88) respectively: Figure 4.3). In Cambodia, as a result of the Pol Pot regime, many residents were forced to move away from their native land from 1975 to 1979. Many moved back to slightly different areas after 1979. Only those individuals that had lived in the same area longer than 30 years (48%) were able to provide comparative information regarding historical and current dolphin distribution in specific areas.

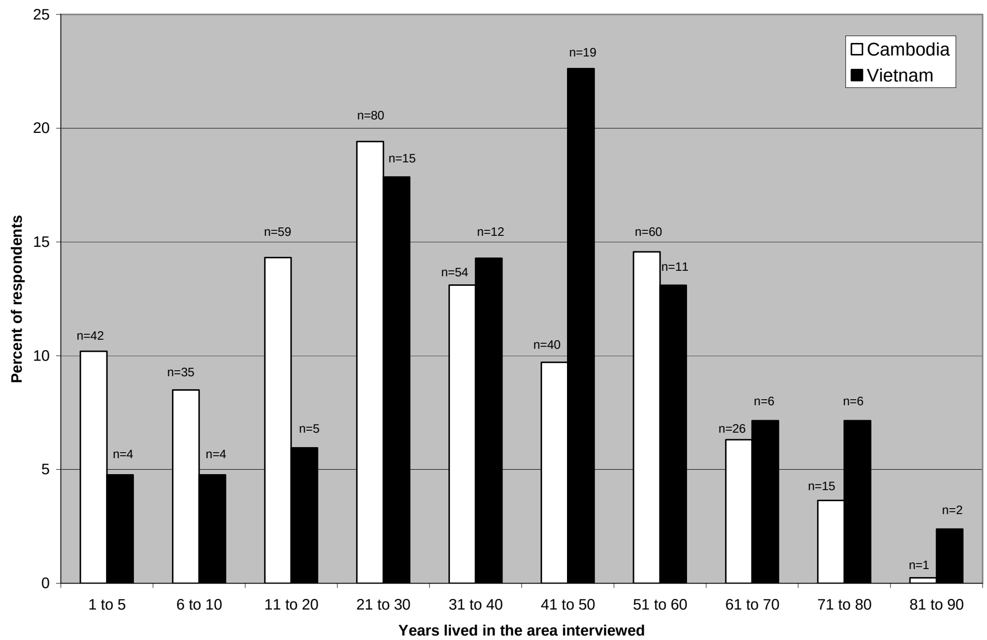

Figure 4.3. The length of time that respondents from Cambodia and Vietnam had lived in the area where they were interviewed. The majority of respondents have lived in the area more than 10 years. In Cambodia, those interviewees that had lived in the area for more than 30 years had returned to their original village after the Pol Pot regime.

Other interviewees were able to provide comparisons between their previous homeland (normally along the river) and the area they lived in at the time of the interview. No significant community movements occurred in Vietnam after the Vietnam War. The average age of respondents and their average time living in the area interviewed for each survey area is shown in Table 4.2.

Table 4.2. The average age (including standard deviation) and average length of time interviewees had resided, or worked, in the area (including standard deviation) where they were interviewed, based on interview surveys conducted throughout the lower Mekong River.

Area	Mean Age	Age Range	Years Lived in Area	Range of Years Lived in Area
Kratie to Khone Falls	40.5 ± 13.9	15 - 81	26.8 ± 18.4	1 - 70
Kratie South to Border	50.2 ± 13.1	22 - 80	37.5 ± 20.7	1 - 80
Tonle Sap River and Lake	52.2 ± 13.0	24 - 81	35.6 ± 22.0	1 - 81
Vietnam	53.4 ± 16.0	22 - 92	42.3 ± 20.5	1 - 88

Ninety-one percent of respondents were male. The location of the interviews varied, depending on where potential interviewees were sighted and the locations of houses along the river. A total of 29.6% of respondents were interviewed while out fishing; 56.8% were interviewed at their home beside the river; and 13.6% were interviewed at the riverside (2.1% of these in a local cafe).

4.5.2. Local Knowledge of Historical Distribution of Dolphins

4.5.2.1. Historical and Current Distribution of Dolphins

Interviewees were asked when they last saw dolphins in the interview area. If interviewees had never sighted dolphins in the area but had sighted dolphins in another area, their response was recorded as 'never sighted dolphins in the area' and the location that they had seen dolphins was recorded. If interviewees had been living in the area for less than two years, their information on historical dolphin distribution was excluded from further analyses. The responses were plotted graphically, to illustrate the differences between historical and current dolphin distributions (Figure 4.4).

Figure 4.5 illustrates historical and current sightings based on observational surveys to provide a comparison with data provided by interviewees. Lloze (1973) reportedly surveyed in Tonle Sap Lake and south along the Mekong River to the Cambodian/Vietnamese border (not surveying into Vietnam). Lloze (1973) caught at least two dolphins from Kampi Pool, Kratie Province for his anatomical studies. Baird and Beasley surveyed from Khone Falls south to Kratie Township and MDCP surveys covered the entire lower Mekong River from Khone Falls, south to the Vietnamese Delta (including Tonle Sap Lake).

Eighty-four percent of interviewees from Tonle Sap River and Tonle Sap Lake had never seen dolphins in the area in which they were interviewed. Only 4% of interviewees had seen dolphins historically in the lake and only two interviewees having sighted dolphins in the past five years. Further proof that Irrawaddy dolphins historically occurred in the lake was evident from various skulls that were recovered from inside the lake by respondents or friends of respondents (Figure 4.6).

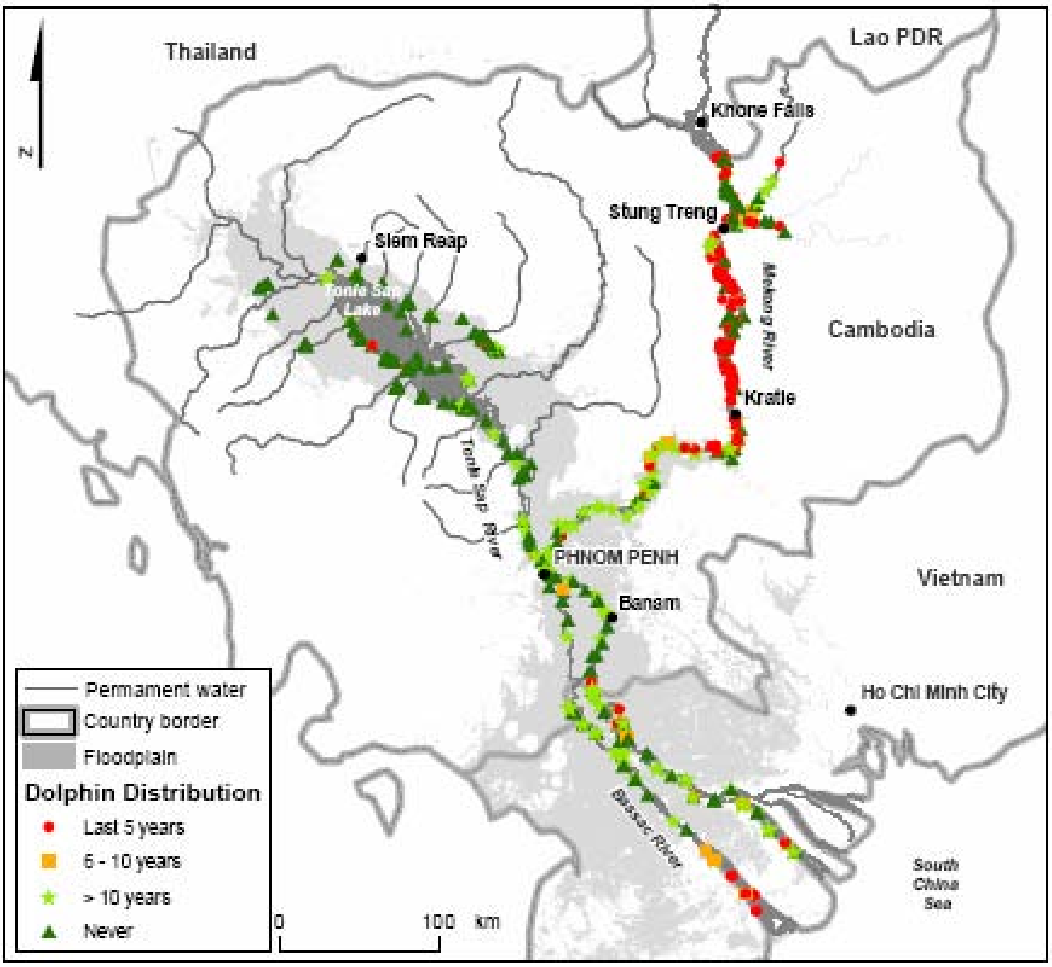

Figure 4.4. Historical and current distribution map of Irrawaddy dolphin reports from the Mekong River based on interview surveys. The Kratie to Khone Falls river section is now reportedly the primary region where the dolphins are sighted most frequently in the Mekong River. Dolphins now rarely occur south of Kratie to the Vietnamese Delta and are even rarer in Tonle Sap River or Lake. Map produced by Matti Kummu (MRC/WUP-FIN Lower Mekong Modelling Project) and reproduced with his permission.

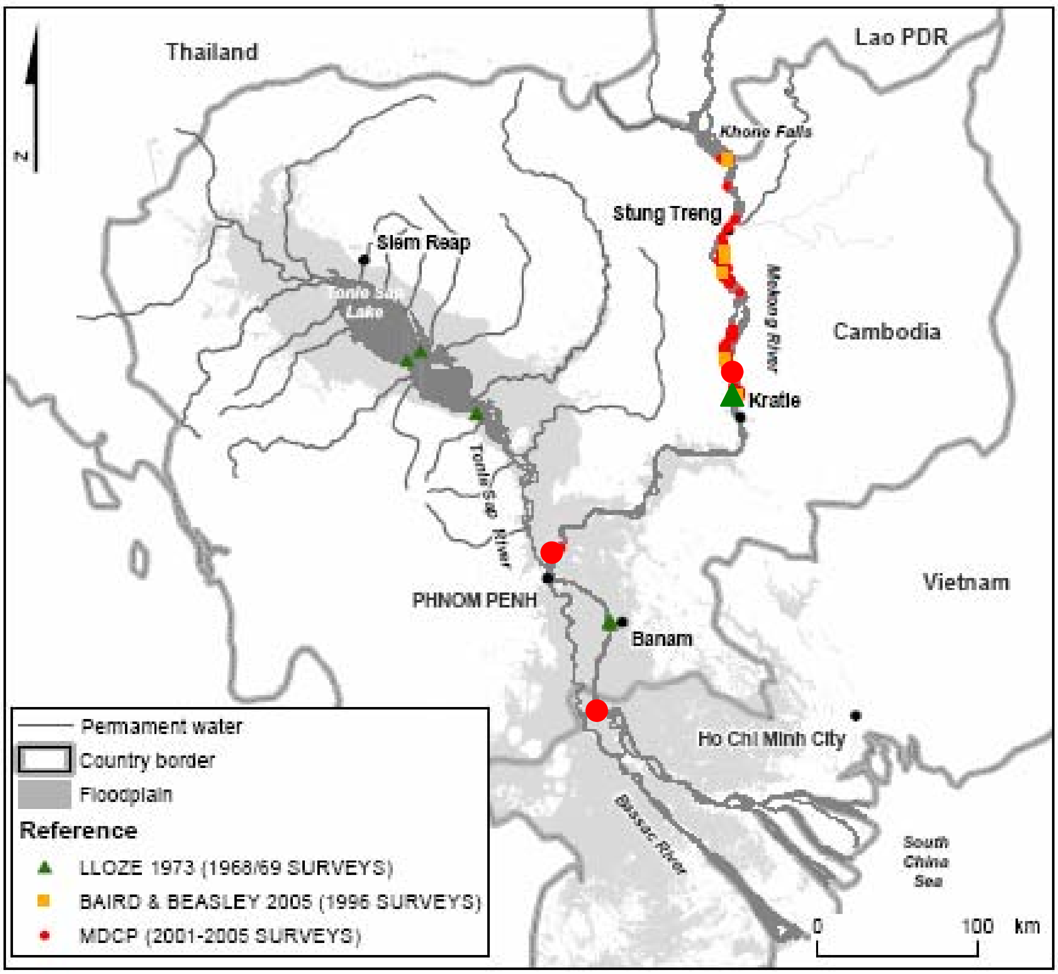

Figure 4.5. Historical and current distribution map of Irrawaddy dolphin observations from the Mekong River based on published boat survey data and my results from Chapters 5 and 6. Lloze (1973) reportedly surveyed in Tonle Sap Lake and south along the Mekong River to the Cambodian/Vietnamese border (not surveying into Vietnam). Lloze (1973) caught at least two dolphins from Kampi Pool, Kratie Province for his anatomical studies. Baird and Beasley (2005) surveyed from Khone Falls south to Kratie Township and MDCP surveys covered the entire lower Mekong River from Khone Falls south to the Vietnamese Delta (including Tonle Sap Lake). The MDCP sighting in Vietnamese Mekong waters represents the location of the three dolphin carcasses, not a live dolphin. Map produced by Matti Kummu (MRC/WUP-FIN Lower Mekong Modelling Project) and reproduced with his permission.

4.5.2.2. Seasonal Distribution of Dolphins

Respondents who could remember the season when they normally sighted dolphins reported that dolphins previously migrated downstream during the wet season (Table 4.3). Dolphins were reported to occur in the Kratie to Khone Falls river section primarily during the dry season (72.7%), when water levels are lowest. South of Kratie to the Vietnamese Delta (which flows into the South China Sea), dolphins were reportedly sighted most often during the wet season (72.4% and 77.6% of respondents respectively). Seventy-two percent of respondents from the Tonle Sap region reported sighting dolphins primarily during the dry season.

Figure 4.6. An elderly man who discovered an old Irrawaddy dolphin skull in Tonle Sap Lake during the low waters of the dry season in the early 1990s. He kept this skull, as he believed it would bring him good luck. This man was not directly interviewed but observed the interviews and then showed us the dolphin skull he had recovered.

Table 4.3. A summary of the number (and percent) of respondents to interview surveys who had previously sighted Irrawaddy dolphins in various sections of the Mekong River and Tonle Sap Lake (Area), during the wet and dry seasons. Most respondents sighted Irrawaddy dolphins during the dry season in the Kratie to Khone Falls river section and Tonle Sap River and Tonle Sap Lake. During the wet season, Irrawaddy dolphins were sighted most frequently south of Kratie, into the Vietnamese Delta.

Area	Number (%) of respondents that sighted dolphins in the dry season	Number (%) of respondents that sighted dolphins in the wet season	Total number of respondents
Kratie to Khone Falls	117 (72.7%)	44 (27.3%)	**161**
Kratie South to Border	27 (27.6%)	71 (72.4%)	**98**
Tonle Sap River and Lake	16 (72.7%)	6 (27.3%)	**22**
Vietnam	24 (22.4%)	83 (77.6%)	**107**

4.5.2.3. Reported Trends in Dolphin Abundance

Most respondents (71.6%) from both Cambodia (68.6%) and Vietnam (83.9%) believed that the dolphin population in the Mekong River had declined since they were children (Table 4.4). In many areas south of Kratie, dolphins have apparently disappeared from areas where they were reportedly common before the 1970s (Vietnam War and Pol Pot regime).

Although 8.8% of the total respondents believed the dolphin population is increasing, these respondents were primarily from the Kratie to Khone Falls river section (Table 4.4). In contrast, all respondents from Tonle Sap River and Lake believed the dolphin population was decreasing. Most respondents who did not have an opinion about temporal changes in dolphin abundance (15.3%) had never seen a dolphin in the river.

Table 4.4. Summary of the reported trends in current dolphin abundance along the Mekong River, compared to when the respondent was a child based on interview surveys. Cambodia is separated into three regions: Kratie to Khone Falls, Kratie south to the Vietnamese/Cambodian border, and Tonle Sap River and Lake. These regions can be seen on Figure 4.4.

Area	Number (%) of respondents reporting '**increasing**' numbers	Number (%) of respondents reporting '**decreasing**' numbers	Number (%) of respondents reporting '**stable**' numbers	Number (%) of respondents that '**did not know**'	**TOTAL**
Cambodia	**37 (10.6%)**	**245 (68.6%)**	**13(3.6%)**	**62(17.2%)**	**357**
Kratie to Khone Falls	32 (18.2%)	93 (52.8%)	10 (5.7%)	41 (23.3%)	176
Kratie south to Vietnamese border	4 (5.6%)	63 (87.5%)	1 (1.4%)	4 (5.6%)	72
Tonle Sap River and Lake	-	91 (83.5%)	2 (1.8%)	16 (14.7%)	109
Vietnam	**1 (1.1%)**	**73 (83.9%)**	**6 (6.9%)**	**7 (8.0%)**	**87**
TOTAL (Cambodia and Vietnam)	**39 (8.8%)**	**317 (71.6%)**	**68 (15.3%)**	**19 (4.3%)**	**444**

4.5.2.4. Causes of Dolphin Population Decline

Many interviewees did not know why dolphin numbers were changing (Cambodia 53%; Vietnam 28%). Of the 71.6% of respondents who believed that dolphin numbers are decreasing, most believed that dolphin deaths resulted primarily from: (1) accidental catch in gillnets, (2) electric fishing and bombs (both during the war and through dynamite fishing), and (3) overfishing (Figure 4.7).

In Cambodia, accidental catches in gillnets and deaths by bombs were reportedly major factors leading to population decline. Interviewees reported that during the Pol Pot regime, soldiers often shot dolphins for target practice, or threw bombs in the water to catch fish, and incidentally dolphins. Dynamite or grenade fishing reportedly continues occasionally in the more remote parts of the upper Cambodian Mekong River and its tributaries.

This situation contrasted with Vietnam, where electric fishing and over-fishing were reportedly major factors resulting in the dolphin decline. Figure 4.7 shows other factors that were mentioned as causing dolphin decline.

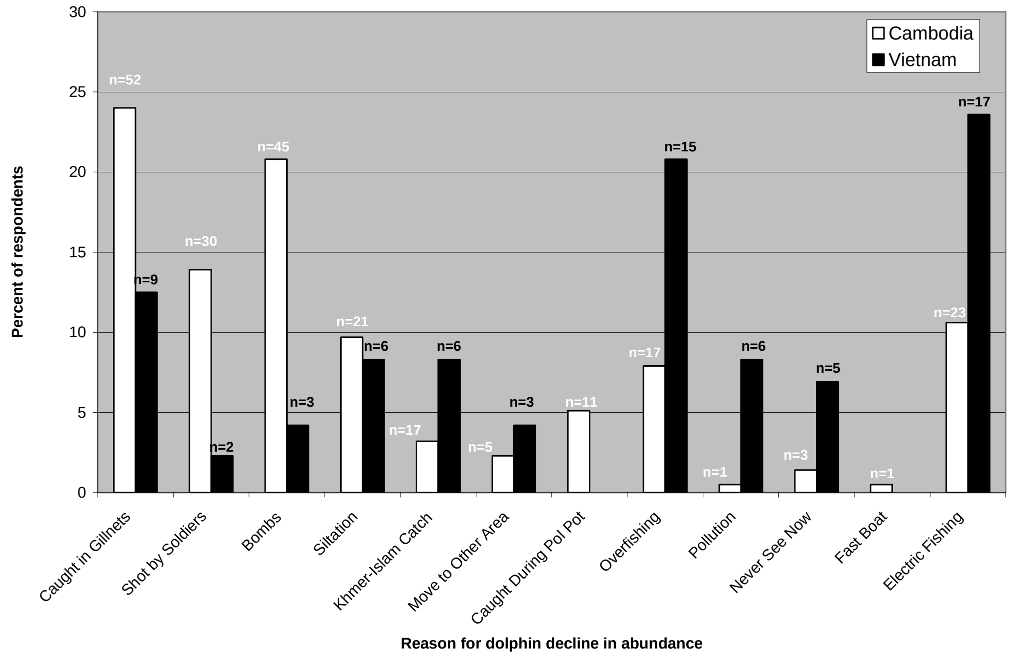

Figure 4.7. Respondents' reasons (percent of respondents) during interview surveys for the apparent decrease in dolphin numbers in the Mekong River. Bars are separated into Cambodia and Vietnam to illustrate differences in perceptions between country.

Direct killing of dolphins in Tonle Sap Lake reportedly began in the late 1950s, when a fishing lot owner became angry with dolphins catching fish near his fishing lot. Five respondents (1.3%) from Tonle Sap Lake reported that this person ordered his workers to catch as many dolphins as possible in seine nets and then kill them for their oil and meat. One interviewee reported, "*over a one-month period, workers caught enough dolphins to fill a large sampan boat that could hold 20–50 dolphins*".

Although many respondents had not observed dolphins being caught during the Pol Pot regime, 5.3% reported that it was the major reason why dolphins had declined in the lake. On 13 May 2004, I interviewed one man who had been a soldier during the Pol Pot regime and had been ordered to catch and kill dolphins in the lake. This man confirmed that during the 2-3 month season that dolphins arrived in the lake, he and other men would catch dolphins in a large seine net and butcher up to 50 dolphins in a two week period. He claimed that he did not want to catch the dolphins, as it would bring bad luck; however, he and the other men were forced to do so by their commanders.

Most of the 8.8% of respondents (*n*=27) who believed that dolphins were increasing in the river, reported that this was as a result of people no longer catching dolphins because of national prohibitions on illegal fishing gear (e.g. electric fishing, dynamite fishing and large-mesh gillnets: Figure 4.8). Other reported factors responsible for the perceived increase in dolphin numbers were that: (1) a conservation group was now working in the area (e.g. MDCP); (2) people saw dolphins every day; (3) people heard news on the radio about the dolphins; and (4) some people were seeing baby dolphins in the river.

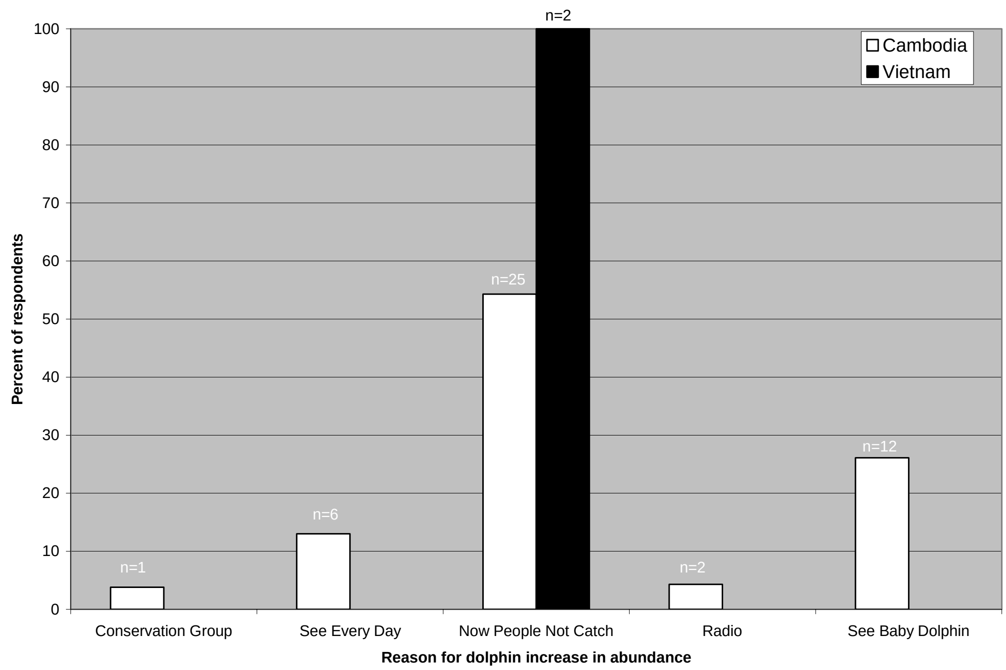

Figure 4.8. Respondents' reasons (percent of respondents) during interviews for the perceived increase in dolphin numbers in the Mekong River. Bars are separated into Cambodia and Vietnam to illustrate differences between country. Only two respondents from Vietnam believed that the dolphin population in the Mekong River was increasing.

4.5.3. Local Perceptions of Dolphin Status and Conservation

4.5.3.1. Perceptions of Dolphin Origins

Sixty-five percent of respondents from Cambodia believe that dolphins are closely related to humans (Table 4.5). This belief reportedly results from the local folklore in Cambodia that dolphins originated from a human female (see '*4.1. Introduction*'). Most respondents in Vietnam also believe that dolphins ware most closely related to humans (60.8%). Although there are no known specific folklores about Irrawaddy dolphins from the Mekong River in Vietnam, many respondents refer to the dolphin as '*old man*', or '*sir*'.

Some Khmer-Islam fishers (1.6% of total respondents, *n*=6) strongly believe that dolphins are more closely related to an aeroplane, than to any other animal (as a result of their rounded head, pectoral fins resembling plane wings and tail fluke resembling the airplane rudder).

Table 4.5. The number (% total) of respondents during interview surveys with various beliefs about the closest relative of Irrawaddy dolphins in the Mekong River.

Area	Fish	Human	Bird	Crocodile	Aeroplane	TOTAL
Cambodia	**98 (31.6%)**	**205 (66.2%)**	**-**	**1 (0.3%)**	**6 (1.9%)**	**310**
Kratie to Khone Falls	45 (32.8%)	89 (65.0%)	-	-	3 (2.2%)	137
Kratie South to Border	29 (42.6%)	38 (55.9%)	-	-	1 (1.5%)	68
Tonle Sap Lake	24 (22.9%)	78 (74.2%)	-	1 (1.0%)	2 (1.9%)	105
Vietnam	**29 (39.2%)**	**45 (60.8%)**	**-**	**-**	**-**	**74**
TOTAL (Cambodia and Vietnam)	**127 (33.1%)**	**250 (65.0%)**	**-**	**2 (0.3%)**	**6 (1.6%)**	**384**

4.5.3.2. Perceived Conservation Importance

Dolphins have a very high conservation value in both Cambodia and Vietnam. A total of 85.9% of all respondents believe it is important (including very important) to conserve dolphins in the river (Cambodia, 88.6%; Vietnam, 75.0%: Figure 4.9)

The two main reasons reported for conserving dolphins in Cambodia were: (1) to conserve them as rare Cambodian natural heritage, and (2) to keep them for future generations (Figure 4.9). In contrast, respondents from Vietnam primarily believed that dolphins were gentle and not harmful to people and so should be conserved. Respondents from Cambodia (9.1%) and Vietnam (1.5%) also gave religious reasons why dolphins should be conserved.

Cambodian respondents also reported that it was important to conserve dolphins because of: (1) their medicinal value, (2) the relationships between dolphins and fish, and (3) international tourism (Figure 4.10).

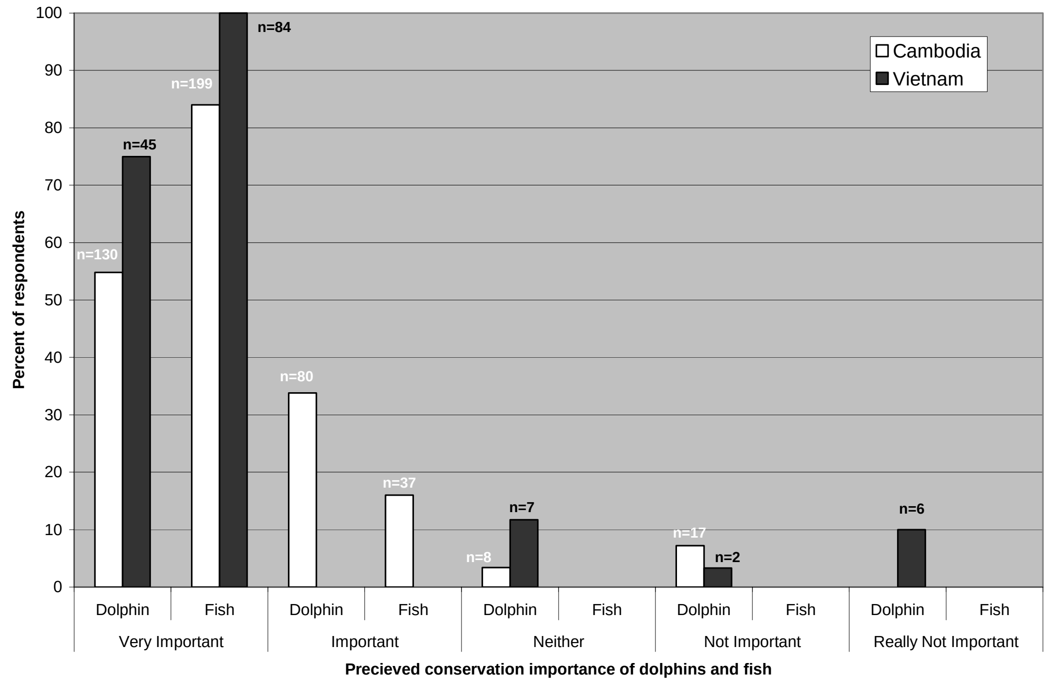

Figure 4.9. The perceived importance of conserving dolphins and fish in Cambodia and Vietnam based on interview surveys.

Fourteen percent of all respondents during interview surveys believe that it is not important to conserve dolphins in the Mekong River (Cambodia, 11.4%; Vietnam 25.0%: Figure 4.9).

The primary reasons given why it is not important to conserve dolphins are that (in order of importance): (1) dolphins have no value and are of no use to people; (2) dolphins eat fish and so compete with fisheries; (3) people had never seen them (respondents from Vietnam only); and (4) dolphins are big and respondents are afraid that they can damage their property (Figure 4.11).

Respondents were unanimous that fish stocks needed to be conserved (Figure 4.9). Most respondents from Vietnam reported that it was very important (rather than important) to conserve fish stocks. These responses presumably resulted from the dire situation facing the Vietnamese Mekong River through over-fishing and significantly reduced fish stocks. Fish stocks in Cambodia are still relatively intact, a fact which may account for 15.7% respondents reporting that fish conservation is important, as opposed to very important (84.3%). No respondents from either Cambodia or Vietnam believed that fish conservation is not important.

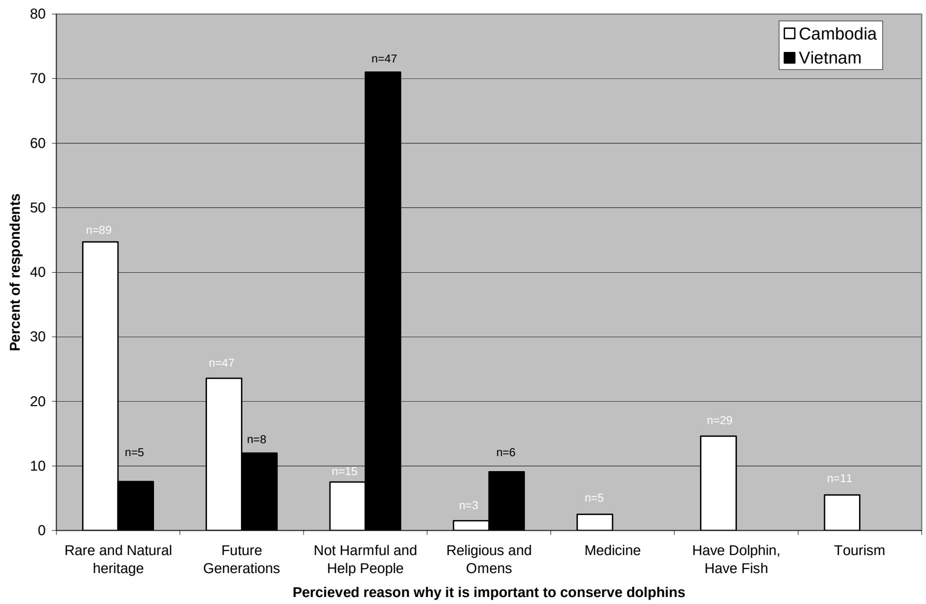

Figure 4.10. Respondents perceived reasons why it is important to conserve dolphins in the Mekong River, based on interview surveys.

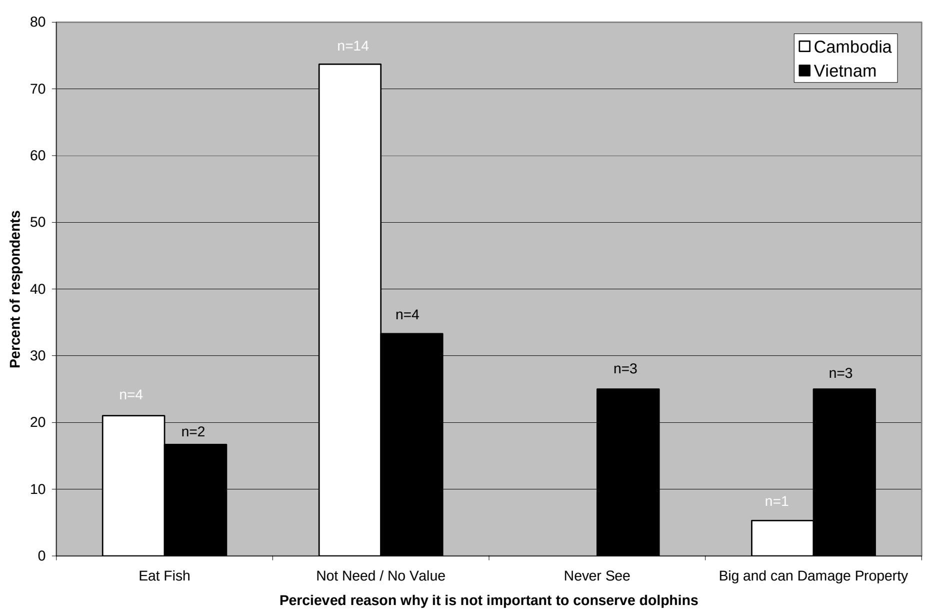

Figure 4.11. Cambodian and Vietnamese respondents, illustrating the perceived reasons why it is not important to conserve dolphins in the Mekong River.

4.6. DISCUSSION

The Mekong River has considerable social, cultural and economic value to the local peoples living along its shores (Chapter 3). Local peoples have an intimate knowledge of the river, its flora and fauna and ecosystem functioning. Despite this knowledge, I know of only two other studies that have utilised local knowledge for the lower Mekong River. In one case, the MRC accessed local knowledge of fish migrations and spawning in the lower Mekong basin from 1997-2000, to build a profile and establish baseline data on the life cycles, habitats and behaviour of fish species throughout the basin. The results contributed significantly to an understanding of fish migrations in the lower Mekong basin, primarily in Cambodia and Laos (Bao *et al.* 2001). Secondly, the LDCDCP documented important dolphin deep pool habitats along the lower Mekong River from 1991-1996, and provided anecdotal reports regarding historical dolphin distribution and perceived threats (Baird and Beasley 2005).

My study provides the first quantified examination of historical dolphin distribution in the Mekong River, as well as describing local perceptions of dolphins and fish conservation which are relevant to conservation and management.

4.6.1. Limitations of Methodology

My study used semi-structured interviews to gather information on Irrawaddy dolphin distribution and local perceptions and knowledge of dolphins in the Mekong River. Chambers (1983 p53-54) argues that most socio-economic surveys are characterised by over-long questionnaires and under-budgeted field work, under-training and under-supervision of field staff, insufficient time for analyses and increasing pressure from sponsors and donors for results, so that when the time comes to produce the report:

> "*exhausted researchers… stare at print-out and tables. Under pressure for 'findings' they take figures as facts. They have neither the time nor inclination to reflect that these are aggregates of what has emerged from fallible programming of fallible punching of fallible coding of responses which are what investigators wrote down as their interpretation of their instructions as to how they were to write down what they believed respondents said to them, which was only what respondents were prepared to say to them in reply to the investigators' rendering of their understanding of a question and the respondents' understanding of what they asked; always assuming that an interview took place at all and that the answers*

> *were not more congenially compiled under a tree or in a teashop or bar, without the tiresome complication of a respondent*".

My observations of such interviews and analyses by organisations in Cambodia (where I have the most experience) support this statement. However, despite these constraints, I conclude that socio-economic surveys do provide very valuable information that would take researchers years to obtain using different techniques. I believe it is the responsibility of the project researcher/manager to ensure that the methodology is appropriate for the situation and that data are appropriately entered and analysed.

4.6.2. Historical Dolphin Distribution and Population Change

4.6.2.1. Historical Distribution and Seasonal Changes

These results of historical distribution are in agreement with those of previous studies (Smith and Beasley 2004b, Baird and Beasley 2005), which indicate that south of Kratie and in major tributaries, the Irrawaddy dolphin population has declined dramatically in both numbers and distribution. Few respondents younger than 30 years had ever sighted a dolphin in the river south of Kratie. Most children did not even know what a dolphin was, which contrasted significantly with adults older than 30 years who were generally familiar with dolphins and their previous occurrence throughout the river. Based on recent reports of dolphins in the Srepok River (APF 2005), near Phnom Penh (Beasley *et al*. 2001) and in the Vietnamese Mekong River, close to the border of Cambodia (Beasley *et al*. 2002) (see Chapters 7 and 9), it is evident that a few dolphins occasionally move into other areas that they previously inhabited, primarily during the wet season.

4.6.2.2. Reported Trends in Dolphin Abundance

Most respondents considered that the dolphin population is declining in the Mekong River. Many respondents south of Kratie reported that they now never see dolphins in the river, compared with when they were young and regularly observed dolphins. The few respondents who considered the dolphin population to be increasing lived in the Kratie to Khone Falls river section (where dolphins still regularly occur: Chapter 7), or near coastal waters of Vietnam (where is it likely that a coastal population of Irrawaddy dolphins occurs). The overwhelming consensus is that the number of Irrawaddy dolphins in the Mekong River has declined dramatically and in some areas they are now rarely, if ever seen (in areas where they were previously commonly sighted).

The historical extent of Irrawaddy dolphin occurrence in Tonle Sap Lake remains unclear. Dolphins are not present on any bas reliefs at Angkor Wat (Chapter 3), whereas many other animal species that occur in and around the lake, such as crocodiles, birds and large fish, are illustrated extensively. There is, however, convincing evidence that dolphins previously existed in the lake:

1. Lloze (1973) documents that he observed dolphins in the lake;
2. two skulls were recovered from the lake (one by Fisheries officials in the 1990s, and one villager was able to produce an Irrawaddy dolphin skull that he found in the lake many years ago: Figure 4.6);
3. one village on the northeast corner of the lake is called '*phum phsout*' or dolphin village, apparently named after one of the first residents observed dolphins frolicking in front of the village during the early 1940s; and
4. there are numerous reports by local residents that during the Pol Pot regime, dolphins were captured in the lake for their oil and meat.

These observations in Tonle Sap were not evident in the historical distribution map (Figure 4.4), because few people who witnessed these events are alive and these events occurred at different locations from where people were interviewed (people were asked if they had seen dolphins at the location interviewed, to facilitate accurate presentation of results). Based on interviews, I conclude that dolphins were present in Tonle Sap Lake from at least the 1950s to the end of the Pol Pot regime (1979). Since the Pol Pot regime, it appears that dolphins only occasionally enter the lake. Similarly, there are reports in the literature (Lloze 1973) and numerous reports from interviews conducted as part of my study, of dolphins occurring in the mainstream Mekong River south of Kratie before the Pol Pot regime. Dolphins are now rarely sighted south of Kratie to the Vietnamese delta, although opportunistic sightings are still reported during the wet season.

4.6.2.3. Perceived Causes of Population Decline

Perceptions of dolphin population decline are different between Cambodian and Vietnamese respondents, reflecting the history of both countries and current condition of the Mekong River. Many local residents in the upper Cambodian Mekong River (Kratie to Khone Falls river section) continue to sight dolphins daily and often hear reports of dolphins being accidentally caught in mesh gillnets - currently the major known cause of dolphin deaths (Chapter 9). After the Pol Pot regime, Cambodia experienced a period of instability and many Cambodian and Vietnamese soldiers had access to firearms and grenades. Explosive fishing remains a problem in remote areas of the lower Mekong River. A dolphin was killed deliberately by a grenade in the Srepok River of Mondulkiri Province, Cambodia, in January 2005, because of fears that its presence would result in fishing restrictions in the area (AFP 2005).

Most respondents in Vietnam believe that dolphin numbers have decreased. Based on these interviews, it appears that dolphins previously occurred throughout the Vietnamese River stretch during all seasons. Many respondents relate a reported decline in fish abundance (a decline also supported by (Sultana *et al.* 2003) to coincide with an associated decline in dolphin abundance. Respondents express great concern about the effects of over-fishing and the use of electric fishing to sustainability of fish in the river.

Many Cambodian respondents (7.1%) report that over-fishing is a major reason for the dolphins' decline in the Mekong River and are concerned about the effects of the dai fisheries on fish stocks (see Chapter 3). This concern reportedly results from the large numbers of fish that are caught by these fisheries as they migrate from Tonle Sap Lake, heading towards the Mekong River and subsequently up to the deep pool refuges of the Kratie to Khone Falls river stretch for the dry season. Any management strategies to conserve fisheries and dolphins in the Mekong River must consider the effect that these fisheries are having on abundance of fish stocks. These fisheries are controlled by the wealthy and elite of Cambodia, which presents challenges for management. It is often much easier to direct management actions (such as prohibition of fishing in important areas or use of a gear type) towards poor subsistence fishers (such as along the Kratie to Khone Falls river stretch), than to address large-scale fisheries issues, which may be a higher, long-term conservation priority.

4.6.2.4. Management Implications Resulting from Local Knowledge of Historical Distribution and Population Change

As a result of data collected for this thesis, the Irrawaddy dolphin population inhabiting the Mekong River was recently classified as *Critically Endangered* by the IUCN (Smith and Beasley 2004a). This classification was based on Criteria 2 (population size estimated to number fewer than 250 mature individuals and a continuing decline, observed, projected, or inferred in numbers of mature individuals); 2a(ii) no subpopulation estimated to contain more than 50 mature individuals; (ii) at least 90% mature individuals in one subpopulation; and Criteria D: population size estimated to number fewer than 50 mature individuals. At the time of the Red List designation, data were sparse concerning historical distribution in the Mekong

River and only limited assessment of the potential decline in extent of occurrence, or area of occupancy was possible. Based on my study, there is convincing evidence that dolphins previously occurred throughout the lower Mekong River during both wet and dry seasons (dry season total area: 4,700 km^2, wet season: 45,515km^2). My interview and boat surveys indicate that dolphins are now primarily restricted to a 190 km section of the upper Cambodian Mekong River (dry season total area: 498 km^2, wet season: 567 km^2: Chapters 5 and 7). This represents a dry season extent of occurrence decline of 90% and wet season decline of 99% (although a few dolphins probably still move downstream during the wet season). Such a decline in extent of occurrence provides convincing justification for urgent conservation and management of this freshwater dolphin population.

4.6.3. Local Perceptions of Dolphins and Conservation

4.6.3.1. Local Beliefs about Dolphins

Most interviewees believe the dolphins have human origins, primarily as a result of folklore and local reverence for dolphins. This reverence is especially strong in the upper Cambodian Mekong River, where dolphins are still seen daily in many areas. This reverence and knowledge about dolphins is apparently being forgotten in areas where dolphins are now seldom seen, or have disappeared. Many children south of Kratie no longer know what a dolphin is, or believe them to be mythical creatures, similar to dragons. Khmer–Islam minority groups express no reverence for dolphins and commonly refer to them only as *similar to aeroplanes* and of *no value*. This lack of reverence probably underlies why Khmer-Islam communities have long hunted dolphins in the Mekong River (also reported by Lloze 1973), and reportedly continue to do so.

4.6.3.2. Local Perceptions of Dolphins

Interviewees report a positive perception of dolphins throughout their historical and current range and are likely to be amenable towards cooperating with conservation activities. This positive perception provides convincing justification for the involvement of local communities in conservation and management activities. Dolphin conservation strategies would also assist in conserving fish stocks (which all respondents believed are important), thus providing increased rationale for communities to cooperate with conservation. The positive perceptions of local people towards conservation can be a powerful stimulus to effecting conservation. In Loma Alta, Ecuador for example, a community-owned protected forest was established in only 14 months after efforts were initiated, as a result of communities' interest in conservation (Becker 2003).

Local communities are often able to provide significant information about the environment that would take scientists years, if not decades, to collect independently. As stated by Gill (1994),

> "*local communities typically live in an area where their families have lived for generations, earn a living from a frequently hostile and unforgiving environment and are faced with the ever-present prospect of paying the price of failure in a way that few professionals with formal qualifications, salaries and health care/benefit systems are ever called upon to do so*".

Furthermore, in areas where communities are illiterate or do not possess writing materials, a 'memory bank' is essential for customs and information to be passed from generation to generation (Gill 1994). Fishers' observations are acquired during fishing and are mediated by knowledge transmitted from previous generations, such as where, and how to fish. This knowledge tends to be linked to a fine spatial scale, but involves intensive sampling over extended periods (Goodwin *et al.* 2000). This intensive sampling often results in a high degree of accuracy and comprehensiveness regarding events in the natural environment. Bao *et al.* (2001) point out that

> "*an immense store of knowledge and experience already exists and has been passed on through generations of people who have inhabited the Mekong basin for centuries. Local knowledge is now increasingly being recognised and used in compiling detailed ecological information and developing and implementing management strategies*".

4.6.3.3. Management Implications Resulting from Local Perceptions of Dolphins and Conservation

The information provided in my study convincingly shows that local communities care about the Irrawaddy dolphin population inhabiting the Mekong River and should be involved in the dolphins' conservation and management. This situation contrasts with local communities which do not hold particular affinities or reverence for an endangered species, such as dugongs (*Dugong dugon*) in coastal waters of Cambodia (Beasley *et al*. 2001). In this Cambodian example, large amounts of money can be gained from selling a single dugong carcass and it is therefore unlikely that fishers would be willing to voluntarily assist with dugong conservation

Effective conservation of freshwater dolphins and other endangered freshwater species should ideally incorporate the knowledge and insights of local communities (Bao *et al.* 2001, Poulsen and Valbo-Jorgensen 2001, Baird and Flaherty 2005). Biological investigations continue to play an important role in developing effective management strategies. However, the integration of biological data with local ecological knowledge and socio-cultural information is now seen as a more viable way of assessing the impact of alternative fisheries' management actions (Baird and Flaherty 2005), rather than relying on biological data alone. Such an example in the lower Mekong River is illustrated through the development of Fish Conservation Zones in southern Laos that were established by local communities (see Chapter 3). Investigations by Baird and Flaherty (2005) assessed the effectiveness of these Fish Conservation Zones and showed that integrated approaches to stock assessment that employ local ecological knowledge and scientific fisheries management have considerable potential for improving Mekong capture-fisheries management.

The extent of local ecological knowledge and positive perceptions towards conservation are only two important factors that can influence the success of conservation and management strategies. Importantly, community-based management measures are likely to be impractical in the absence of government recognition and support of local riverine tenure. As reported by (Johannes et al. 1998),

> "*the absence of government support for community-based management in Southeast Asia countries and the unwillingness of governments to recognize the critical significance of this approach is often the biggest impediments to effective fisheries management in these areas*".

Success, or failure, will also be partly determined by other characteristics of arrangements that are yet to be formalised. As reported by Sutton (2000), these include:

1. the specific nature of the relationship between government and the local interest group and the role of each party;
2. the degree to which the local group represents the wide-ranging interests of all stakeholders throughout the province;
3. the level of support from the general public for such arrangements;
4. the ability of such arrangements to preserve the traditional public fishing rights of the residents of that province; and
5. the ability of associated local groups to maintain an adequate level of funding for research and management efforts.

Importantly, a continuing relationship among fishers, scientists, managers and government departments is critical to successful conservation (Goodwin *et al.* 2000). Close communication between all stakeholders and community involvement in the development and implementation of management practices will be a positive step forward towards effective conservation of the remaining Irrawaddy dolphin population in the Mekong River.

4.7. CONCLUSIONS

Chapter 4 aimed to investigate the historical status of the Irrawaddy dolphin population and local perceptions and knowledge relevant to its conservation (thesis objective 3: Chapter 1). A summary of the major conclusions from Chapter 4 are listed below:

- My study used local knowledge and perceptions to evaluate the conservation status of Irrawaddy dolphins in the Mekong River.
- Questionnaires were designed to record basic data and to overcome widespread concerns with using questionnaires in developing countries.
- Analyses of these interviews indicate a decline in dolphin occurrence throughout the majority of the lower Mekong River section. This represents a dry season extent of occurrence decline of 90% and a wet season decline of 99%.
- In association with this range decline, there has been a significant decline in abundance. Dolphins reportedly previously occurred regularly south of Kratie Township to the Vietnamese Delta and are now virtually never sighted there.
- The Kratie to Khone Falls river segment was identified by interviewees as the most important habitat remaining for dolphins in the lower Mekong River.
- Limited interviews were undertaken in the Sekong, Srepok and Sesan Rivers of Cambodia but no dolphins had recently been sighted by interviewees.
- Interview results suggest that freshwater Irrawaddy dolphins are now considered locally extinct in the Vietnamese Mekong River.
- Local communities have very positive perceptions of Irrawaddy dolphins, which significantly assists with securing local cooperation for management strategies.
- This study confirms that interviews with local villagers provide detailed information on changes in species distribution and abundance over time, as well as local perceptions towards riverine flora and fauna. These factors are essential for consideration when developing appropriate research and conservation protocols applicable to the species and/or landscape to be managed.
- Chapter 11: Table 11.3 summarises the main research and conservation implications from this chapter.

5. ESTIMATING ABUNDANCE AND ASSESSING TRENDS OF IRRAWADDY DOLPHIN NUMBERS IN THE MEKONG RIVER, BASED ON CAPTURE-RECAPTURE ANALYSIS OF PHOTO-IDENTIFIED INDIVIDUALS

Accurate and reliable estimates of total population size and trends in abundance are critical in formulating management initiatives for endangered species conservation. Recent advances in analytical techniques using capture-recapture of photo-identified individuals has enabled researchers to obtain reliable abundance estimates from a wide range of species. However, as a result of the small size of endangered populations, it often remains difficult to assess trends in abundance, even with modern analysis techniques. In this chapter, I estimate the population size of Irrawaddy dolphins in the Mekong River using closed population capture–recapture analyses of photographically-identified individuals. Based on the resulting estimates of precision, I estimate the statistical power necessary to detect a population change with on-going surveys. I conclude this chapter by discussing the conservation and management implications of my results.

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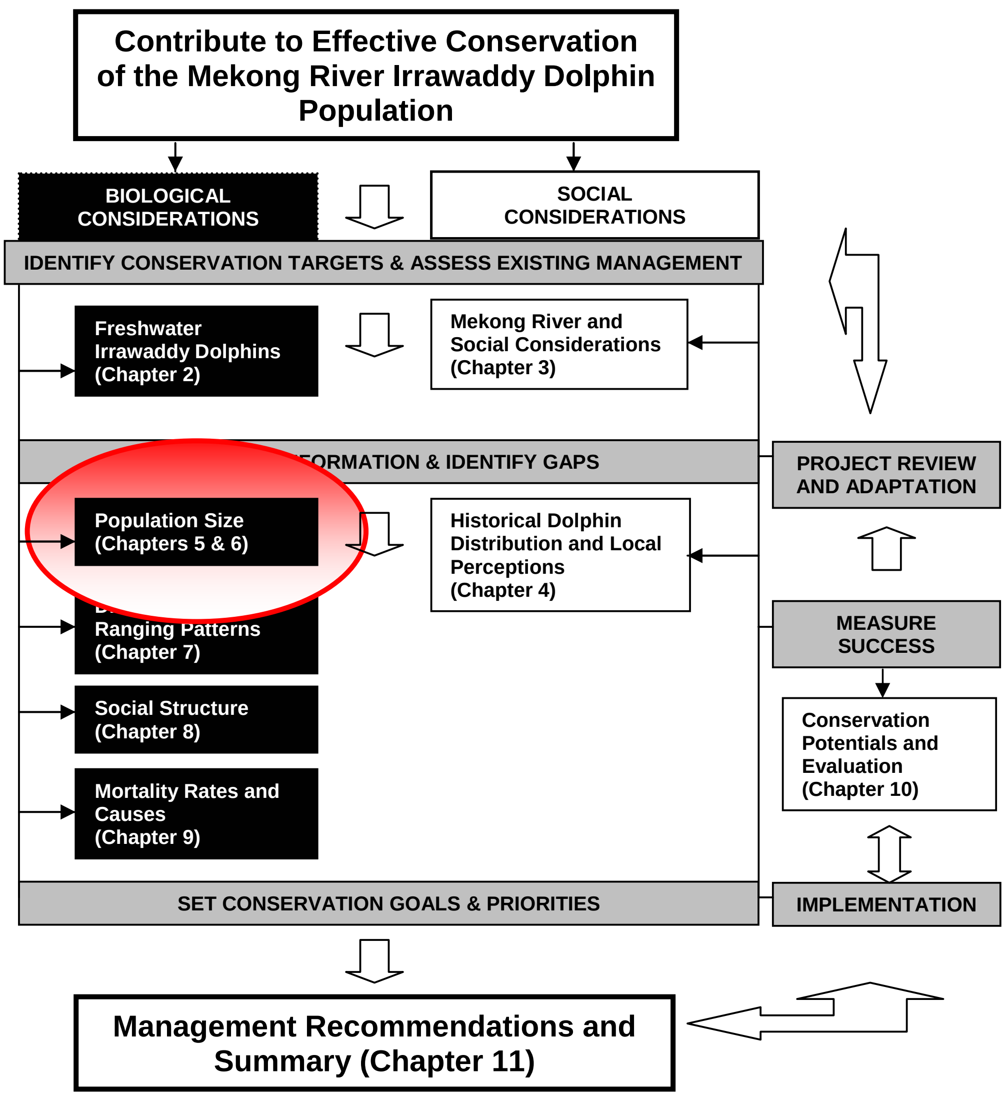
A well-known individual Chiteal (CH01) from Chiteal Pool on the Laos/Cambodian border (back), swimming with her 7 month old calf Phnom (CH12)

5. ESTIMATING ABUNDANCE AND ASSESSING TRENDS OF IRRAWADDY DOLPHIN NUMBERS IN THE MEKONG RIVER, BASED ON CAPTURE-RECAPTURE ANALYSIS OF PHOTO-IDENTIFIED INDIVIDUALS

Chapter 5 investigates a biological consideration in the context of the ‘’*collecting information and identifying gaps*’ section of my conceptual framework. The aim of Chapter 5 is to provide baseline data on the population size of Irrawaddy dolphins in the Mekong River, using capture-recapture analyses of photo-identified individuals (thesis objective 4a: Chapter 1).



5.1. INTRODUCTION

Freshwater Irrawaddy dolphins are found in three major river systems and two inland lakes in Asia (Chapter 2). Four of the five freshwater populations have recently been listed as *Critically Endangered* by the IUCN (Kreb and Smith 2000, Smith 2004, Smith and Beasley 2004b; c). A comprehensive understanding of the population dynamics of these freshwater populations is urgently required for development of effective management strategies and long-term monitoring.

Accurate and reliable monitoring is necessary for the effective management of threatened species, such as freshwater Irrawaddy dolphins (Lettinik and Armstrong 2003) and is essential for investigating the effectiveness of conservation activities. An integral component of any management strategy is an assessment of the number of individuals in a population and trends in abundance (Taylor and Gerrodette 1993). However, estimating the number of individuals in a cetacean population presents practical difficulties because they live in aquatic environments; are wide ranging; and spend much of their time underwater (Wilson *et al.* 1999). Surveys of riverine cetaceans are particularly challenging because of the complex geomorphology of river systems making standardised surveys difficult; the tendency of dolphin groups to aggregate in preferred habitats (such as confluences); and the difficulty of surveying the straight-line transects required for distance sampling survey techniques (Smith and Reeves 2000) (Chapter 6).

The recognition of individuals within a population based on the identification of distinctive and unique body features is a valuable tool that can be used effectively to research and to monitor animal populations. This approach has proved particularly useful for cetaceans (Würsig and Jefferson 1990, Samuels and Tyack 2000, Parra and Corkeron 2001). Commonly for small delphinids, distinctive body features include dorsal fin nicks, notches, scars, cuts and unusual dorsal fin shapes. If present, unusual body pigmentation is also used, in combination with distinctive dorsal fin characteristics. Hammond *et al*. (1990) provide a comprehensive review of the use of photo-identification for cetacean studies. Parra and Corkeron (2001) outline the feasibility of the technique for use with the Australian snubfin dolphin (the Irrawaddy dolphin's closest relative).

Applied capture-recapture methods began to appear in the 1930s and 1940s (Cormack 1964, White *et al.* 1982), to assist with estimating population size. Specific individuals within a population are *captured* (usually either physically or photographically), *marked* (either physically with a tag, or photographed) and then *recaptured*/*resighted*, during one, or more future sampling occasions. The use of capture-recapture studies has increased as a result of the development of powerful software, such as Programme MARK (Cooch and White 2004).

Species differ in their suitability for photographic capture-recapture studies. River dolphin species, such as the Amazon River dolphin, or boto (*Inia geoffrensis*) (Trujillo 1994) and Ganges River dolphin (*Platanista gangetica*) (Samuels and Tyack 2000) are difficult to photograph. These species often surface quickly and unpredictably, inhabit turbid environments, and have relatively small or non-existent dorsal fins. In comparison, some larger cetaceans, such as killer (Balcomb *et al.* 1982, Bigg *et al.* 1986) and humpback whales (Katona *et al.* 1979, Steiger *et al.* 1991, Gill and Burton 1995) are often more predictable in their movements, surface or dive slowly, inhabit clear water environments and have large appendages. Such features may result in virtually all animals within a population being reliably identified (Samuels and Tyack 2000).

There are few published photo-identification studies on river dolphins. In the Amazon River, Trujillo (1994) trialled a photo-identification study on the boto and tucuxi. The initial results were considered promising, however further investigations concluded that the vast majority of dolphins are not readily distinguishable by human eye and that their erratic surfacing behaviour renders photo-identification research techniques impractical (Martin and da Silva 2004), even if theoretically possible (Trujillo 1994).

The first known photo-identification study of Asian river dolphins was undertaken by Hua (1990), who tried to identify individual baiji, from the Yangtze River of China. Approximately 1000 photographs were taken, however, no individuals were identified. Further studies by Zhou *et al*. (1998), positively identified seven individuals (based on nicks, notches and scars on the dorsal fin), from 84 high quality images (out of a total of 1,178 images). A capture–recapture model based on these results estimated 30 dolphins (no estimate of standard error provided), between the Zhenjiang and Hukou section of the Yangtze River.

From 1999-2002, Kreb (2004) conducted a comprehensive capture-recapture study of freshwater Irrawaddy dolphins inhabiting the Mahakam River. Slightly-modified Petersen (closed population) and Jolly-Seber (open population) analyses resulted in estimates of 55 (95% CI = 44–76; CV = 6%) and 48 individuals (95% CL = 33–63; CV = 15%) respectively. This study established the small size of the population, providing important information for management. Stacey (1996) conducted preliminary photo-identification studies on the freshwater Irrawaddy dolphin population in the Mekong River at Chiteal Pool on the Laos/Cambodian border. She showed that individuals were visually identifiable but concluded that collection of suitable photographs was a challenge at that site, largely because of the dolphins' elusive behaviour. Nonetheless, I decided to trial this technique to determine its feasibility with increased survey effort.

5.2. STUDY AREA

I undertook photo-identification studies along the lower Mekong River (13,200 km surveyed from 2001-2005: Chapter 6). No dolphins were seen south of Kratie Township (a result also confirmed by interview surveys: see Chapter 4). Consequently, all photographs were taken in the Kratie to Khone Falls section of the upper Cambodian Mekong River (see Chapter 3).

The Kratie to Khone Falls river section is characterised by alternating deep pool/riffle river sections. There are four 'primary areas' that dolphins regularly inhabit during the dry season, made up of eleven 'critical deep water habitats' (Chapter 7), (Figure 5.1):

- *Kampi Area*: consisting of Kampi and Chroy Banteay pools,
- *Koh Pidau Area*: consisting of Kontoy Koh Rongue, Koh Pidau, Anchen, Khasak Makak and Sampan pools,
- *Stung Treng Area*: consisting of Tbong Klar, Kang Kohn Sat and Koh Suntuk pools, and
- *Chiteal Area*: consisting of only Chiteal pool.

There is one additional 'primary area' that dolphins regularly inhabit during the middle of the wet season:

- *Phum Kreing Area*, which is used by dolphins from the Kratie and Koh Pidau primary areas (Chapter 7) and is only included in the wet season analyses.

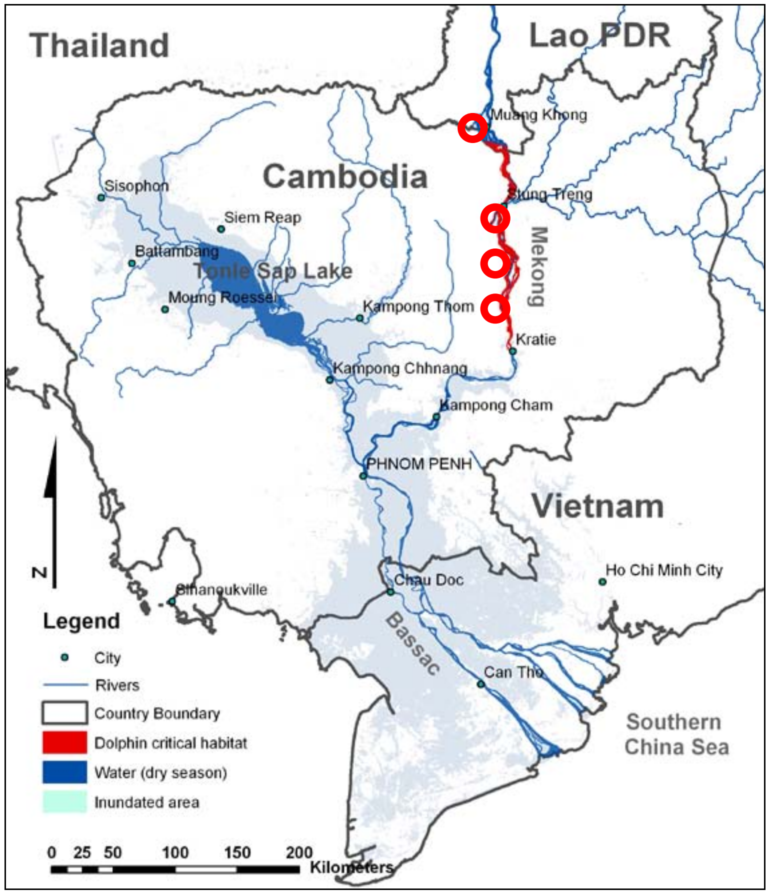


Figure 5.1. The study area in the lower Mekong River from Muang Khong (Laos/Cambodian border), south to the Vietnamese Delta. The river section in red is the Kratie to Khone Falls River section, which is the dolphins' primary habitat during the dry season. The four primary areas occupied by dolphins during the dry season are indicated by red circles. From north to south, the areas are: Chiteal, Stung Treng, Koh Pidau and Kampi.

5.3. MATERIALS AND METHODS

5.3.1. Data Collection

5.3.1.1. Survey Timing

I undertook photo-identification during boat surveys from 2001–2005 (Chapter 6). In addition, I dedicated 32 days specifically to photo-identification. When conducting photo-identification in parallel with boat surveys, however, finishing the day's survey took precedence over photographing individuals, reducing photographic effort on many occasions. Most photo-identification was undertaken during the dry season (late October to the end of May) and at the start of the wet season (late May to June).

5.3.1.2. Methodology

My final capture-recapture analyses were influenced significantly by changes in equipment and experience over my research period. From 2001-2003, photographs were taken using a Canon EOS3 SLR camera, with a 70–200 mm (f. 2.8) lens and converter (2x). This configuration of lenses resulted in a maximum focal length of 400 mm. Fujichrome 100/200 slide and Fujicolour print film were used during 2001-2002; however, from 2003-2004, print film was preferred because of the high cost and logistical constraints of developing slide film in Cambodia. During 2004-2005, photographs were taken using a Canon EOS 10D digital camera, with a 300 mm (f. 2.8) lens and converter (2x) (Figure 5.2). With the 1.6 x digital camera conversion, this arrangement resulted in an effective focal length of 960 mm, which significantly improved photographic image quality.

Once a dolphin group was sighted and group size estimated (see Chapter 6), photographs were taken of all individuals within the group. The primary feature for photo-identification was the dorsal fin plus any other scars or pigmentation patterns shown on the dorsal surface. Because of the dolphins' shy and erratic surfacing behaviour and the turbidity of the river, I found photographing dolphins in the Mekong River difficult and time-consuming. Throughout 2001, dolphins were approached slowly and once the boat had arrived near the group the motor was turned off. However, irrespective of the angle from which I approached the group, or how slowly the boat travelled, the dolphins nearly always dove away from the boat (probably because of the engine noise) and then actively avoided the boat for the remainder of the sighting. As a result, few identifiable photographs were taken during 2001.

From 2002 onwards, I changed the approach methodology. Once photographic effort began, the survey boat travelled to the most northerly location of the deep water pool in which the dolphins were sighted (the hired guide advised me of the location) and the motor was turned off (irrespective of the position of the dolphins). The boat then quietly drifted downstream past the area where the dolphins had been sighted (which was often the core area of dolphin concentration: see Chapter 7) (Figure 5.3). Upon reaching downstream of the area (which could take as long as six hours per 500 m when water velocity was low), the boat then travelled back up to the same starting position and the process was repeated. When using this 'approach', the dolphins normally ignored the boat after 15-20 minutes and continued with their previous behaviour: often coming as close as 10 m to the boat. The significant depth of some deep pools (up to 90 m deep), prevented anchoring the boat while taking photographs (Chapter 7). On days specifically dedicated to photo-identification, I often spent an entire day photographing in one deep-water area. This method resulted in close and clear images of the majority of individuals within each group.

Figure 5.2. Photo-identification was one of the primary techniques used to estimate abundance of Irrawaddy dolphins in the Mekong River. From 2004-2005, high quality photographic equipment was used to photograph dolphin groups. I used a combination of a Canon digital camera with 300 mm fixed lens and a converter (2x), which resulted in a focal length of 960 mm. Using this arrangement, I obtained very clear, high quality dolphin images. Photo by Brendan Boucher.

Each dolphin group was photographed and relevant data recorded (e.g. environmental data, individual behaviours, particular associations, and relevant information about each photographic image, such as date, time, image size and resolution) (Chapter 6). When boat surveys were continued, or photographs of the group were completed, a blank photograph was taken to separate photographic events and ensure groups were not confused. On the few occasions that groups were sighted in close proximity but did not interact, care was taken to ensure that one group was photographed, followed by the second group and that photographic effort was not combined, or group composition confused.

I attempted to ensure that the photographic effort was similar throughout all primary areas and made an effort to photograph every individual within each group, irrespective of whether dolphins appeared to have distinctive dorsal fin markings.

Figure 5.3. The survey boat drifting in Chiteal pool in the Mekong River, to obtain photographic images of individual Irrawaddy dolphins. I often spent an entire day was spent drifting in one deep water pool, to obtain adequate photographs. I normally took all photographs. The boat driver and research assistants observed the dolphin group as I was photographing, to estimate group size and composition, as well recording any unusual behaviours or events. Photo by Yim Saksang.

5.3.2. Identification from Photographs

5.3.2.1. Photo-identification Quality Grading

The first stage of analysis was to grade each photograph according to image quality (Hammod *et al*. 1990: Figure 5.4), as a series of binary variables into the programme EXCEL version 5.1:

- *Unusable* – a photograph which consisted of a blank image to separate groups, a splash of water, or an image of a dolphin but no dorsal fin in the image (e.g. only a head, tail, or flipper in the image).
- *Poor* – an image where the dorsal fin could not be clearly seen, the image was blurry, the dorsal fin was not perpendicular to the camera, or was severely backlit by the sun. Only very distinct individuals were identifiable.
- *Good* – an image that was clear, the dorsal fin was nearly perpendicular to the camera and there was little backlighting. Most identifying features were seen if present, although slight angles, or dark lighting, made identification questionable.

- *Excellent* – an exceptionally clear, in-focus image, where the dolphin took up more than half the image, the dorsal fin was perpendicular to the photographer and the lighting was excellent. All distinguishing features were seen, if present.

Figure 5.4. Two examples of photographic image quality. An excellent image (left), in which nicks, notches and even scratches can be clearly seen in focus. A good quality image (right), which although in focus, is not exactly perpendicular to the camera.

I catalogued each image based on the presence, or absence of identifiable features. Slides and prints were analysed using an 8x loupe and digital images directly from my computer. Each usable image was then classified into one of the following two categories:

- *Unrecognisable* – the dolphin had no distinctive features on its dorsal fin or body that could be used to identify it (nothing more was done with these images).
- *Subtle Markings* – the dolphin had only very subtle markings and therefore not sufficiently identifiable to be included in the capture-recapture analysis.
- *Recognisable* – the dolphin could be individually recognised based on distinctive features on its dorsal fin and/or body.

5.3.2.2. Photo-identification Catalogue

Once a dolphin was considered recognisable, the relevant photographs were compared with the photo-identification catalogue. If a new individual was confirmed, its photograph was added to the catalogue and it was given an area code and unique identification number. At a later date, the individual was given an appropriate name, based on its distinctive dorsal fin/body features, or area sighted. As many features as possible were used to confirm matches and reduce the possibility of false positives (*i.e.*, classification as a new individual when it was already identified in the catalogue) (Würsig and Jefferson 1990, Wilson *et al.* 1999).

The identification codes are based on the area that the identified dolphin was first sighted, as follows: Kampi (KA), Chroy Banteay (CB), Phum Kreing (PK), Kontoy Koh Rongue (KKR), Koh Pidau (GO), Anchen (AC), Khasak Makak (KM), Tbong Klar (TK), Kang Kohn Sat (KKS), Koh Suntuk (KS) and Chiteal (CH). The first dolphin sighted in the area was named (‘AREA’) 01. Subsequent dolphins were labelled consecutively. For example, KA01–Klasico, was the first dolphin to be identified at Kampi Pool; KA05–Rags, was the fifth dolphin to be identified at Kampi Pool.

5.3.3. Capture-Recapture Assumptions

An assessment of the robustness of the various capture-recapture assumptions in the context of my study is provided in Table 5.1. Throughout the study, bias was minimised through relevant photo-identification techniques, in order to address all model assumptions.

5.3.4. Data Selection

One of my major assumptions was that the population was closed to immigration and emigration (but not to births and deaths). Boat and interview surveys were undertaken throughout the dolphins’ known habitat (*i.e.*, from southern Laos south to Vietnam, including Tonle Sap Great Lake) (Chapters 4 and 6). Based on these surveys, I concluded that dolphins were restricted to the Kratie to Khone Falls river segment during the dry season (late October to the end of May) - although there was the potential for movement downstream during the wet season (June to early October), when water levels rose significantly. All photo-identification data from the wet season (which included the Phum Kreing primary area), were excluded from the capture-recapture analyses.

Table 5.1. The assumptions of mark-recapture and consequences of the methods used in this study to address them.

Assumption summary	**Detailed capture-recapture assumption**	**Failure to address assumption?**	**Study methods**	**Potential for assumption violation**
Mark Recognition	A marked animal will be recognised with certainty if recaptured.	Over-estimation of abundance if poor quality photographs or ambiguous markings are used.	Only good and excellent quality photographs were used for analyses. Dolphins with subtle markings were exluded from capture-recapture analysis. A dolphin was not considered re-sighted, or a new individual, unless I was certain about the decision – which was normally based on assessment of a number of photographs from different angles throughout the sighting. If there was any indecision, this individual was classified as unrecognisable but noted for future consideration.	Extremely unlikely
Behavioural Responses	1. Marked animals have the same probability of being captured as unmarked animals.	1. Over-estimation if dolphins stay away from the boat once marked and under-estimation if dolphins are attracted to the boat once marked.	1. Photographs were taken of existing marks on the dorsal fin. Therefore, no physical interaction with the animal was involved to cause the dolphins to avoid the boat, once photographed. In addition, great care was taken not to disturb dolphin groups when taking photographs and the boat engine was always turned off during photo-identification attempts.	1. None
	2. The action of capture should not change the probability of recapture.	2. Over-estimation if dolphins approach the boat and under-estimation if dolphins swim away from the boat before detection.	2. The boat always approached the group with care and the engine was stopped when photographing a dolphin group..	2. Unlikely
Mark Loss	Marks are not lost during the study.	Over-estimation if marks are lost during the study.	A combination of dorsal fin nicks, notches and cuts (‘long lasting marks’; *sensu* Wilson *et al*. 1990) was used to identify an individual. Scratches on the body were used as an additional feature to confirm identification, but were not the primary identification method. Unique pigmentation was not used as a primary identification feature. No deformities were evident on any individuals in the population, although two individuals had very distinctive fin shapes, recognisable over time.	Low

Assumption summary cont…	**Detailed capture-recapture assumption cont…**	**Failure to address assumption? cont…**	**Study methods cont…**	**Potential for assumption violation cont…**
Geographical Closure	An estimate of abundance that represent population size has limited value unless the population can be defined (Wilson *et al.* 1990)	Inaccurate and imprecise estimate of population size if population is considered closed, when it is open, and vice versa.	Based on boat and interview surveys in other Mekong River segments of historical dolphin distribution (Chapters 4 and 6), I concluded that the entire Mekong River Irrawaddy dolphin population is now restricted to the Kratie to Khone Falls river section during the dry season.	Low: but possible
Heterogeneity of Capture Probabilities	Within a sample, all individuals have the same probability of capture.	The presence of heterogeneity results in under-estimation of population size.	Attempts were made to photograph every individual encountered in a group and preferential photographing of any particular individual was avoided (Wilson *et al*. 1990). Also, the entire known distribution of the population in the Kratie to Khone Falls river section was surveyed to reduce the probability of missing animals inhabiting remote areas.	Minimised: but likely to be violated because of inherent differences in behaviour of individuals.

Dolphins apparently move little, if at all, between the four dry season primary habitats (*i.e.*, Kampi, Koh Pidau, Stung Treng and Chiteal) (Chapter 7). Although it would have been preferable to estimate abundance for each primary area, limited re-sightings in the Stung Treng primary area prevented such analysis. Photo-identification data were therefore pooled across all primary areas to increase the sample size and obtain one population estimate. Individuals identified and recorded as calves (n=2) were not included in the capture–recapture analyses because their probability of capture was not independent from that of their mothers (Wells and Scott 1990, Wilson *et al.* 1999).

All data from 2001–2003 were excluded from the capture-recapture analyses because of the significant differences in the photographic quality and number of images taken. This approach resulted in closed population model analyses, with data separated into three sampling intervals: January-April 2004, May–July 2004, and April 2005.

5.3.5. Estimating the Proportion of Animals with Long-lasting Marks

When photographing a dolphin group, all individuals within range were photographed, irrespective of whether they appeared to have distinctive marks. Assuming that identifiable individuals were no more, or less, likely to approach the boat, I estimated the proportion of identifiable individuals in the total population by taking a random sample of 50% of the total excellent quality photographs from 2004–2005. The total number of identifiable individuals was then divided by the total number of photographs in the random sample, to provide an unbiased estimate of the proportion of identifiable individuals in the population (Wilson *et al.* 1999, Chilvers and Corkeron 2003, Parra 2006).

Abundance estimates obtained through the capture–recapture analyses are only relevant to the marked animals within the population. Therefore, to include the unmarked portion of the population in the estimates, the total population was derived as:

Equation 5.1. $$N_{total} = N / \theta$$

Where N_{total} is the total population size, N is the estimate of marked animals from the population models and θ is the estimated proportion of animals that are identifiable (Wilson *et al.* 1999, Chilvers and Corkeron 2002, Parra 2006).

The variance of N_{total} is given by:

$$Var(N_{total}) = N_{total}^{2}\left(\frac{var\,N}{N^{2}} + \frac{1-\theta}{n\theta}\right)$$

Equation 5.2

Where *n* is the total number of animals from which θ was estimated (Williams *et al.* 1993) and varN is the square root of the variance of the marked animals. Confidence intervals for total population size were calculated by assuming that the error distribution was the same as for the estimated models, with the lower and upper confidence limits equivalent to the number of standard errors away from the estimate (Chilvers and Corkeron 2002, Parra 2006).

5.3.6. Estimating Total Population Size

In order for the capture-recapture estimate to be robust, the basic assumptions are that natural marks should be recognisable over time; unique to the individual; have an approximately equal probability of being sighted and resighted (Würsig and Jefferson 1990). The recapture, or resighting at time (t + 1) of an individual marked at time t, depends on three events and their associated probabilities: (1) the probability of the individual surviving from time t to time t + 1, (2) the probability of the individual being present in the study area at time t + 1, and (3) the probability that, if alive and present at time t + 1, the individual will be caught, or sighted.

I used a closed population model assuming that there was no immigration or emigration between sampling periods as a result of the populations' restricted distribution during the dry season and lack of movement south to Vietnam and coastal waters of the South China Sea, and vice-versa (see Chapter 6). Data were also available for births and deaths within the population during this sampling period, which I considered to be reliable. All capture-recapture analyses were conducted using the programme CAPTURE, within MARK 5.1 (White 2004). The programme CAPTURE contains eight models for estimating population size (Otis *et al.* 1978). The eight models incorporate three sources of variation in sighting probabilities: a time response (M_t), behavioural response (M_b) and individual heterogeneity (M_h). The eight models are therefore the above three and the various combinations of them (M_{tb}, M_{th}, M_{bh}, M_{tbh}), plus one model in which the capture probabilities remain constant (M_o) (Williams *et al.* 1993, Chilvers and Corkeron 2003). CAPTURE includes a model selection procedure based on goodness-of-fit tests and discriminate function analyses, to indicate the best fitting model to the data-set.

I then used results from the closed population model and the number of calves and dead animals (see ‘*6.3.7. Estimating the Number of Newborns/Calves and Dead Animals*’), to estimate the total population size during the sampling period.

5.3.7. Estimating the Number of Newborns/Calves and Dead Animals

In order to correct the closed population model for known births and deaths, I obtained unbiased estimates of the number of births and deaths in the population during the sampling period.

5.3.7.1. Estimate of the Number of Newborns/Calves

The number of newborn dolphins and calves was estimated visually while conducting the photo-identification study. A *newborn* was defined as a dolphin approximately 1 m (or less) in length, swimming constantly in close proximity to another dolphin (presumably the mother), surfacing in a ‘corkscrew’ fashion (irregular surfacing with its head jerking high out of the water), with obvious foetal folds (Figure 5.5). Newborns were normally slightly darker in colour than older dolphins. A *calf* was defined as a dolphin approximately 1 m (or slightly more) in length, swimming constantly in close proximity to another dolphin (presumably the mother), but surfacing in a regular fashion. The number of individual newborns and calves was recorded throughout the year, taking into account: (1) the critical area where sighted, acknowledging minimal movement by adults (Chapter 7); (2) potential movements to adjacent areas; and (3) an association match, or lack of, with an identified adult, presumably the mother, to minimise double counting.

There was a very low probability that a newborn/calf could have been confused with a juvenile during the study period because of: (1) the larger size of the juveniles, (2) the slightly lighter colour of the juvenile but lack of scratches evident over the body (3) the juveniles consistent independence, often swimming away from the mothers side, and (4) the long duration of observations that we conducted for each sighting to correctly determine group size and age class.

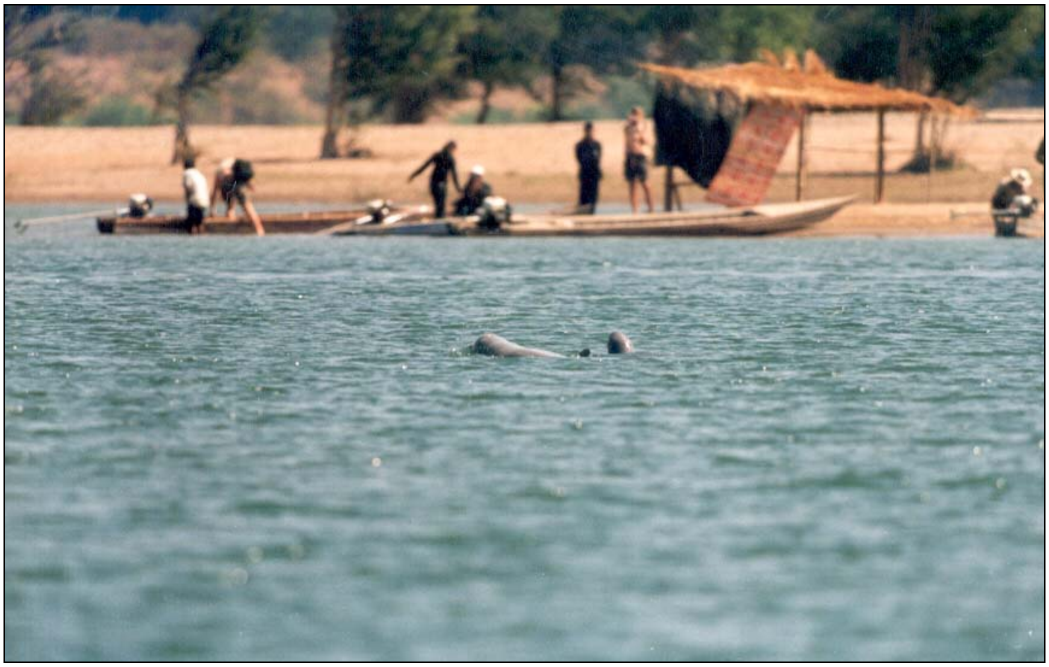


Figure 5.5. An example of a newborn dolphin surfacing beside its mother, sighted during boat surveys. This individual was sighted in Chiteal Pool in January 2004 with adult, Chiteal (CH01). The newborn (named Phnom: CH11), was resighted in Chiteal Pool during every survey conducted to April 2005. Phnom swam constantly with CH01 and exhibited subtle marks on its body (but not dorsal fin) which were acquired in April 2004 and matched from then on in all good and excellent photographs.

5.3.7.2. Estimating the Number of Dead Animals

An estimate of the number of dead animals was facilitated by an active and on-going carcass recovery program that was undertaken throughout the study period, along the entire lower Mekong River (including Tonle Sap Great Lake) (Chapter 9). All dolphin carcasses reported or found during surveys were recovered and relevant photographs, measurements and samples collected (Figure 5.6). For a dolphin to be confirmed as dead, the carcass had to be recovered, or I had to observe some part of the body (e.g. skeleton or tissue) or a photograph of the deceased animal. All other reports of dead dolphins were recorded as unconfirmed and excluded from analyses.

Figure 5.6. The project team members responsible for the dedicated carcass recovery program photographed with three newborn dolphin carcasses recovered during March 2004 in the Kratie and Koh Pidau primary areas. Photo by: Mr. Chivv That (Kratie Fisheries Office).

5.3.8. Study Constraints

Throughout this three-year photo-identification study, various considerations influenced the data used in the final analyses:

- I endeavoured to equalise photographic effort in all dry season critical areas throughout the entire upper Cambodian Mekong River (including the Laos/Cambodian border). However, unsuitable weather conditions and other logistical difficulties reduced photographic effort in the Stung Treng primary area each year. This anomaly may result in the final abundance estimates being biased slightly downward.
- From 2001-2004, as a result of logistical constraints (*i.e.*, personnel, time, resources and finances), photo-identification was undertaken in combination with direct count and line-transect boat surveys designed to obtain population estimates (see Chapter 6). This arrangement resulted in significantly fewer photographs being taken compared with surveys dedicated solely to photo-identification. In 2005, dedicated photo-identification studies were conducted, which greatly increased photographic effort and sample size.
- Photo-identification during 2001-2003 was hampered by the use of a print camera, and a small telephoto lens. The print camera resulted in few photographs being taken because it was very expensive to develop print film. The small telephoto lens resulted

in photographs of poor quality. As a result of these constraints, data collected from 2001-2003 was not used in the capture-recapture analysis.

- Although improved equipment was used from 2004 onwards, it was consistently difficult and time-consuming to approach and photograph dolphin groups that often avoided the boat and surfaced unpredictably and inconspicuously. To balance these difficulties, significant time was saved because dolphins consistently occurred in known critical habitats along the river, thereby reducing the search effort required to locate groups.

5.4. ANALYSIS OF STATISTICAL POWER OF MONITORING PROGRAMS

Power analyses were conducted to estimate the probability of detecting upward or downward trends in abundance. This method followed Gerrodette (1987):

Equation 5.3 $$r^2n^3 \geq 12CV^2(Z_{\alpha/2} + Z_{\beta})^2$$

Where *r* is the rate of change, *n* is the number of samples, CV is the coefficient of variation, and $Z_{\alpha/2}$ and Z_{β} are the probabilities of committing Type I (the probability of rejecting a null hypothesis when it is true) and Type II (the probability of accepting a null hypothesis when it is false) errors respectively.

The probability for making a Type I (α), or Type II (β) error, was set at 0.05. I used the range of CV values obtained from the capture-recapture population estimates, to investigate the time required to detect different rates of population change by conducting annual surveys. The power analyses were run using the programme TRENDS Windows Version 3.0 (Gerrodette 1993).

5.5. RESULTS

Photo-identification studies were undertaken from 27 January 2001 to 23 April 2005. A total of 210 hours were spent photographing dolphins over 227 days. The number of hours spent photographing dolphins varied between years and ranged from 14 hours in 2001 to 40 hours in 2005. Data from 2001-2003 were excluded from capture-recapture analyses (see '*5.3.8. Study Constraints*').

In 2004-2005, photographic images consisted of 3% prints and 97% digital images. A total of 10,602 frames were taken. Of these images, 4,441 (42%) did not show a dorsal fin and were unsuitable for photo-identification. These images were commonly blank, or showed only water/splash, or a head/tail/body. Of the 6,161 (58%) photographs that included a dorsal fin, 4,513 (73%) were considered poor quality, 1,252 (20%) good quality and 396 (7%) excellent quality (see '*6.3.2.1. Photo-identification Quality Grading*' for explanation of picture quality).

The proportion of photo-identification effort for each primary area (see Chapter 7), was not statistically different between 2004 and 2005 (T-test, CI=0.95, $P>0.05$). However, there were subtle differences in effort: (1) at Chiteal Pool in 2004, when photo-identification effort was increased to photograph two newborn calves and associated individuals (see Chapter 8); and (2) at Kampi Pool during 2005, when proportionately more photograph effort was spent compared to other areas (Figure 5.7). During 2005, only one month of photo-identification effort was conducted because of time and logistical constraints. Minimal effort was possible in the Stung Treng primary area because the exposed topography resulted in consistent high winds and wave action. Unsuitable weather conditions were not a major consideration in any other primary area.

Although photographic effort was proportionately similar between years, there was a significant difference in overall effort in each of the primary areas (T-test, Sig. 0.05, $P<0.05$). More effort was conducted in the Kampi area because of its location close to where I was based in Kratie Township. The effort in Koh Pidau and Chiteal areas was similar and the least effort was conducted in the Stung Treng area (Figure 5.8).

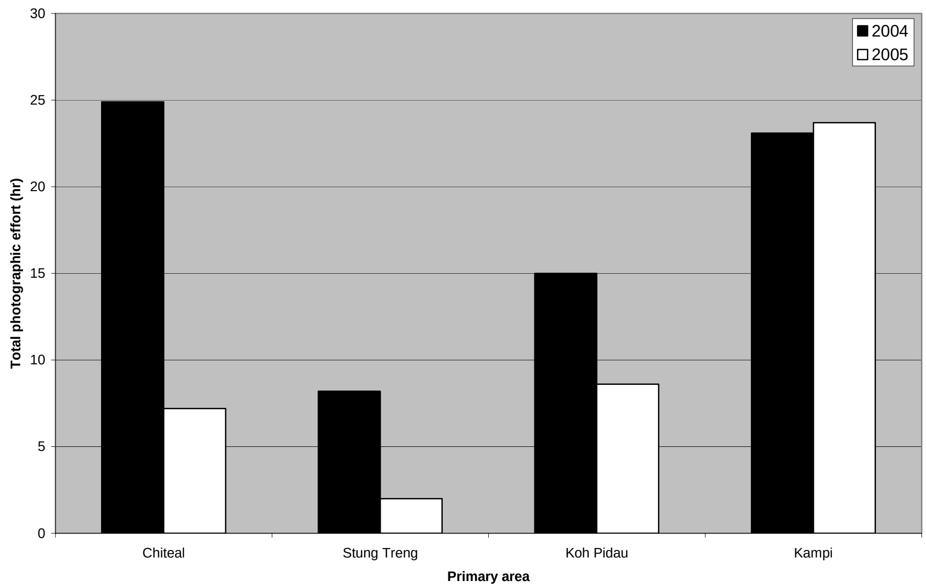


Figure 5.7. Total photo-identification effort (based on the total time photographing Irrawaddy dolphin groups in the Mekong River) in 2004 and 2005 (data from 2001-2003 were excluded from these analyses). Photographic effort was higher in 2004 (71.2 hr) compared with 2005 (41.5 hr) because photo-identification effort was restricted to one month during 2005 (April).

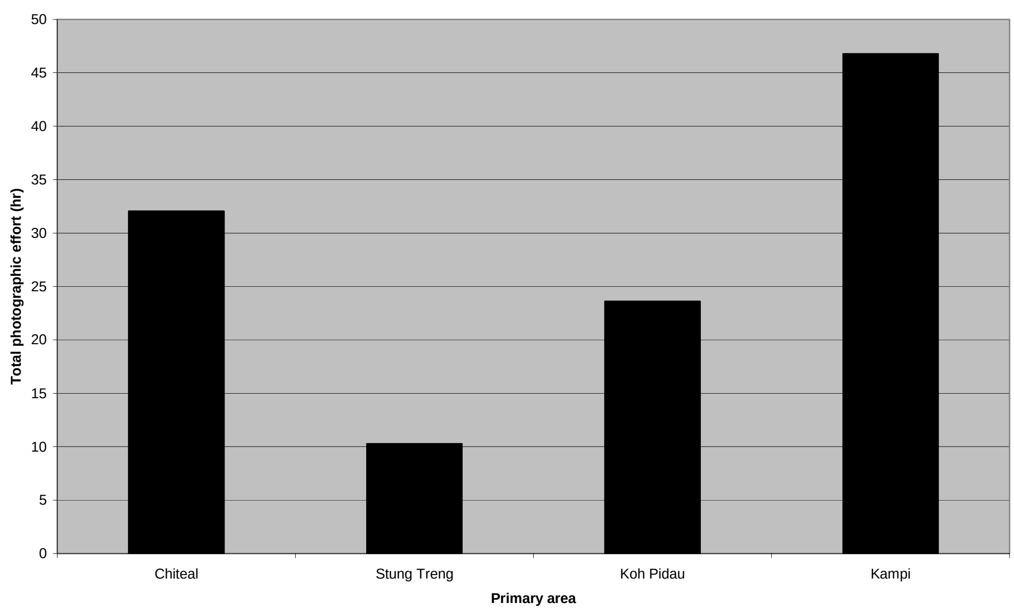


Figure 5.8. Total time (hours) photographing Irrawaddy dolphin groups in each primary area in the Mekong River from 2004-April 2005. Throughout the study, most photo-identification effort was conducted at Kampi Pool, with the least being undertaken at Stung Treng.

5.5.1. Number of Dolphins with Long-Lasting Marks

Ninety-nine dolphins were identified from 2001–2005. The total number of dolphins identified in each critical area ranged from 1-31 individuals (Figure 5.9). The discovery curve of identified individuals based on number of groups sighted is shown in Figure 5.10. The number of identified individuals in the population reached a plateau at the end of 2003; however, substantially more dolphins were identified in 2004. This dramatic increase from 2004 onwards resulted from improved photographic quality by using a digital camera with long lens (equivalent to 960 mm). Only nine new dolphins (9% of total population identified) were identified in 2005, despite significant photographic effort.

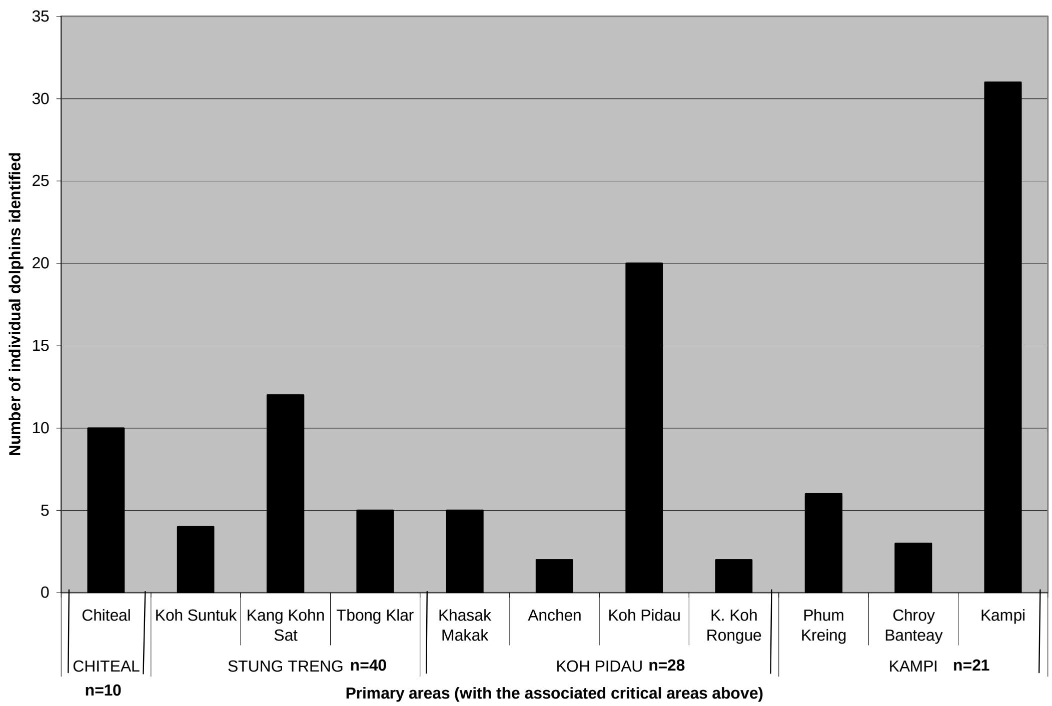


Figure 5.9. The number of individual dolphins photo-identified in each primary area (consisting of 11 critical areas where dolphins were identified) along the Kratie to Khone Falls river stretch of the lower Mekong River, from January 2001-April 2005. The four primary areas are: Kampi, Koh Pidau, Stung Treng and Chiteal. n = the total number of individuals identified in each primary area.

Ninety dolphins were identified in 2004 and 2005. Seventy-six percent of identified individuals were sighted on more than one day, and up to 18 days, across all three sampling periods (Figure 5.11). Of the 90 identified individuals in the population, 40% (36 individuals) were sighted in all three sampling periods.

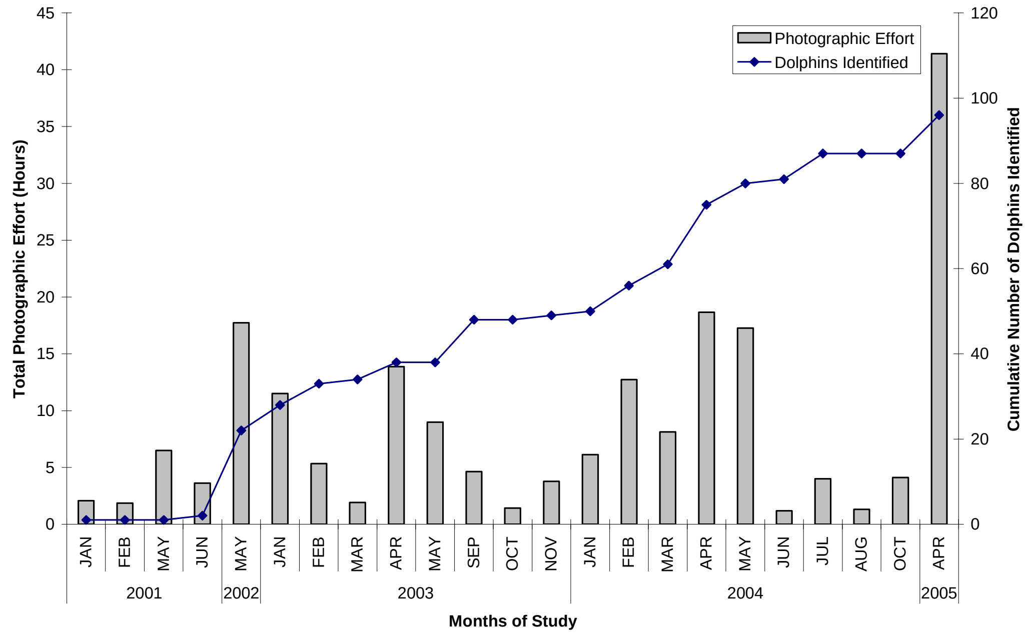


Figure 5.10. Discovery curve of the cumulative number of Irrawaddy dolphins identified between January 2001 and April 2005 in the Mekong River. The bars represent the total photographic effort for each survey month and the line represents the cumulative number of dolphins identified.

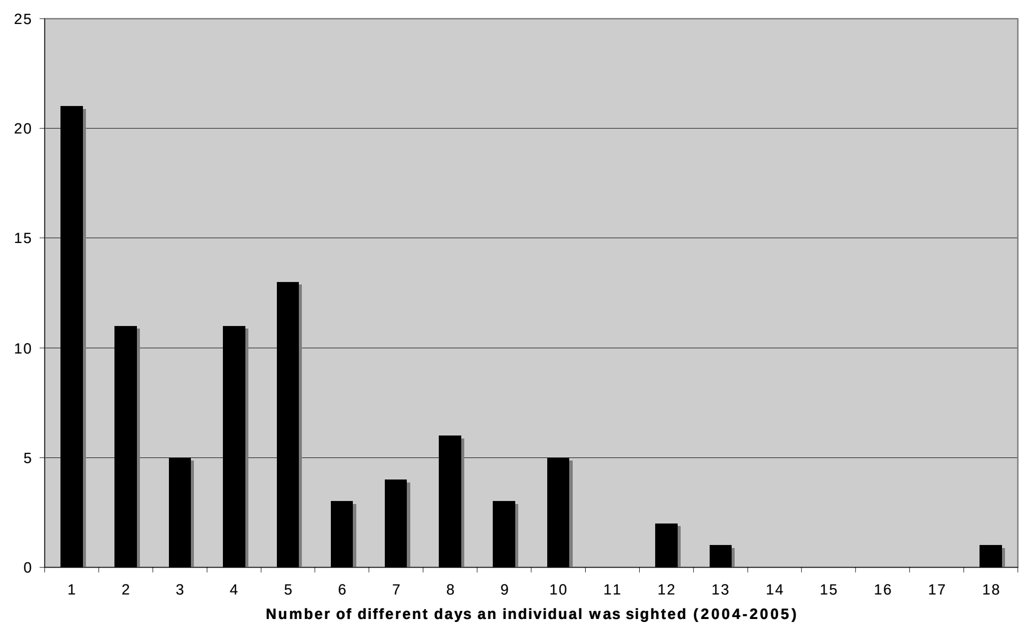


Figure 5.11. The number of times individually identified dolphins were sighted in the Kratie to Khone Falls river section of the Mekong River during 2004–2005. The individual sighted 18 times is Klasico (KA01) sighted only in Kampi Pool, Kratie Province.

5.5.2. Proportion of Dolphins with Long Lasting Marks

Photographic data from 2004-2005 show an average of 83.0% of Irrawaddy dolphins with long-lasting marks in the Mekong River (Table 5.2).

Table 5.2. The number of excellent quality photographs in each year from 2004-2005 and the associated proportion of individuals identifiable in the total population

Year	Total useable photographs	# Excellent photographs (% of useable total)	Photographs used in analysis	Number of recognisable individuals	Proportion identifiable
2004	3197	214 (7%)	214	180	84.1
2005	2964	182 (6%)	182	149	81.9
Total	**8221**	**484**	**484**	**329**	**83.0 (2004–2005)**

5.5.3. Model Selection and Population Size

The most appropriate closed population model selected by CAPTURE based on minimum Akaike's Information Criteria (AIC) value accounted for individual heterogeneity (M_h), with a suggested jackknife estimator. The population estimates and associated statistics for the M_h model are shown in Table 5.3. The number of marked individuals was estimated to be 109 in Jan-April 2004, 115 in May–Jul 2004, and 115 in April 2005. The interpolated total population estimate for 2003–2004 was 113 ± s.e. 7.44 (95% CI = 103–132).

Accounting for the number of unmarked dolphins in the population (17%), the total population estimate of Irrawaddy dolphins inhabiting the Mekong River for 2004–2005 was 136 ± s.e. 9.67 (CV = 0.07; 95% CI = 116-156) (Table 5.3).

5.5.4. Number of Calves and Dead Animals

5.5.4.1. Number of Calves

Although calves were sighted during both dry and wet seasons along the Kratie to Khone Falls river segment, I confirmed only two calves surviving more than three months between January 2004 and April 2005 (Table 5.4). However, there remains a high probability that some other calves may have survived and not been recorded.

Table 5.3. Population estimates of Irrawaddy dolphins in the Mekong River, using a closed population model.

Time Frame	n[1]	P[2]	Marked Animals N[3]	SE[4]	CV[5]	95% CI[6]	Proportion ID[7]	Total Population N Total	SE	CV	95% CI
Jan-April 2004	66	0.7	109	5.68	0.05	98 - 121	0.83	132	7.69	0.06	112 - 151
May-Jul 2004	63	0.7	115	7.39	0.06	101 - 130	0.83	139	9.64	0.07	119 - 158
Apr-05	59	0.7	115	7.39	0.06	101 - 130	0.83	139	9.64	0.07	119 - 158
2004 - 2005 Estimate	90	0.7	113	7.44	0.07	103 - 132	0.83	136	9.67	0.07	116 - 156

[1]. n = the number of animals captured
[2]. p = capture probability
[3]. N = estimate of number of marked animals
[4]. SE = standard error
[5]. CV = coefficient of variation
[6]. CI = confidence interval
[7]. Proportion ID = proportion of identifiable animals

A high calf mortality rate (see '*6.5.4.2. Number of Dead Animals*') indicates that most newborn calves sighted in the river died within 1-2 months of birth. The mean number of known births over the study period (up to April 2005) is one dolphin per year. When divided by the estimated population size in 2005, this result gives a mean minimum annual birth (and early survival) rate of 0.7% per year for the population. It is likely that this number is biased downwards, as a result of data being available for only four months in 2005 (January-April).

5.5.4.2. Number of Dead Animals

It is probable that not all dolphin carcasses were reported from 2001–2002. However, the number of dead dolphins' recovered from 2003 onwards is likely to be a fairly robust estimate of the minimum number of dolphins dying in the river each year (see Chapter 9). Therefore, analyses of the annual mortality are from 2003 onwards.

Between January 2003 and April 2005, 38 dolphin carcasses were recovered: seven carcasses in 2005 (from January to April), 16 in 2004 and 15 in 2003. Of these recovered carcasses, two, five and ten were adults respectively (Table 5.4). Yearly data were available from 2003–2004, where the mean number of known adult mortalities was 7.5 dolphins per year, representing a mean minimum annual adult mortality rate of at least 5.5% of the population per year. Chapter 9 discusses the known and potential causes of dolphin mortality in the Mekong River.

Table 5.4. Known Irrawaddy dolphin minimum birth and mortality rates in the Mekong River from January 2003–April 2005.

Year	Known births (surviving more than three months)		Known mortalities ADULTS	Known mortalities CALVES	Total mortalities
2003	0		10	5	15
2004	2		5	11	16
2005 (to April)	0		2	5	7
Total	**2**		**17**	**21**	**38**
Annual Mean (2003 - 2004)	**1**		**7.5**	**8**	**15.5**

The estimated birth (and early survival) (hereafter referred to as recruitment) rate is ~0.7%/year and adult mortality rate is 5.5%/year. These figures suggests that the Irrawaddy dolphin population inhabiting the Mekong River is currently decreasing by at least 4.8%/year.

5.5.5. Total Population Size

My population size estimate assumed a closed population, with no immigration or emigration. Total population size estimates were corrected for the known annual adult mortality (5.5%) and recruitment rates (0.7%) for 2004. These rates were divided by three for data up to April 2005 (since only four months of data were available for 2005: 1.8% and 0.2% respectively). This resulted in an estimated 6.4% population decline from January 2004–April 2005.

Assuming equal variances equal to previous calculations, I estimated that accounting for births and deaths within an otherwise closed population, a total of at least 127 Irrawaddy dolphins ± SE 9.0 (CV: 0.07, 95% CI = 108–146) inhabited the Mekong River, as of April 2005.

5.6. EFFECTIVENESS OF MONITORING PROGRAMS

A power analyses was undertaken to investigate the time required to detect a population trend (either increasing or decreasing), with differing levels of precision. As discussed by Taylor and Gerodette (1993), the results show that:

1. the length of time required to detect a trend in population size decreases with increasing rate of population change;
2. the precision of the annual estimates of population size has a considerable effect on trend detection; and
3. as rate of change increases, the importance of precision in the population estimates decreases (Figure 5.12).

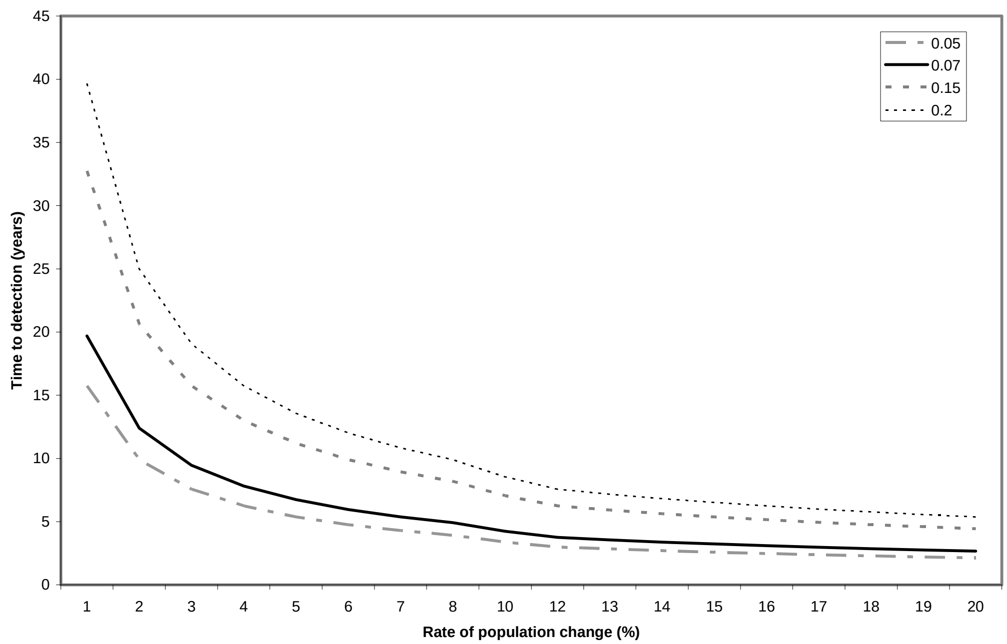


Figure 5.12. Relationships between different rates of population change, time to detection of trend and coefficient of variation (CV) for annual population estimates for Irrawaddy dolphins in the Mekong River. The CVs used to present data variability are the values obtained for population estimates, including two lower CVs (0.15 and 0.20), for comparison. The probability of both Type I and Type II errors was set at 0.05.

With the highest level of precision obtained for abundance estimates (CV = 0.07), I estimated that it would take six years to detect a population decline of 5% per annum, but only two years to detect a 20% per annum decline. If the precision were reduced to 0.20 (perhaps by infrequent sampling), it would then take 13 years to detect a population change of 5% per annum and four years to detect a 20% per annum change. By the time a trend in abundance is detected, the population will have increased or decreased significantly. For example, a population of 136 (CV = 0.07) dolphins decreasing at 5% per year, would consist of only 102 individuals by the time such a trend was detected (six years). If the rate of decline were 20% per year, only 94 individuals would remain, when the trend was detected after four years (Table 5.5).

The estimates of recruitment rate (0.7%) and adult mortality (5.5%) indicate that at a minimum, the population may be declining at a rate of around 4.8% each year. With the population estimate of 127 individuals, based on capture-recapture analyses (accounting for known births and deaths), with a continuing decline of 4.8%/year and current levels of survey precision, it will take six years to detect this decline, by when the population will consist of only 95 individuals.

Table 5.5. The effect of different annual rates of population change on the number of years required to detect population trends with yearly survey intervals (*t* = 1), for Irrawaddy dolphins in the Mekong River. Data variability is specified at CV = 0.07, which corresponds to the highest level of precision obtained for the abundance estimates. The probability of Type I and Type II errors was set at the 0.05 level. Power analysis based on Gerodette (1987).

CV	Rate of change	Number of surveys required (n)	Number of years to detection (t(n-1))	Total % change at detection of decreasing population	Total % change at detection of increasing population
0.07	0.05	6.74	5.74	-0.25	0.32
	0.10	4.24	3.24	-0.29	0.36
	0.15	3.24	2.24	-0.30	0.37
	0.20	2.67	1.67	-0.31	0.36

5.7. DISCUSSION

Photographic studies have proved invaluable in studying Irrawaddy dolphins that inhabit the Mekong River. My study has provided the first comprehensive abundance estimates for this population, as well as estimates of population decline. This information is directly relevant to developing a comprehensive management strategy, to assist with conservation of this *Critically Endangered* freshwater dolphin population.

5.7.1. Estimates of Population Size

The total population size for the Irrawaddy dolphin population that inhabits the Mekong River, as of April 2005 (accounting for births and deaths over the study period), is estimated as 127 Irrawaddy dolphins ± s.e. 9.0 (CV: 0.07, 95% CI = 108–146), using a capture-recapture closed population model. This estimate is precise (based on the associated coefficient of variation), however, the CV is artificially low because the error in estimating the proportion of identifiable individuals is not included. A continuation of photo-identification effort each dry season, using established approach methods and the current photographic equipment, would enable further analyses using robust design population models and subsequent estimates of survival probability (Pollock 1982). The robust design approach allows for unequal catchability in population size estimates using closed population models, while survival, which is not as affected by unequal catchability, is estimated using the open Jolly-Seber population model (Pollock *et al.* 1990).

My estimate of 127 (95% CI = 108-146) individuals was precise, however, probably not accurate. It is likely that the total population estimate of Irrawaddy dolphins in the Mekong River is greater than 127 individuals, as the discovery curve of individuals identified had not reached a plateau by the end of the survey period. Throughout my study, I also conducted line-transect surveys using distance sampling techniques. The higher estimates obtained using distance sampling methodology (see Chapter 6), provide additional evidence to suggest that the capture-recapture estimate was probably biased downwards. There is also associated error in estimating the percent of individuals that were identifiable that was not incorporated into the calculations (see '*Estimating the Proportion of Animals with Long-lasting Marks*').

New individuals identified in 2005 were primarily from the Stung Treng area. This area is remote and located away from Kratie Township, where I was based. The financial constraints of surveying such a remote area, in addition to consistently unfavourable weather conditions, resulted in a proportionally smaller number of dolphins being photographed in this area, compared to photo-identification rates in other primary areas. As a result, this bias will be the major factor causing the capture-recapture analyses to underestimate total population size by an unknown amount. This underestimation is unlikely to be greater than 40-50 individuals, based on a comparison of:

1. the percentage of habitat availability between Stung Treng and other primary areas;
2. a comparison of the number of individuals photo-identified in other critical areas where significantly more photographic effort was conducted (eg. Koh Pidau (30 individuals identified) which has a similar percentage of habitat availability to Stung Treng); and
3. a comparison of sighting frequencies and group sizes between critical areas obtained through boat surveys.

The Stung Treng primary area should be a focus for future photo-identification studies. Regardless of any underestimation caused by a lower effort in the Stung Treng primary area, the total population size of Irrawaddy dolphins in the Mekong River is worryingly small. The total population numbered at least 127 individuals and probably no more than 180 in the entire river system, as of April 2005 – and based on mortality levels was in decline.

5.7.2. Risk of Small Populations

The risks of small population size to the long-term population viability of an endangered species are discussed by the IUCN Red Listing criteria (IUCN 2000) and outlined in Chapter 2. The dolphin population in the Mekong River is small and now fragmented into three sub-populations within the 190 km Kratie to Khone Falls river stretch (*i.e.*, Chiteal, Stung Treng and Koh Pidau/Kampi), which rarely, if ever, interact (see Chapter 8). The restricted range of the three sub-populations further reduces the potential for genetic mixing and increases the probability of extinction through stochastic perturbations (*i.e.*, demographic, environmental, genetic stochasticity and natural catastrophes). However, on a more positive note, the existence of sub-populations can also reduce extinction risks, if stochastic factors are uncorrelated between regions (Caughley and Gunn 1996)

As a result of this small population size, the Irrawaddy dolphin population that inhabits the Mekong River is particularly susceptible to extinction, even if their environment is favourable for their growth and persistence (Shaffer 1981). Effective conservation and management actions are urgently required to ensure the long-term survival of this population.

5.7.3. Survival, Mortality Rates and Population Trends

Chapter 9 provides a comparison of mortality and recruitment rates between the Irrawaddy dolphin population in the Mekong River and other small dolphin populations. The apparently very low recruitment rate (0.7%/year) and high adult mortality rate (5.5%/year) are of great concern, especially as these data are conservative (based on confirmed numbers only). Conservation and management to increase the probability of the populations' survival should investigate causes of mortality (particularly of newborns), reduce adult mortality, and continue population monitoring.

5.7.4. Management Implications

Urgent and effective management actions are required if the Irrawaddy dolphin population is to survive in the Mekong River. My study clearly illustrates that management agencies must not wait for proof of a declining population before conservation strategies are implemented. Resulting from the small population size, unsustainable mortalities and closed population (*i.e.*, no immigration of new individuals into the river system: Chapters 4 and 6), effective strategies are urgently required to reduce anthropogenic human-induced mortality to zero (discussed further in Chapter 9). Although reducing dolphin mortalities to zero may be infeasible, this must be the target if the population has any chance of survival. Chapter 2 discusses the importance of freshwater dolphin conservation.

Most, if not all freshwater Irrawaddy dolphin populations are small and declining, with continuing threats to their future survival (Smith *et al.* 2003a) (Chapters 2 and 3). Although effective management to aid recovery of rare species often relies on the assessment of trends in population abundance (Forcada 2000), statistical power to detect a decreasing trend diminishes as a population becomes smaller (Taylor and Gerrodette 1993), which is a particular concern for long-lived, slow breeding species, such as cetaceans. Typically, declines can only be detected over a long series of surveys, or when major changes in population size have already occurred, compromising the fate of the species (Wilson *et al.* 1999, Forcada 2000). Monitoring programs represent a considerable investment of time and resources and require careful consideration at the outset. Statistical power calculations, as illustrated in this study, are a useful method to assist with addressing practical questions related to required sample size, length of programme and resources (Taylor and Gerrodette 1993, Wilson *et al.* 1999). As a result of current population declines in the Mekong River (*i.e.*, at least 4.8%/year) and current survey precision (*i.e.*, 0.07), it would take six years to detect a decline in the Mekong dolphin population, when the population would consist of only 95 individuals. The potential for conservation success on a mammal population of such a small size would be significantly reduced (Reed *et al.* 2003).

High priorities for continued monitoring are continuation of photo-identification surveys and the carcass recovery program. Based on current mortality rates and survey precision, a declining trend may be detected after six years. However, at this time the population would have been significantly reduced. It is imperative that effective conservation strategies, such as gillnet free areas and ICDPs, are implemented as soon as possible. In the event that mortality rates continue at the present level and/or a declining population is detected earlier than the estimated six-year period, it will be imperative that implemented conservation strategies are deemed ineffective and adapted and revised accordingly.

As stated by Taylor and Gerrodette (1993) '*endangered populations leave little margin for recovery from incorrect management decisions*'. The potential for successful conservation of the Irrawaddy dolphin population that inhabits the Mekong River remains unclear. However, I believe the probability of population recovery will be significantly improved if:

1. qualified and experienced managers are responsible for various project components (e.g. research, education and awareness, policy development);
2. effective on-the-ground conservation activities are implemented immediately;
3. all stakeholders including local communities and government departments are involved in, and support, the management process; and importantly
4. funding, local interested personnel and resources are available for the conservation process.

5.8. CONCLUSIONS

Chapter 5 aimed to provide baseline data on the population size of Irrawaddy dolphins in the Mekong River, using capture-recapture analyses of photo-identified individuals (thesis objective 4a: Chapter 1). A summary of the major conclusions from Chapter 5 is listed below.

- I trialled photo-identification studies of Irrawaddy dolphins in the Mekong River from 2001-2005.
- A combination of: (1) knowledge of the most effective method of approach to photograph dolphin groups, and (2) high quality photographic equipment, has proved that photo-identification is feasible and provides precise estimates of population size using capture-recapture analyses of photographically-identified dolphins.
- It was more productive for identifications to have dedicated photographic effort, rather than taking photographs in combination with line-transect/direct count boat surveys.
- Ninety dolphins were photographically identified from 2004-2005. The identifications had not yet been reached a plateau by the end of my study, which indicates a higher total population size than was estimated by my capture-recapture analysis.
- A closed population model was used for capture-recapture analysis, which necessitated some reliable estimate of births and deaths. The mean adult mortality rate was estimated as 5.5%/year. The mean minimum recruitment rate was estimated as 0.7%/year. Therefore, based on the results of the closed population model, the population is estimated to be declining at 4.8%/year (see Chapter 9).
- Eighty-three percent of individual dolphins were identifiable during the study period.
- It was estimated through capture-recapture analysis that a minimum of 127 dolphins (range: 108-146, CV=0.07), inhabited the Mekong River, as of April 2005.
- Reduced photographic effort in the Stung Treng critical area and a resulting lack of resightings probably resulted in a downward bias of the capture-recapture abundance estimates.
- With the highest level of precision obtained from capture-recapture abundance estimates (CV=0.07), it would take 6 years to detect a 5% per annum decline and only 2 years to detect a 20% per annum decline.
- The Irrawaddy dolphin population in the Mekong River is very small and appears to be declining.
- Management strategies are urgently required to reduce anthropogenically-induced mortality to zero. The potential for successful conservation of the Irrawaddy dolphin population that inhabits the Mekong River remains unclear. Significant, coordinated

conservation efforts will be required by conservation organisations, funding agencies, governments, local stakeholders and communities.

- Chapter 11: Table 11.4 summarises the main research and conservation implications from Chapter 5.

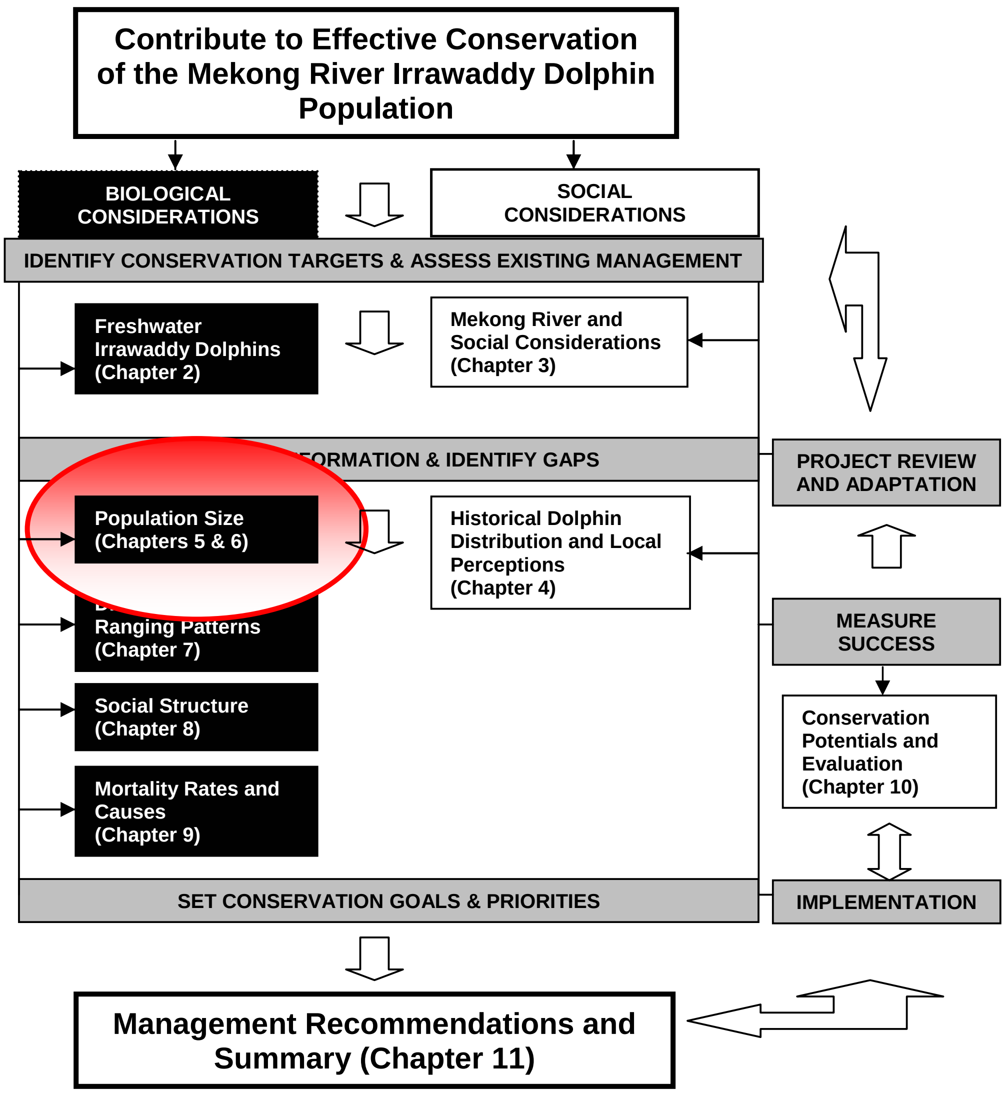
6. POPULATION SIZE ESTIMATES OF FRESHWATER IRRAWADDY DOLPHINS IN THE MEKONG RIVER, BASED ON DIRECT COUNTS AND DISTANCE SAMPLING TECHNIQUES

Reliable information on abundance is essential to develop management strategies for endangered species conservation and monitor trends in abundance. With limited resources for endangered species conservation, available resources must be used effectively to obtain the required information. In this chapter, I estimate the abundance of Irrawaddy dolphins inhabiting the Mekong River through direct count and distance sampling techniques, investigate the statistical power necessary to detect a population change with ongoing line-transect surveys, and identify the survey methodology that provides the most reliable estimates of Irrawaddy dolphin population size.

The survey boat used for all boat surveys south of Kratie Township to the Vietnam/Cambodian border

6. POPULATION SIZE ESTIMATES OF FRESHWATER IRRAWADDY DOLPHINS IN THE MEKONG RIVER, BASED ON DIRECT COUNTS AND DISTANCE SAMPLING TECHNIQUES

Chapter 6 investigates a biological consideration when '*collecting information and identifying gaps*' within my conceptual framework. The aim of Chapter 6 is to provide baseline data on the population size of Irrawaddy dolphins inhabiting the Mekong River, using direct counts and distance- sampling techniques (a continuation of thesis objective 4a: Chapter 1) to compare with capture-recapture estimates (Chapter 5).



6.1. INTRODUCTION

As I outlined in Chapter 2, river dolphins are amongst the most threatened of marine mammals, with generally small and declining populations (Reeves *et al.* 2003). Few rigorous studies have investigated the abundance of river dolphins, although notable exceptions exist from studies in South America (Vidal *et al.* 1997, Martin *et al.* 2004, Martin and da Silva 2004) and the Mahakam River of Kalimantan, Indonesia (Kreb 2002, 2005). Surveys for river dolphins face particular challenges, which include the complex morphology of freshwater systems, annual flood cycles, and the logistical, personnel and financial difficulties of working in developing countries (Smith and Reeves 2000). In addition, surveys have often been conducted without a well-defined study design. Virtually all available population estimates from Southeast Asia lack measures of precision and are biased in unknown, or at least unquantified, ways (Smith and Reeves 2000).

Most previous estimates of the abundance of Asian river dolphin populations have been based on direct counts. However, little information has been gathered on the proportion of dolphins potentially missed by the observer team(s). In contrast, recent line/strip-transect combination studies on the Amazon River dolphin or boto and tucuxi have provided some of the most comprehensive estimates of a river dolphin population to date, accounting for dolphins that may be missed by the survey team (Vidal *et al.* 1997, Martin *et al.* 2004). Nevertheless, because of the wide distribution of boto and tucuxi, even these surveys have not yet been able to estimate total population numbers throughout the entire river system.

As I discussed in Chapter 2, freshwater Irrawaddy dolphins inhabit three river systems in Asia: the Ayeyarwady River of Myanmar, the Mahakam River of Indonesia, and the Mekong River of southern Laos, Cambodia and Vietnam (Smith *et al.* 2003a). Abundance estimates have been obtained from all three river systems using several boat survey techniques (Table 6.1). Unlike the populations of river dolphins in South America discussed above, Irrawaddy dolphin populations are very small and restricted in range, enabling surveys to cover each subpopulation's entire distribution, in a relatively short period of time (e.g. two to three weeks), as summarised in Table 6.1.

Few studies have estimated the abundance of the Irrawaddy dolphin population inhabiting the Mekong River. Baird and Mounsouphom (1994) observed dolphins in the Chiteal Pool on the Laos/Cambodian border during the dry season of 1992–93. The dolphins were usually found in groups of two to ten individuals, but 17 different dolphins were seen at least once. Preliminary photo-identification studies at the same pool were undertaken in 1994 (Stacey 1996); however, only six dolphins were identified and the number of dolphins using the pool was not estimated. Using visual and acoustic methods, Borsani (1999) estimated that at least eight to ten dolphins were present in Chiteal Pool in late March/early April 1998, but there were no specific details of the methodology used to estimate abundance. In 1996, Baird and Beasley (2005) used downstream pool count surveys to estimate the population size of Irrawaddy dolphins in the Mekong River. Forty dolphins were sighted in the river between Kratie to Khone Falls (Figure 6.1) leading to the tentative conclusion that no more than 200 dolphins remained in the river. This estimate allowed for dolphins potentially missed in the river stretch surveyed, as well as dolphins possibly inhabiting river stretches south of Kratie Township, including Tonle Sap Lake. However, there were no associated estimates of precision or accuracy. No other surveys to estimate population abundance have been discovered.

Precise and accurate population estimates are essential to assess the conservation status of the Irrawaddy dolphin population inhabiting the Mekong River and to design management initiatives necessary to ensure their continued survival. I conducted both direct count and distance sampling survey techniques and compared the resulting estimates to capture-recapture estimates based on photographically identified individuals, as described in Chapter 5. In addition, I used land-based studies to test the effectiveness and validity of each method (Appendix IV). I also compared the various techniques to evaluate the most appropriate survey methodology for establishing accurate and precise total population estimates, as a basis for long-term monitoring. I discuss the feasibility of these methods for surveys of other freshwater dolphin populations.

6.2. STUDY AREA

As detailed in Chapter 3, the study area consisted of the entire lower Mekong River Basin, from Khone Falls (Laos/Cambodian border) south to the Vietnamese Delta (including Tonle Sap Lake in Cambodia) (Figure 6.1).

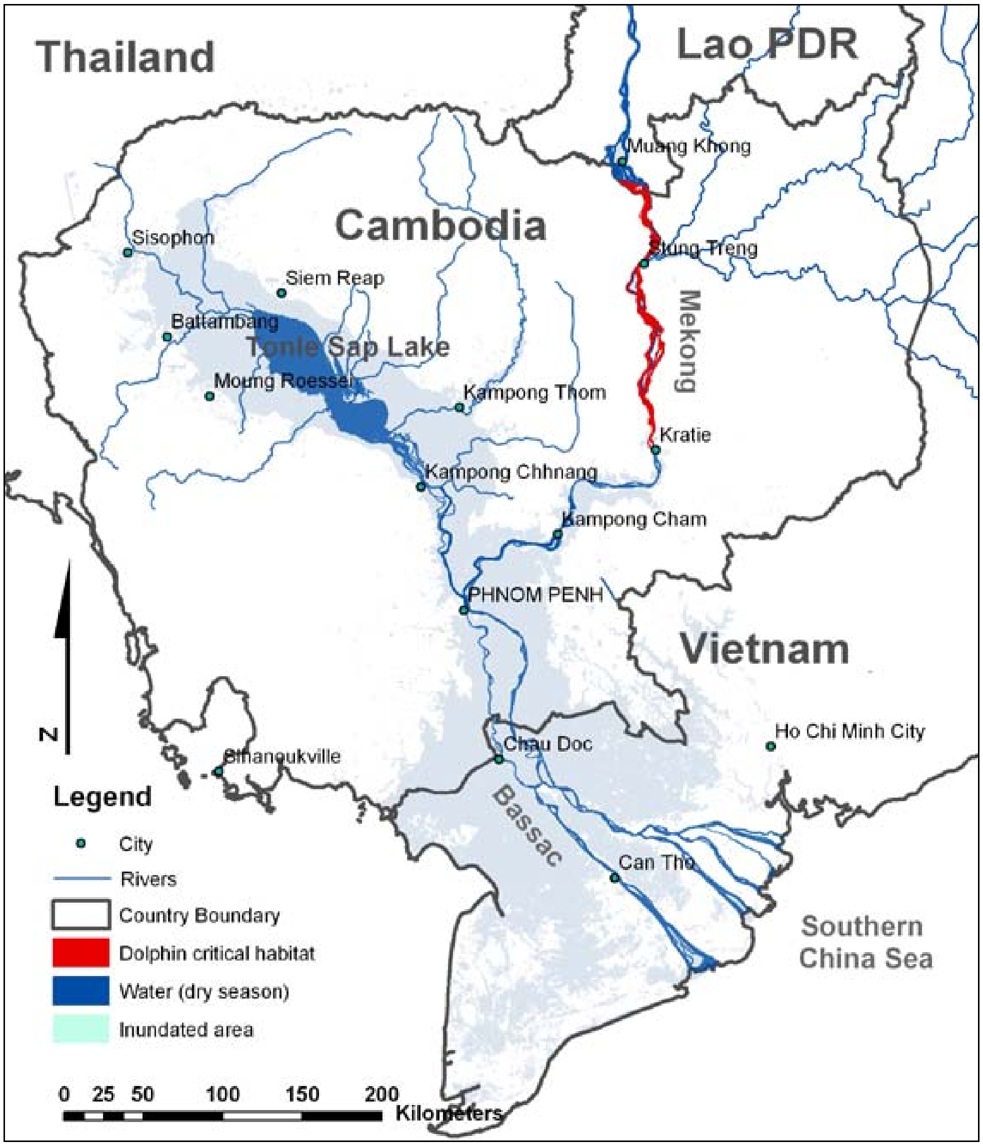


Figure 6.1. Map showing the study area where boat surveys were conducted. The area ranged from the Laos/Cambodian border (Muang Khong) south to the Vietnamese Delta (including Tonle Sap Lake). The Kratie to Khone Falls river section (shown in red), is the only area in the river where dolphins were sighted.

6.3. BOAT SURVEY METHODS

6.3.1. Direct Count Surveys

Based on published and unpublished literature and personal communication (see Chapter 4), I assumed that the Irrawaddy dolphin population in the Mekong River was restricted to the Kratie to Khone Falls river section (190 km) during the dry season. Direct count methodology was therefore considered appropriate in this section because: (1) the entire known range of the population in the dry season was searched; and (2) the methodology used was designed to ensure sighting biases were reduced.

Direct counts generally provide minimum population size estimates. However, since the population appeared closed and was found in a limited geographic area (*i.e.*, 190 km), I hypothesised that the direct count estimates could also be used to obtain an estimate of the total population, assuming that the proportion of dolphins which were not counted during surveys, as a result of perception and availability biases (Marsh and Sinclair 1989), could be estimated.

Direct count surveys consisted of *upriver direct counts* and *downriver pool counts*. Upriver direct count methodology followed Smith and Reeves (2000) and were conducted during all surveys from Kratie north to Khone Falls in association with line-transect methodology. Downriver pool count methodology followed Baird and Beasley (2005) and was used during all surveys from Khone Falls south to Kratie in association with boat counts (the boat counts are not analysed for my thesis). Investigating these two direct count survey techniques provided further information towards assessing the most appropriate survey methodology to estimate dolphin population size in the Mekong River.

Land-based observations were also conducted, in combination with some upriver direct count boat-based surveys, to estimate the proportion of dolphins potentially missed by boat-based observers in deep pool habitats (Appendix III).

6.3.2. Line-transect Distance Sampling

Direct count surveys inevitably miss an unknown proportion of dolphins. Therefore, line-transect methodology was trialled following Jefferson (Jefferson 2000), with adaptations to the Mekong River. Table 6.2 summarises my assessment of the likelihood that the line-transect assumptions were met. Line-transect distance sampling was conducted in the Kratie to Khone Falls river section and south of Kratie to the Mekong Delta (including Tonle Sap Lake) (Figure 6.1). Separate land-based observations were conducted at Kampi Pool (situated 15 km north of Kratie Township), to estimate surface and dive times, which are relevant when estimating the probability that dolphins are sighted on, or near, the track-line for line-transect analyses (Buckland *et al.* 2001) (Appendix VI).

Table 6.1. Summary of surveys conducted to assess the freshwater Irrawaddy dolphin population size in the Ayeyarwady and Mahakam Rivers in Asia.

Population	Year	Survey type	Total distance / hours	Dolphins/sightings per linear km	Total number sighted	Population estimate	Reference
Ayeyarwady	1880s	Observational	--	--	--	--	Anderson (1879)
Ayeyarwady	1996	Direct count: upper reaches between Sagaing Bridge and Ma U Village	247.9 km	0.012 sightings	3 groups (12 individuals)	minimum 12	Smith *et al*. (1997b)
Ayeyarwady	1998	Direct count: Between Bhamo and Mandalay (part of a nature tourism programme)	359.6 km / 27.6 hr	0.16 dolphins	14 groups (59 individuals (55 - 70))	minimum 59	Smith and Hobbs (2002)
Ayeyarwady	1999	Direct count: upstream Mandalay to Bagan	497.2 km	0.022 sightings	11 groups (37 individuals)	minimum 37	Smith and Hobbs (2002)
Ayeyarwady	2002	Direct counts: Two independent teams	1,787 km in mainstream; 201 km in side channels	0.021 sightings	8 groups (37 (33-47) individuals	minimum 37	Smith *et al*. (2003a)
Ayeyarwady	2003	Direct counts with rear observer: upstream	420 km mainstream; 120 km in side channels	0.038 sightings	16 groups (59 (51-83) individuals	minimum 59	Smith (2004)
Ayeyarwady	2003	Direct counts with rear observer: downstream	414 km	0.024 sightings	10 groups (43 (40-50) individuals	minimum 43	Smith (2004)
Ayeyarwady	2004	Direct counts with rear observer: upstream	425.2	0.031 sightings	13 groups (72 (65-76) individuals	minimum 72	Smith (2004)
Ayeyarwady	2004	Direct counts with rear observer: downstream	426.3 km	0.023 sightings	10 groups (33 (31-35) individuals)	minimum 33	Smith (2004)
Mahakam	1978	--	--	--	--	100 – 150	(Hardjasasmita 1978)
Mahakam	1993	Opportunistic boat surveys	--	--	--	68	Priyono (1994)
Mahakam	1999 - 2000	Direct count with rear observer: entire Mahakam River	4260 km / 397 hr	0.09-0.14 dolphins	18 - 35 per year	35	Kreb (2004)
Mahakam	1999 - 2000	Modified strip-transect: entire Mahakam River	4261 km / 397 hr	0.04-0.14 dolphins	14.3 - 42.7 per year	43	Kreb (2004)
Mahakam	1999 – 2000	Line-transect surveys: Semayang and Melintang Lakes	52 km	--	1 sighting	--	Kreb (2004)

Table 6.2. A summary table of the assumptions of line-transect methodology, the effect of failure to address the assumption adequately, the methods used in this study to address potential violations and the potential in this study for assumptions to be violated.

Line-transect assumption	Failure to address assumption	Study methods	Potential for violation
Dolphins are spatially distributed in the sampled area according to some stochastic process with rate parameter = D (number per unit area).	If the study area is not large relative to the typical detection distances, a large proportion of the strips, or half width, might fall outside the study area and this proportion will tend to increase with distance from the line. Estimation will be biased appreciably if allowance is not made for this effect.	Lines were placed randomly with respect to dolphin distribution, based on a randomly selected start point for each survey day. Stratification post-survey was conducted based on habitat types in which dolphins were commonly found (e.g. deep pool areas) and areas that dolphins were never sighted (e.g. all other habitat types in the river).	**Likely**: non-random dolphin distribution in the river
Dolphins directly on the transect-line are always detected.	Failure to detect all dolphins on the transect-line results in underestimation of abundance.	The recorder guarded the centre-line to increase the probability of sighting all dolphins on the track-line. Additionally, land-based observations estimated the proportion of dolphins missed by the boat survey team (Appendix III).	**Extremely unlikely**
Dolphins are detected at their initial location, prior to movement in response to the boat or observers.	Dolphins that move towards the observer before detection results in overestimation. Dolphins that move away from the observer before detection results in an underestimation of abundance.	Binoculars were used to sight dolphins before any movement occurred. However, Irrawaddy dolphins were generally not attracted to boats (*i.e*. do not bow-ride). Observers recorded the reaction of the dolphins to the survey platform (*i.e.*, heading towards, away, neutral).	**Extremely unlikely**
Distances and angles are measured accurately.	Rounding data (i.e. 0, 5, 10 m) results in a serious bias of density. Underestimation of distance data results in an overestimation of density and vice versa.	Distance estimation exercises were conducted using laser-range finder binoculars. Angles were collected using binoculars with in-built compass. Rounding of data was discouraged at all times.	**Unlikely**
Undetected movement in response to the observer (*i.e*. repeated double counting).	Consistent double counting of dolphin groups results in overestimation of abundance.	Groups were left behind when effort restarted. Photo-identification was used to identify group distinctiveness.	**Unlikely**
Able to identify the object of interest (*i.e.*, dolphin) correctly.	Confusion with other species results in an overestimation of abundance.	Occasionally, there was potential confusion with large fish. However, the dolphin must have been resighted by at least one observer for the sighting to be valid.	**Extremely unlikely**
Dolphins are uniformly distributed with respect to distance from the transect line out to the truncation distance.	Extrapolation in narrow river sections results in overestimation of abundance. Narrow river sections affect the detection function	As a result of the river banks, it is likely that the detection function was affected by an inability to record further distances.	**Very likely**: in the narrow river sections.

6.3.3. Timing of Surveys

My boat surveys throughout the lower Mekong River and Tonle Sap Lake were primarily conducted during the dry season (late October to end of May) because: (1) surveys at this time have the highest probability of sighting dolphins since groups aggregate in deep water areas; (2) I assumed that as a result of a lack of deep water pools below Kratie, most, if not all, dolphins would occur in the Kratie to Khone Falls river stretch during the dry season; and (3) a lack of dolphin sightings below Kratie Township would justify the conclusion that estimates of abundance in the Kratie to Khone Falls river section provides a robust estimate of total population size. Table 6.3. summarises the details of the survey timing.

I also undertook boat surveys during the wet season (June to early October) to assess the feasibility of line-transect abundance estimation when water levels are higher. However, no further analyses were conducted on this data because there were significant logistical and safety difficulties when surveying large expanses of water; dolphins' tended to disperse throughout the river system and into tributaries at this time; only a very small number of dolphin groups were sighted.

6.3.4. General Search Effort

The data collected varied between survey types and areas (Table 6.3). A minimum of three and a maximum of five observers were used. Only two 'on-effort' observers searched for dolphins at any one time. Sightings were classified as 'off-effort' when dolphins were sighted but the observers were not actively searching for dolphins on the survey track-line; observers were on the river bank and sighted dolphins; or observers sighted a group more than 1 km directly behind the boat.

During search effort, one observer continually searched for dolphins through 7 x 50 binoculars. The second observer searched by naked eye and completed the data sheets. The additional observer(s) rested during on-effort periods, in order to reduce observer fatigue. Positions were rotated every 30 minutes. Three individuals were primary observers for my entire five year study. Other observers were obtained from local government agencies, or were volunteers. All observers were fully trained in survey methodology and data sheet completion.

Boat survey speed was kept constant at 7–9 km/hr. During the dry season, the river ranged from a maximum width of 2 km to a minimum width of 20 m. Tributaries ranged from a maximum width of 500 m to a minimum width of 10 m. In river sections greater than 1 km, the boat surveyed in a zigzag fashion, so that there was no more than 1 km from the point of departure on one river bank, to the return point upriver on the same river bank (characteristic of the Kratie to Khone Falls river section). In river sections less than 1 km in width, the boat travelled down the middle of the river (Figure 6.2). All surveys were undertaken in straight-lines (including zigzags; see Martin *et al*. 2004), with random start points to facilitate distance sampling analyses. This approach had no effect on the direct count estimates.

6.3.5. Data Recorded

Because Irrawaddy dolphins surface inconspicuously, boat surveys were only conducted when the water surface was calm. Water surface conditions were recorded as ‘river-state’, with categories similar to Beaufort sea state. River-state was recorded as flat calm (denoted as 0), minimum ripples (1), continuous ripples with a height of ~5 cm (2), wavelets of ~10 cm (3), and wavelets >10 cm (4). Observations were suspended when a river state of (3) or greater, was reached. Data on location, observers, river-state and habitat type were recorded at the start of every survey and at least every 30 minutes thereafter, or when environmental conditions changed.

Additional environmental data on habitat type were collected during surveys in the Kratie to Khone Falls river section, as a result of the non-random distribution of dolphins and potential need for data to be stratified based on habitat type during analyses. The categories below characterise the main habitats found along the Kratie to Khone Falls river section during the dry season:

- **mainstream river**: all river sections south of Kampi Pool. These river sections were characterised by a wide channel, uniform substrate, low water velocity, medium depth (1–10 m) and presence of a thalweg (the middle of the chief navigable channel on a waterway), below Kampi Pool and further south.
- **rapids**: narrow to medium channel, rocky substrate, high water velocity, shallow depth (0–3 m).

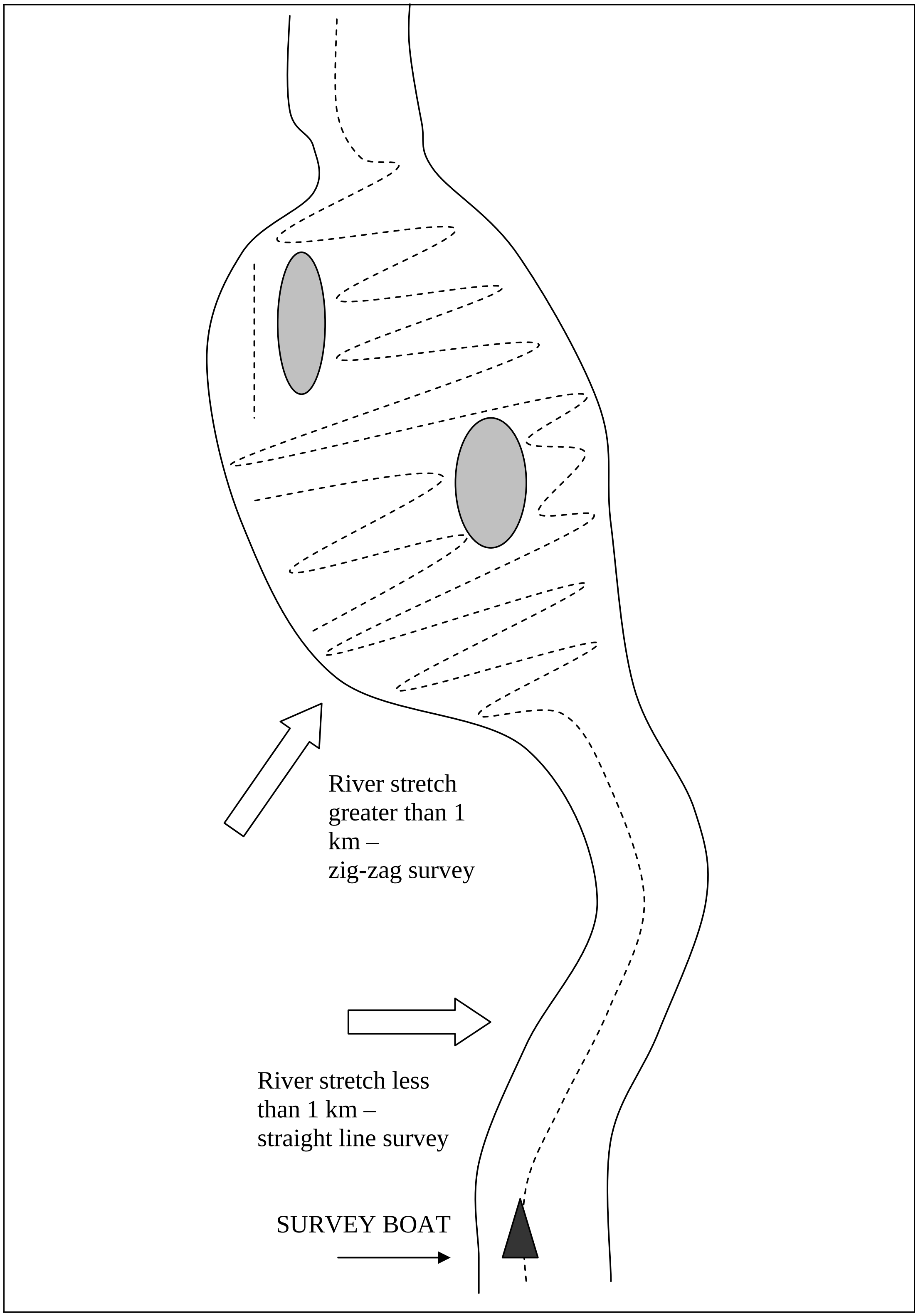


Figure 6.2. Survey protocol for the Kratie to Khone Falls River section. Survey lines started at a random location in the river, depending on the area to be surveyed for that day. River stretches greater than 1 km wide were surveyed in a zigzag manner, while river stretches less than 1 km wide were surveyed in as straight a line as possible. The oval areas in the middle of the river represent mid-channel islands.

- **shallow and islands**: medium to wide channel, rocky substrate visible underwater, low water velocity, shallow depth (0-3 m) and presence of numerous small grassy and tree covered islands within the channel.
- **deep pool**: medium to wide area, low water velocity, very deep (10–80 m) (Figure 6.3).

Figure 6.3. Chiteal deep pool located on the Laos/Cambodian border (Laos is on the opposite bank)

- **upstream river segment**: area of river upstream of Kampi Pool, where there were no obvious mid-steam trees or sandbanks. Depths alternated between shallow (3-5 m) and deep (20 m), but with no obvious indications of bottom topography. This area was also characterised by occasional large mid-channel islands.
- **meandering tributary**: area of branched and narrow channels, rocky substrate, low to medium water velocity, shallow (0–5 m). Often impossible to survey during lowest low water as a result of the shallow water depth.
- **tributary**: a river branch off the mainstream Mekong River, of any size.

The optimal time to record critical habitat type profiles was during lowest low water, when the dolphins experienced minimum habitat availability[13].

6.3.6. Sighting Data Recorded

A dolphin group/cluster was defined as a tight aggregation with one or more dolphins in close proximity (0-500 m), in apparent association and sighted independently of any other groups,

[13] During the wet season, water levels rose vertically approximately 15-25m, resulting in a uniform habitat type of ‘mainstream river’. No other features (e.g. trees, sandbars, rapids, small tributaries) were evident in the river during high water, as a result of the significant increase in water depth. Wet season surveys are not included in these analyses.

moving in the same direction and often, but not always, engaged in the same activity (Mann 1999).

Following Smith and Reeves (2000), group size was estimated, based on ‘low’, ‘high’ and ‘best’ estimates of the number of animals. Group size was normally estimated after 15–30 minutes of careful observation. ‘Low’ was the absolute minimum number of dolphins the observer team sighted in the group; ‘high’ was the absolute maximum number of dolphins sighted in the group; and ‘best’ was the best estimate of the number of dolphins, acknowledging minimum and maximum estimates. The more confident the observer team was about the estimate, the smaller the difference between these three numbers, and vice-versa. I was present on virtually all surveys and decided the final group size estimates after consultation with the observer team. It was very rare that previously independent groups began interacting after 30 minutes or more, or additional groups entered the area. However, if this did occur, group size was re-estimated and comments recorded.

Information was also recorded on group composition. As explained in Chapter 5, a *newborn* was defined as a dolphin approximately 1 m in length, swimming constantly in close proximity to another dolphin (presumably the mother), surfacing in a ‘corkscrew’ fashion (irregular surfacing with its head jerking high out of the water), with obvious foetal folds (Figure 6.4). A *calf* was defined as a dolphin slightly larger than 1 m in length, swimming in a regular manner and constantly in close proximity to another dolphin (presumably the mother). A ‘*juvenile*’ was defined as a dolphin approximately 1.5–1.9 meters in length (see Appendix VII), occasionally swimming in close proximity to other dolphins but occasionally alone, and dark grey in colour. Juveniles normally had few identifying marks on the dorsal fins and few scratches over their bodies. An *adult* was defined as a dolphin 2 m or greater in length.

It was not possible to define the sex of individual dolphins in the Mekong River during surveys, as there was no evidence of sexual dimorphism (although Kreb (2004) reported sexual dimorphism for the Mahakam population). A female was confirmed when seen consistently swimming with a newborn calf near her side (see Figure 6.4).

At the location of every dolphin sighting, environmental parameters such as depth, temperature, turbidity, river state, habitat type, water velocity, name of deep water pool in vicinity and approximate distance from the sighting location, and name of closest village, were recorded. Once this information was recorded and group size estimated, photographs were taken whenever dolphin behaviour allowed for close approach (see Chapter 5). I took all photographs, while the other observers continued to observe the group. All data were recorded on standardised data sheets.

Figure 6.4. A newborn calf sighted in Chiteal Pool (on the Laos/Cambodian border of the Mekong River) in January 2004. The mother of the calf (to the left) was identified as CH01_Chiteal. The calf was surfacing in the typical 'corkscrew' fashion of a newly born dolphin, with its head jerking high out of the water. The foetal folds are also obvious just behind its head (as indicated by the black arrow).

6.3.7. Reducing the Potential for Double Counting for Direct Counts

The potential for double counting dolphin groups during direct counts was reduced by:

1. undertaking each survey continuously up the river during each survey period;
2. finishing surveys around sunset and beginning at sunrise each day, thereby only allowing a minimum period (e.g. eleven hours) when dolphins could potentially move between survey areas;
3. finishing each survey day at either the start, or the end, of a major shallow-water rapid section of the river ($\leq$30 cm in depth, extremely turbulent and rocky), making these areas difficult, if not impossible, for dolphins to pass during the dry season (Figure 6.5),
4. photographing all groups, whenever possible (Chapter 5) and later comparing individuals sighted in each group to ensure that double counting did not occur; and
5. continuing the survey immediately once photo-identification was completed and ensuring that the dolphin group was left behind the boat.

If there were any further doubts about double-counting, I considered:

1. comparisons of best group size estimates and group composition between groups in question;
2. the time elapsed between both encounters; and
3. whether a stop on shore was made (e.g. for lunch or an interview), to allow the dolphins to swim past the survey team.

If a group was thought to be double counted during direct count surveys, the second sighting was excluded from further analysis.

6.3.8. Independent Observations

Independent observations were not possible during the early stages of the study (2001–2003) as a result of: (1) the small size of the survey boat used for the Kratie to Khone Falls surveys; (2) the position of the driver at the back of the boat which prevented rear observations; and (3) the initial inexperience of the observer team. Once data collection for line-transect surveys had been adequately mastered by local observers, it became possible for the boat driver and one off-effort observer to act as independent observers during three surveys conducted in 2004 and 2005. Independent observations were possible during all surveys south of Kratie Township and were facilitated by the larger sized boats used for surveys (Figure 6.6).

Independent observers searched for dolphins and reported any dolphin sightings to the primary observer team once the dolphins were missed by the primary team and were estimated to be 1 km behind the survey boat. Once a dolphin was reported by the independent observers, formal effort was stopped and the boat returned to the initial location of sighting, in order to confirm the sighting and obtain group size information. Once the sighting was investigated, the boat returned to the location where effort had stopped and the survey was continued.

6.3.9. Distance Estimation

Before each survey, observers received training in distance estimation, calibrated with a laser range-finder, until they were accurate to within 10% of the actual distance. Observers constantly practised their distance estimation with the laser range-finders during surveys, to improve their distance estimation capabilities.

Table 6.3. Summary of direct count and line-transect methodologies used to estimate Irrawaddy dolphin population size in the Mekong River

Methodology	Area conducted	Survey duration	Boat type	Variations to general search effort	Sighting information
Direct Counts: Upriver	30 km below Kratie 190 km north to Khone Falls	January to June 2001-2005: 10 day survey duration in each survey	Long-tailed boat (Figure 6.5)[1.] Viewing height of 1m (sitting) to 2 m (standing)	No variations	Location of sighting
Direct Counts: Pool Count	Khone Falls downstream to Kratie. Conducted directly after (within one or two days) the upriver surveys were completed	January-June 2002-2004: 3-4 day survey duration in each survey		1. Adapted from Baird and Beasley (2005) 2. Boat travelled at 15-20 km/hr and stopped at 10 pre-designated deep pool habitats 3. Boat stopped then area searched for 20 mins	Location of sighting
Line-transect	1. Kratie to Khone Falls (in combination with upriver direct counts) 2. South of Kratie to the Vietnam /Cambodian border 3. Tonle Sap River and Lake 4. Vietnamese Mekong River	1. January-June 2001-2005 2. May 2003 3. May 2004 4. May 2005	1. Long-tailed boat 2. Large cargo boat (observers 6 m above the water surface: Figure 6.6) 3. Long-tailed boat 4. Large trawl boat (observers 4 m above water surface: Figure 6.6)	1. Data collected (see sighting information). 2. The lake was searched by running random lines parallel to the shore because of unpredictability of the weather and wave conditions. 3. No variations 4. Surveys were stopped every 10 km (approx 1 hr) to facilitate interviews along river (Chapter 4)	1. Distance from boat to dolphin group (estimated by observer using range finder binoculars where possible) 2. Angle of the bow of boat and dolphin group relative to north (binoculars with inbuilt compass) 3. Location of sighting 4. Actual location of dolphin group (GPS)

1. A boat with an observation platform higher from the water surface would have increased the observer's field of view. However, this arrangement was not possible, as a result of the geomorphology of the river section and shallow water sections. The long-tailed motor-boat used for these surveys is the only boat type able to survey the entire river section during the dry season. Some sections were still too shallow, even for such a small boat (Figure 6.5). In deeper water, larger survey boats were used.

Figure 6.5. Boat used during surveys in the Kratie to Khone Falls river section. This image shows one of the regions in the dry season where boat survey effort was stopped for the day, as a result of the low probability that dolphins passed through the area because of the shallow depth, large number of rocks and high water velocity.

Figure 6.6. Survey boat used for line-transect surveys south of Kratie to the Cambodia/Vietnam border, with two observers on-effort at all times. The observer using binoculars stood behind the observer using his/her naked eye. The naked eye observer was also responsible for recording environmental and sighting data. (left). Boat used for surveys of the Vietnamese Mekong River (right).

6.3.10. Line-Transect Data Analyses

Survey data were analysed using line-transect analysis methods, which use information on the amount of survey effort and the distribution of sighted objects to estimate density and abundance (Buckland *et al.* 2001). All sighting data were converted to perpendicular sighting distances (PSD), to establish the distance of the dolphin group from the transect line. Perpendicular distance was calculated from radial distance and sighting angle using the following formula:

Equation 6.1. $y = r\,\theta$

where y is perpendicular distance, r is radial distance, and θ is the sighting angle. For line transects, I assumed that $g(0) = 1$, *i.e.* that all dolphins along and near the track-line were seen. Land-based surveys provided additional data to test if this assumption was valid (Appendix IV).

Analysis of distance-sampling data was carried out using the program DISTANCE (version 5.1. Beta), developed and made available by the Research Unit for Wildlife Population Assessment, University of St Andrews. Five percent of all distant sightings were truncated post-survey, to remove outliers and to facilitate modelling, as recommended by Buckland *et al.* (2001). Correlation analyses were conducted on the group size data (clusters) to establish a relationship between group size and distance from the track-line. Larger clusters generally have a higher probability of being sighted further from the track-line in comparison with smaller clusters. A size bias correction was available in DISTANCE options if required, for the mean cluster size of the population (E(s)), calculated from the log of the estimated group sizes regressed against the detection probability. Theoretical considerations and the examination of empirical data suggest that the detection function should have a 'shoulder' near the line or point, indicating that detection remains nearly certain at small distances from the line (Buckland *et al*. 2001). The model fit was tested in the programme DISTANCE using the goodness of fit test. Line-transect data were combined from 2003–2005, because of the low number of sightings within each year.

6.4. LAND-BASED OBSERVATIONS

Land-based observation surveys were designed to provide information on: (1) the proportion of dolphin groups that the boat-survey team potentially missed; and (2) dive times of Irrawaddy dolphins in the Mekong River. If either (or both) of these factors were potentially biasing the line-transect results, correction factors would be applied to total population estimates.

6.4.1. Dolphins Missed/Group Size Observations

Land-based observation surveys were designed to provide two important pieces of information relevant to direct count estimates:

(1) *dolphins missed* **-** the proportion of dolphins potentially missed during upriver direct count boat surveys; and

(2) *group size comparisons* **-** a comparison of group size estimates between land and boat-based observation teams (see Appendix IV).

6.4.2. Observing Surface and Dive Times

Land-based surface and dive time observations were conducted to establish the amount of time dolphins were at, or near the surface, and available to be sighted by the boat-based survey team during line-transect surveys (see Appendix IV).

6.5. ANALYSIS OF STATISTICAL POWER OF MONITORING PROGRAMS

Following Gerodette (1987), power analyses were conducted to estimate the probability of detecting upward or downward trends in abundance from the line-transect data.

Equation 6.2. $$r^2n^3 \geq 12CV^2(Z_{\alpha/2} + Z_\beta)^2$$

Where *r* is the rate of change, *n* is the number of samples, CV is the coefficient of variation, and $Z_{\alpha/2}$ and Z_β are the probabilities of Type I and II errors respectively. The probability for making a Type I (α), or Type II (β) error, was set at 0.05. I used the CV values obtained from the line-transect estimates of abundance, to investigate the time it would take to detect different rates of population change by conducting annual surveys. The power analyses were run using the program TRENDS Windows Version 3.0 (Gerrodette 1993).

6.6. STUDY CONSTRAINTS

Table 6.4 summarises the various constraints to be considered when interpreting the results of my study. These considerations are important for any attempt to replicate line-transect in a river system.

Table 6.4. A summary table of the constraints involved in boat and land-based surveys for Irrawaddy dolphins in the Mekong River. Each constraint has an associated indication on the potential for it to be problematic to data analyses.

Survey method	Constraint	Potential for problems
Direct Counts	- Personnel constraints and local staff capacity precluded having independent observers on upriver direct counts until 2004-2005. - The narrow configuration of the survey boat meant that independent observers were only able to search to the side, or slightly behind, the boat.	**Problem**: reduced sample size to assess the probability of missing dolphin groups. **Problem**: difficulty to independently observe dolphin groups.
Line-transect	- Line-transect data from 2001–2002 were not included in the analyses because of inadequacies in data collection methods used. - Financial and personnel constraints during 2004–2005 resulted in line-transect surveys not being conducted every month of the dry season. - The different heights of the survey boats in Kratie to Khone Falls section and south of Kratie Township. - Further sighting distances were constrained by the river banks - As a result of the zig-zag design in the wider river segments, proportionally more search effort was conducted in these areas - The sample size of sightings was very small, prohibiting precise estimates. Surveys could have been repeated in areas of high abundance, but the very small populaton size, lack of resources, and importance of surveying other areas for dolphin presence, prohibited such additional surveys.	**Not problematic**: no effect on final analysis. **Problem**: reduced sighting sample size. **Not problematic:** no dolphins sighted south of Kratie Township. **Problem:** affects the detection function. **Not problematic:** dolphins did not concentrate near river-banks. **Problem:** very small sighting sample size
Land-based	- No land-based estimates were obtained of the proportion of dolphins outside critical areas that were missed by the boat-based survey team (see Appendix IV). - Personnel constraints limited the number of observers at one land-based site. At least two observers per site were preferred to facilitate group size estimations and reduce observer fatigue (see Appendix IV.	**Problem**: no estimate available to compare with sightings in critical habitats. **Potentially problem:** increased observer fatigue and potential difficulty in estimating group size with one person.

6.7. RESULTS

A total distance of 13,200 km was surveyed over 249 days of boat surveys (1,044 hours), from 2001-2005. Table 6.5 summarises effort and number of dolphin groups sighted for each survey method. Wet season boat survey data are excluded from any further analyses, as a result of the small number of dolphin groups sighted.

Table 6.5. Summary of boat survey type, duration and number of Irrawaddy dolphin groups sighted during boat surveys in the Mekong River.

Survey time	Years	Total days	Total distance (km)	Total time (hr)	# Groups sighted
On-effort Direct Count (Line transect)	2001 – 2005	119	5594.4	553.2	129 (73)
Pool Count	2002 - 2005	47	2473.7	127.1	132
Line Transect Below Kratie to Vietnam	2004 – 2005	25	1753	143.1	0
Wet Season	2003 - 2004	58	3348.4	220.6	10
TOTAL		**249**	**13169.5**	**1044**	**271**

6.7.1. Direct Counts

6.7.1.1. Upriver Direct Count Surveys

Upriver direct count surveys were undertaken over 119 days from 2001–2005. A total of 5,595 km of survey was undertaken over 553 hours (Table 6.6).

Table 6.6. A summary of the upriver direct count surveys conducted to estimate population size of the Irrawaddy dolphin population that inhabits the Mekong River. The summary includes the dates of each survey, total effort conducted (in both distance and time) and the number of individual dolphins sighted based on 'best', 'low' and 'high' estimates[1].

Year	Month	Total days	Distance (km)	Time (hrs)	# Groups sighted	Best estimate	Low estimate	High estimate	# Groups / linear km
2001	**January**	**7**	369.8	32.8	**7**	35	30	40	0.019
	February	**6**	326.4	31.5	**8**	46	38	59	0.025
	May	**6**	300.8	27.6	**8**	**68**	**54**	**88**	0.027
	June	**6**	328.8	30.1	**5**	31	26	40	0.015
2002	**May (4-10)[2].**	**7**	337.8	38.6	**7**	43	36	56	0.021
	May (18-23)	**6**	285.3	28.4	**9**	**52**	**38**	**66**	0.032
2003	**January**	**10**	405.7	40.3	**12**	41	32	53	0.030
	February	**8**	336.6	29.9	**8**	42	38	50	0.024
	March	**6**	312.7	30.9	**12**	56	49	77	0.038
	April	**8**	392.3	36.7	**8**	**64**	**55**	**82**	0.020
	May	**10**	447.9	46.2	**9**	63	50	81	0.020
2004	**January**	**10**	464.6	46.3	**8**	**67**	**59**	**81**	0.017
	March	**9**	340.1	34.8	**6**	58	50	72	0.018
	April	**6**	334.9	46.2	**11**	66	54	83	0.033
	May	**6**	270.6	18.1	**6**	47	43	57	0.022
2005	**April**	**8**	340.1	34.8	**5**	**55**	**49**	**65**	**0.015**
	TOTAL	**119**	**5594.4**	**553.2**	**129**				**0.023**

1. The shaded estimates are the highest estimates obtained for each year.
2. Two direct count surveys were undertaken in May 2002.

The 'best' minimum population size estimates obtained during these surveys ranged from 31–68 (June 2001 and May 2001 respectively). The highest number of dolphins sighted during upriver direct counts was 68 individuals (range: 54–88) in May 2001 (the height of the dry season for that year). Although the best estimate declined to 52 individuals (range: 38-66) in 2002, 67 individuals (range: 59–81) were sighted in January 2004. Only one month of surveys were undertaken in April 2005, which resulted in a best minimum estimate of 55 individuals (range: 49–65).

6.7.1.2. Downriver Pool Count Surveys

Downriver pool count surveys were undertaken over 47 days from 2002–2005. A total of over 2,400 km of survey was undertaken over 127 hours (Table 6.7).

Table 6.7. A summary of the downriver direct count surveys conducted to estimate population size of the Irrawaddy dolphin population that inhabits the Mekong River. The summary includes the dates of each survey, total effort conducted (distance and time) and the number of individual dolphins sighted based on 'best', 'low' and 'high' estimates[1].

Year	Month	Total days	Distance (km)	Time (hrs)	Best estimate	Low estimate	High estimate
2002	**May (11-12)**[2]	**3**	151.3	7.2	35	30	49
	May (23-24)	**3**	148.8	7.1	**50**	**35**	**70**
2003	**January (13-14)**	**3**	151.2	7.2	45	39	58
	January (25-26)	**3**	155.4	7.6	31	25	40
	February	**3**	149.7	7.1	60	52	72
	March	**3**	197.9	12.1	56	47	72
	April	**4**	219.9	10.5	67	54	84
	May	**4**	202.9	11.5	**69**	**57**	**84**
2004	**January**	**4**	161.8	8.6	60	52	73
	February	**4**	168.0	7.9	47	37	59
	March	**3**	189.0	10.0	50	42	60
	April	**4**	192.7	10.1	52	47	65
	May	**3**	189.6	9.7	**66**	**58**	**83**
2005	**April**	**3**	195.5	10.6	**40**	**33**	**55**
	TOTAL	**47**	**2473.7**	**127.2**			

1. The shaded estimates are the highest estimates obtained for each year.
2. Two pool count surveys were undertaken in May 2002 and January 2003.

The 'best' estimates obtained during the downriver pool count surveys ranged from 35–69 (May 2002 and May 2003 respectively). The highest number of dolphins sighted during downriver pool counts was 69 individuals (range: 57–84) in May 2003 (the height of the dry season for that year). The lowest estimate of 35 individuals (range: 30–49) was obtained at the start of May 2002. Estimates of 66 individuals (range: 58–83) were observed in May 2004, which declined to 40 individuals (33–55) in 2005.

Direct count estimates were inversely correlated with water levels; where more dolphins were sighted as water levels reduced (Figure 6.7). In all years apart from 2003, the estimates from the upriver direct counts were slightly higher than the downriver pool counts, although the results were not significantly different (Paired samples T-test, P>0.05; average population size: direct count 53.8 ± s.d. 9.77, pool count 54.2 ± s.d. 10.82).

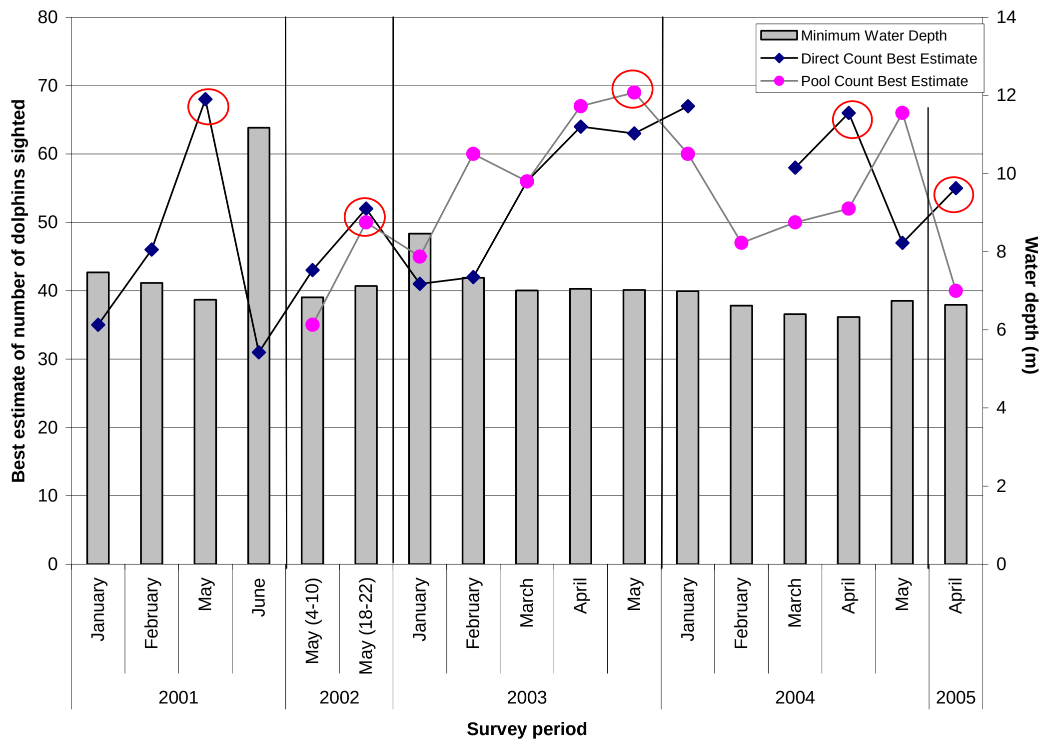


Figure 6.7. A summary graph showing 'best' estimates of total dolphins seen for upriver direct counts (shown by the diamonds) and downriver pool counts (shown by the squares), from 2001-2005. A red circle indicates the maximum 'best' estimate for each year. No data were available for direct counts in February 2004. The bars as shown on the right axis represent the minimum water level for the month (obtained from the Mekong River Commission).

6.7.1.3. Independent Observations

Independent observations were undertaken during upriver direct count surveys in January and April 2004 and April 2005. Two groups of dolphins (22% of sightings) were sighted by the independent observer team in April 2004. The independent observers did not sight any dolphins not seen by the primary survey team in January 2004 or April 2005 (Table 6.8).

Table 6.8. Summary of on-effort and combined independent observer sightings during surveys conducted in January and April 2004 and April 2005. Two dolphin groups were sighted only by the independent observer team only in April 2004, representing 22% of sightings for that survey period. These data indicate that boat-based observers had the potential to miss at least 22% of dolphins in the survey area.

Month	On-effort sightings	Off-effort sightings	% of groups sighted only by independent observers
January 2004	8	0	--
April 2004	9	2	22%
April 2005	5	0	--
TOTAL	**22**	**2**	**7%**

6.7.2. Line-Transect Surveys in the Kratie to Khone Falls River Section

Line-transect surveys undertaken in combination with direct count surveys resulted in a total of 5,594 km of survey effort over 553 hours. Personnel constraints precluded obtaining accurate angle and distance data for the first few years of the study and only data from January 2003 to April 2005 were analysed. This resulted in an associated effort of 4,510 km of survey effort undertaken over 320 hours, during 66 survey days (Table 6.9).

Table 6.9. Summary of the combined line-transect and upriver direct count boat surveys conducted in the Kratie to Khone Falls section of the Mekong River. The summary provides information on survey duration and effort, with corresponding minimum population size estimates of Irrawaddy dolphins.

Year	Month	Survey days	Total # sightings	Distance (km)	Time (hrs)	Best estimate	Low estimate	High estimate
2003	**January**	10	12	405.7	40.3	41	32	53
	February	8	8	336.6	29.9	42	38	50
	March	6	12	312.7	30.9	56	49	77
	April	8	8	392.3	36.7	64	55	82
	May	10	9	447.9	46.2	63	50	81
2004	**January**	10	8	464.6	46.3	67	59	81
	April	6	11	1810	55.8	66	54	83
2005	**April**	8	5	340.1	34.8	55	49	65
	TOTAL	**66**	**73**	**4509.9**	**320.9**			

From January 2003 to April 2005, 73 dolphin groups were sighted during line-transect surveys, with an average of 6.6 individuals per group. Dolphins were only sighted in, or close to, deep water pool areas in the Kratie to Khone Falls river section.

Dolphins were sighted at various perpendicular sighting distances (0.82 m to 1845 m) from the track-line (Figure 6.8). All perpendicular sighting distances larger than 988 m (5% of outliers), were excluded from further analyses. Sighting rates dropped off significantly after 640 m perpendicular sighting distance from the transect line (Figure 6.8). Group size was positively correlated with perpendicular sighting distance (Pearsons correlation = 0.44, P = 0.000) (Figure 6.9). Therefore, the cluster size-bias regression method (from the DISTANCE program) was used to estimate cluster size.

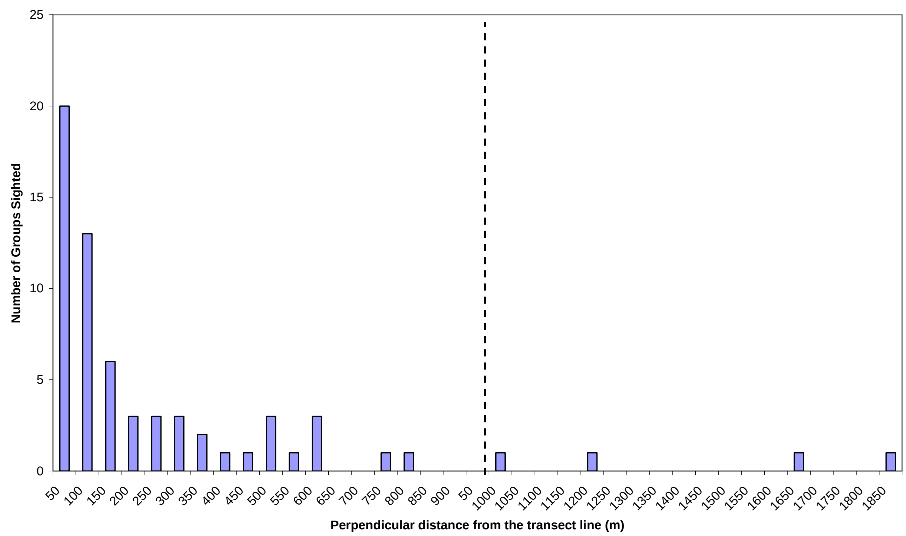


Figure 6.8. The number of Irrawaddy dolphin groups sighted during boat surveys in the Mekong River, at various perpendicular sighting distances from the survey transect line. Sighting rates dropped off significantly after 640 m perpendicular sighting distance. All data to the right of the dotted line (988 m) were truncated from the final analysis (5% of outliers).

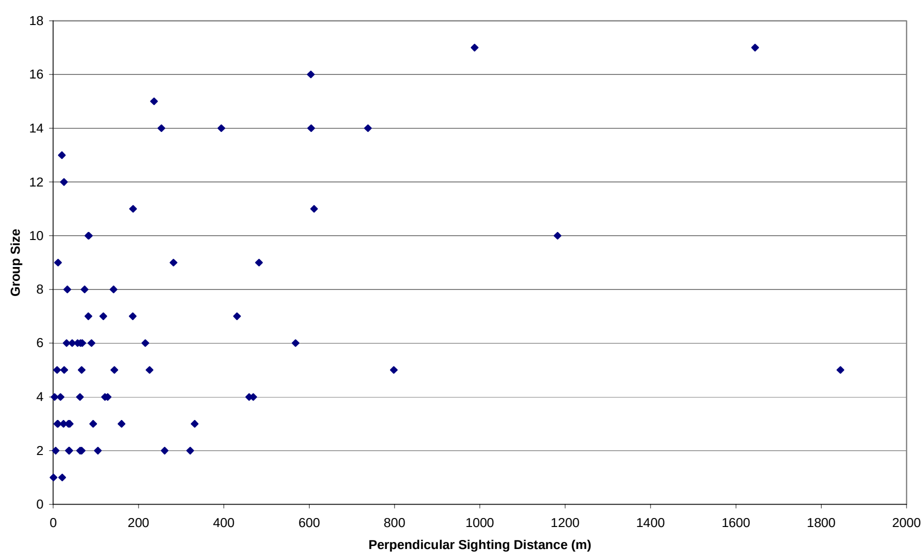


Figure 6.9. A scatterplot of the relationship between the size of a detected cluster and the distance from the line to the geometric centre of the cluster. The correlation coefficient is 0.4. A coefficient with a value of 0 indicates that cluster size and distance from the transect line are not correlated and 1 indicates a very high correlation.

6.7.2.1. Habitat Availability and Total Size of Survey Area

The total size of the area surveyed from Kratie to Khone Falls during lowest low-water was calculated via a Geographical Information System as 498 km^2 (Mekong River Commission GIS data).

During May 2003, data were collected on estimates of habitat type available to dolphin groups during lowest low-water. The results indicate that 26.4% of the available habitat from Kratie to Khone Falls consisted of pool areas (131.5 km^2), which are 10 m, or greater in depth (deep enough for dolphins to inhabit during the height of the dry season). The remaining 73.6% of river consisted of less preferable dolphin habitat (366.5 km^2), where dolphins had never been sighted during boat surveys (Table 6.10).

Table 6.10. Habitat type and availability in the Kratie to Khone Falls river section. Dolphins are most commonly sighted in deep pool areas during the dry season which comprise only 26.4% of available habitat in the Kratie to Khone Falls river section.

Habitat type	Total distance (km) (May 2003)	% of river surveyed	Total area (km^2)
Deep Pool	89.2	26.4	131.5
Upstream River Segment	71.2	21.1	105.0
Mainstream River (below Kampi Pool)	45.7	13.5	67.4
Rapids	36.5	10.8	53.8
Shallow and Islands	95.2	28.2	140.3
TOTAL	**337.8**	**100.0**	**498.0**

Importantly, of the hundreds of potentially habitable deep pool areas (areas with a depth of greater than 10 m), dolphins tend to regularly inhabit only eleven (seven in Kratie Province and four in Stung Treng Province) comprising only 56.32 km^2. These critical areas represent only 43% of deep pool habitat and 11% of the total area in the Kratie to Khone Falls river section during the height of the dry season (Chapter 7).

6.7.2.2. Line-Transect Abundance Estimates

I stratified the Kratie to Khone Falls study area (498 km^2) based on: (1) deep water habitats (131.5 km^2), and (2) all other habitats combined in the river, since dolphins are rarely found out of deep pools habitats (366.5 km^2). Various detection function models, with different truncation distances and bin sizes, were fitted to the line-transect sightings data using the program DISTANCE. On the basis of the AIC and Goodness-of-Fit (GOF) values, a Hazard Rate model fitted to a histogram with 98 m bins was adopted, with 5% of outliers truncated (AIC=770.37, GOF=X^2 = 6.7, df =7, p = 0.46) (Figure 6.10). This analysis estimated a density of 2.86

individuals per km^2 for a total population estimate of 161 dolphins (95% C.I. 89–289; CV=0.30) inhabiting deep pool areas in the Kratie to Khone Falls river section, as of April 2005.

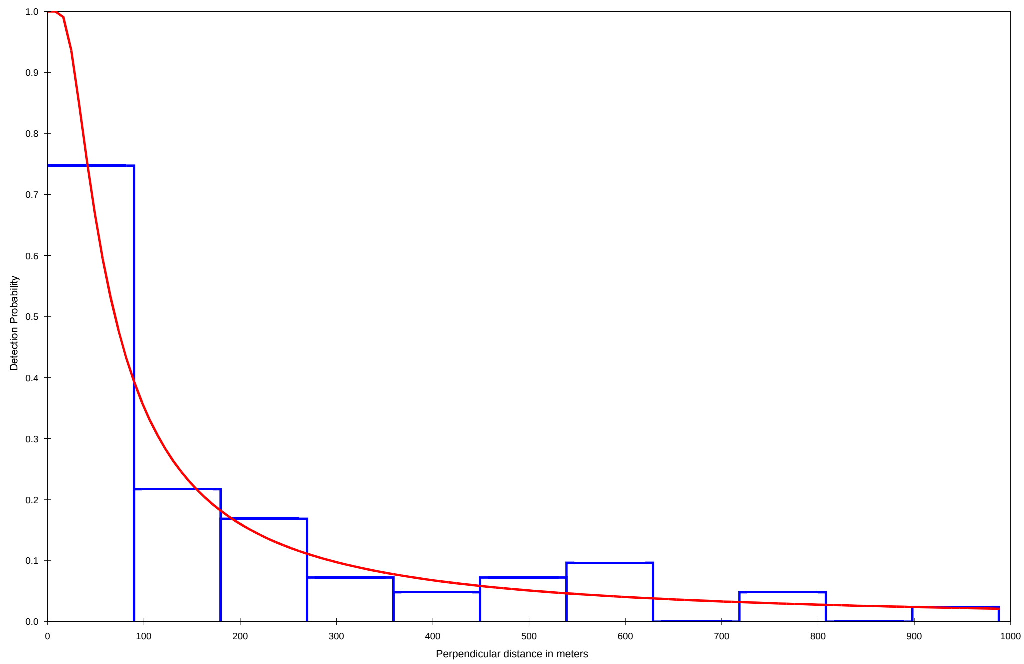


Figure 6.10. The Hazard rate detection probability curve (red line) fit to the histogram of observed detection distances (blue) obtained during line-transect surveys for Irrawaddy dolphins in the Mekong River. The analysis is based on all sightings 2003-2005 within deep pool habitats. Five percent the outliers truncated.

6.7.2.3. Comparative Yearly Line-Transect Abundance Estimates

Yearly estimates of abundance were analysed; however, variances were high because of small sample sizes. The resulting estimates for each year were variable and ranged from 46 (n = 5, CV = 58.90, 95% CL = 8–262,) in 2005 to 283 (n = 43, CV = 34.46, 95% CL = 144–557) in 2003. Line-transect data were therefore combined across years to increase precision (Table 6.11).

Density (D) was obtained using the formula:

Equation 6.3.

$$D = \frac{n \ E(s)}{2L \ . \ ESW} = \frac{62 \times 4.24}{2 \times 801 \times 0.134} = \mathbf{1.226}$$

Where: n = the total number of sightings, E(s) = the effective strip width (m), L = the total distance surveyed, and ESW = the effective strip width.

Population size (N) was obtained using the formula:

Equation 6.4. N = D A = 1.226 x 131.5 km2 = **161 (95% CI: 89-289)**

Where A = the total area of deep pool habitat and D = Density

Table 6.11. Estimates of Irrawaddy dolphin abundance from line-transect surveys within deep pool habitats in Kratie to Khone Falls river section. The Model Fit was the model chosen by the program DISTANCE, resulting from the lowest AIC value. All data were truncated using 5% of outliers *.

Year	Model fit	AIC	# of sightings	L (km)	ESW (m)	E(s)	D	%CV	N	N LCI	N UCI
2003 - 2005	**Hazard Rate**	**770.00**	**62**	**800.74**	**134.22**	**4.24**	**1.23**	**0.30**	**161**	**89**	**289**

* L (km) = the total distance travelled, ESW = the effective strip width, D = density of individuals per km^2, %CV = the coefficient of variation, N = population size, N LCL = lower 95% confidence interval and N UCL = the upper 95% confidence interval.

6.7.3. Line-Transect Surveys Below Kratie

Line-transect surveys below Kratie were undertaken during 25 days in 2004–2005. A total of 1,700 km of survey effort was undertaken over 143 hours (Table 6.12). No dolphins were sighted.

Table 6.12. Summary of line-transect duration and effort south of Kratie Township to the Vietnamese Delta.

Year	Month	Location	Total days	Distance (km)	Time (hrs)	# dolphins sighted
2004	**March**	Tonle Sap	9	567.1	40.4	0
2004	**May**	Kratie to Phnom Penh	4	449.6	38.5	0
2004	**May**	Phnom Penh to Border	3	250.0	22.0	0
2005	**May**	Vietnam	9	486.3	42.3	0
		TOTAL	**25**	**1753.0**	**143.2**	**0**

I conclude that there now is a very low probability that any dolphins are found south of Kratie Township during the dry season.

6.8. LAND-BASED OBSERVATIONS

6.8.1. Proportion of Dolphins Missed by the Boat-based Observer Team

Direct counts may have been biased as a result of boat-based observers missing dolphin groups during the upriver surveys. Land-based survey data are provided in more detail in Appendix IV. All dolphin groups sighted by land-based observers (*n*=16), were sighted by boat-based observers. Boat-based observers sighted one group (of one to two individuals) not seen by the land-based observers (Table 6.13). This group was at the most southerly end of Kang Kohn Sat Pool and probably out of sight of the land-based observation team at the time of the sighting. On all occasions, only one dolphin group was in any given deep water pool at the time of the survey. It was therefore assumed that the land-and boat-based survey teams were observing the same group. These results indicate that, at least in critical deep pool habitats, there is only a very small probability that boat-based observers are missing dolphin groups. No comparative data are available from outside these critical areas.

Table 6.13. Number of dolphin groups sighted by land- and boat-based observer teams. Land-based observations were undertaken over two years of the study period. The boat-based observers did not miss any dolphin groups that were sighted by land-based observers in critical dolphin habitats. A total of 16 dolphin groups were sighted by land-based observers and 17 dolphins groups sighted by the boat-based observers.

Year	Month	Total days	Time (hr)	# Groups sighted by land-based teams	# Groups sighted by boat-based teams
2003	**January**	2	36	2	2
	March	4	47	5	5
	April	1	17	2	2
	May	5	70	5	6
2004	**January**	4	39	2	2
	TOTAL	16	209	16	17

6.8.2. Group Size Estimates

Direct counts may have been biased if boat-based observers were incorrectly estimating group size when compared to land-based observations (it was assumed that the land-based observers were more likely to sight dolphin groups and obtain accurate group size estimates than the boat-based survey team because of their higher vantage point and stability on land: see Appendix IV). The boat-based observers over-estimated group size by, on average, only one dolphin. Of the 16 occasions when both land-based and boat-based observers sighted dolphins, 31% of estimates (five occasions) gave the same best estimates and 38% of estimates (six occasions) were within one dolphin. All larger group size differences of four to six dolphins (25%, *n* = 4), occurred at Koh Pidau Pool, where dolphins commonly occur over a larger area than in other pools (Appendix IV). These results indicate that the boat-based observers are not significantly under- or over-estimating dolphin group size.

6.8.3. Land-based Observations to Estimate Sighting Probability

A total of 284 minutes (4 hours and 44 mins), were spent collecting surface and dive times. A total of 74% of the total dives (211 minutes) were 30 seconds of less in duration. Twenty-eight percent of dives (73 minutes) were longer than 30 seconds, with an average of 54 seconds (range 31-287 seconds).

6.9. POWER TO DETECT TRENDS

As explained in Chapter 5, power analyses were undertaken to investigate the time required to detect a population trend (either increasing or decreasing), using: (1) levels of precision obtained from the line-transect analyses; (2) a relative increase in precision (CV=0.20); and (3) a substantial increase in precision (CV=0.10) (Figure 6.11).

With the highest level of precision obtained for abundance estimates in dolphin-critical areas (CV = 0.30), I estimated that it would take 17 years to detect a population change of 5% per annum and six years to detect a 20% per annum change. With an increased level of precision of 0.20, I estimated that it would take 14 years to detect a population change of 5% per annum and five years to detect a 20% per annum change. If the precision were improved to CV=0.10 by increased sampling, the time to detect a change would be reduced to eight years to detect a population change of 5% per annum and two years to detect a 20% per annum change (Figure 6.11).

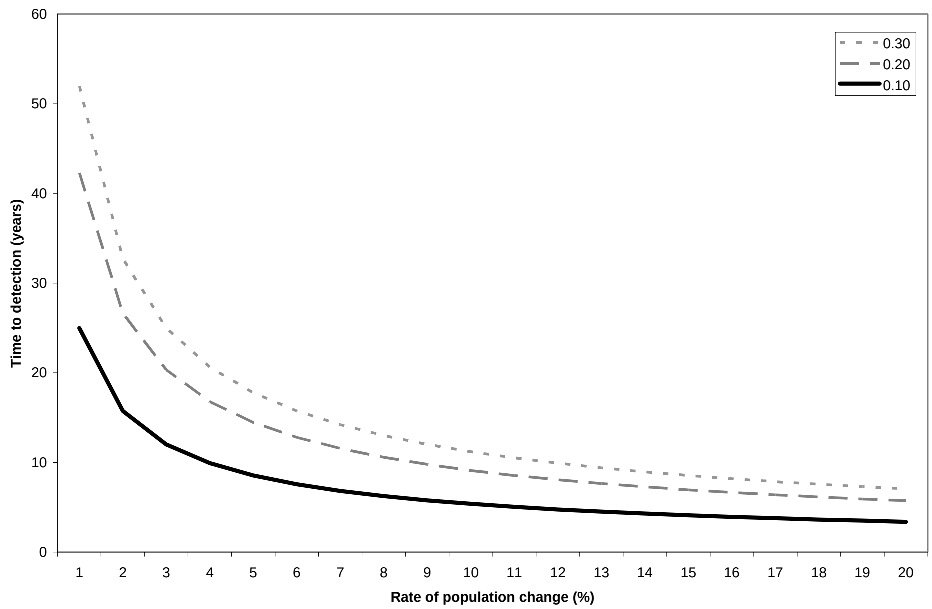


Figure 6.11. Relationships between different rates of population change, time to detection of trend and coefficient of variation (CV) for annual population estimates. The highest level of precision obtained for line-transect estimates was CV=0.30. Additionally, comparative CVs of 0.20 and 0.10 are presented in the event that increased sampling was possible.

These analyses indicate that, by the time a trend in abundance is detected, the population would have increased or decreased significantly. For example, with current highest levels of precision (CV = 0.30), a population of 161 dolphins decreasing at 5% per year, would consist of only 68 individuals by the time such a trend was detected (17 years). If the rate of decline was 20% per year, only 42 individuals would remain (detected after six years) (Table 6.14).

Table 6.14 . Effect of different annual rates of population change on the number of years required to detect population trends with yearly survey intervals (*t*=1). Data variability is specified at CV = 0.30, which corresponds to the highest level of precision obtained for the line-transect abundance estimates from this study.

CV	Rate of change	Number of surveys required (n)	Number of years to detection (t(n-1))	Total % change at detection of decreasing population	Total % change at detection of increasing population
0.30	0.05	18	16.77	-0.58	1.27
	0.10	11	10.20	-0.66	1.64
	0.15	9	7.55	-0.71	1.87
	0.20	7	6.05	-0.74	2.02

6.10. DISCUSSION

My study provides the first reliable estimates of Irrawaddy dolphin population size in the Mekong River based on boat surveys. Previously direct counts have been used to estimate abundance of river dolphin populations, with assumptions that most animals were sighted during periods of low water levels (Smith and Reeves 2000, Smith *et al.* 2001, Smith and Hobbs 2002, Smith and Beasley 2004b). This study investigates the potential biases of estimating abundance using direct count methodology and compares alternative methodologies. In addition, this study presents the first line-transect estimates of abundance for an Asian river dolphin population.

6.10.1. Importance of Kratie to Khone Falls River Section

Based on the results of my study, the Kratie to Khone Falls river section is the most critical habitat for dolphins in the Mekong River (see Chapter 7). Extensive boat surveys failed to sight any dolphins below Kratie Township: this lack of sightings was further evidenced by intensive interviews with local fishers (Chapter 4). Therefore, abundance estimates from the Kratie to Khone Falls river section in the dry season as discussed here, are representative of total population size. The dry season deep pool habitats that dolphins favour between Kratie to Khone Falls constitute only 11% of the available habitat in this river section. Effective management of these habitats is therefore critically important for the dolphins' future survival in the Mekong River.

6.10.2. Direct Count Considerations

The results from my surveys suggest that direct count methodology is both an inaccurate and imprecise method of estimating total dolphin abundance in habitats such as the Mekong River. Ninety dolphins were photo-identified between 2004-2005 (Chapter 6); however, the highest best estimate of dolphins in the Mekong River using direct counts was 67 individuals (January 2004 upriver surveys). Based on this initial comparison, direct counts are underestimating population size by at least 35%. Although both upriver direct counts and downriver pool counts were standardised throughout the study period, total estimates fluctuated greatly.

All dolphin groups sighted by the land-based observers in critical areas were also sighted by the boat-based team (Appendix IV), indicating that, using this survey methodology, boat-based observers have a high probability of observing dolphins (100% in this study), if dolphins are within critical areas. As a result of evidence that some proportion of dolphins are being missed by the boat-based survey team (discussed above), it is likely that this occurs outside critical habitats, possibly when dolphins are moving between deep pool areas. Due to logistical constraints, I did not investigate the probability of boat-based observers sighting dolphins outside of critical areas. Surface and dive time observations indicate that dolphins are regularly available to be sighted by the boat-based observer team. The maximum dive time recorded over 284 minutes of land-based observations was 249 seconds (4 minutes and 9 seconds), however 74% of all dives were a duration of 30 seconds or less.

As outlined in Chapter 8, average group size during the dry season was 6.8 dolphins $\pm$ 0.20 (range=1-18, mode=6, median=6, n=405). I hypothesised that the total number of dolphins estimated by direct counts may be lower than line-transect and photo-identification estimates (Chapter 6) as a result of the boat-survey team consistently underestimating group size. However, I found that boat-based observers consistently over-estimated group size when compared to land-based observer estimates (nine out of eleven occasions), but only by an average of one dolphin (range=1-6). There is therefore only a small probability that the total estimates for each upriver direct count survey and downriver pool count survey represent significantly more, or less dolphins than were actually observed during the survey.

I found that the downriver pool count estimates were very similar to those obtained for the upriver direct counts and showed similar trends. However, pool counts were conducted over slightly more than half the distance (2,474 km) and in one-third the time (127 hrs) compared with upriver direct count surveys (4,269 km and 431 hr respectively). If personnel and resources are scarce and a relative index of abundance is all that can be obtained, it is more cost-effective to undertake pool counts, stopping only at the critical dolphin habitats (3-4 days duration), rather than direct counts which search the entire Kratie to Khone Falls river section (6-10 days duration). However, as mentioned above, direct count methodology is not recommended for long-term monitoring.

6.10.3. Line Transect Considerations

Many of the assumptions of line-transect sampling were considered at the start of this study (Table 6.2) and every attempt was made to minimise potential biases resulting from undertaking line-transect methods in a river system. Unreliable and imprecise yearly estimates (2003-2005) were obtained as a result of the small number of sightings each year (where at least 60-80 sightings are needed to estimate the Effective Strip Width: Buckland *et al*. 1989). The small number of sightings obtained was primarily a result of the very small size of the Irrawaddy dolphin population inhabiting the Mekong River. Addtionally, this low number of sightings resulted from financial and personnel constraints, which prevented line-transect surveys from being conducted during every month of the respective dry seasons. It was therefore necessary to pool line-transect data from 2003–2005, rather than obtaining unreliable yearly abundance estimates.

Land-based observations (Appendix III) show that during the dry season dolphin groups are at the surface for long periods, with dives longer than 30 seconds being an average of 54 seconds (range 31-249). This result indicates that dolphins are consistently available at, or near the track-line for detection by observers, and dive times are not significantly biasing abundance estimates. However, a limitation of this land-based methodology is that observations were conducted over-looking only one deep water area and did not provide surface and dive times for dolphin groups that may be moving between critical areas. Based on other cetacean studies (e.g. harbour porpoise *Phocoena phocoena*), dolphins exhibit significantly longer dive times when travelling (Barlow *et al.* 1988). It is therefore possible that dolphins in the Mekong River have a reduced probability of being sighted outside dolphin-critical areas, particularly when travelling. Similar dive-time observations were conducted on 90 Irrawaddy dolphin groups sighted in Malampaya Sound, Philippines (Smith *et al.* 2004), which resulted in an average dive time of 11.9 seconds and average surface time of 1.3 seconds. Smith *et al*. (2004) concluded that although the behaviour of Irrawaddy dolphins was relatively inconspicuous, their short surfacing intervals ensured a very high probability of detection on the track-line. Although my study site was different, based on the results obtained from my land-based studies, the conclusion of Smith *et al*. (2004) is also applicable to Irrawaddy dolphins inhabiting the Mekong River.

6.10.4. Methodological Considerations

There is a notable lack of shoulder in the detection probability curve (Figure 6.10). This may be as a result of the river-banks preventing sightings at the further distances. To minimise further biases in the line-transect data, my team and I were very careful not to round data; continually undertook distance estimation tests to encourage exact estimates of sighting distances; and did not focus on spotting dolphins on the trackline. The complex geomorphology of the Mekong

River makes random, straight-line surveys a challenge. Yet, this study resulted in reasonable estimates of abundance based on line-transect surveys, with a related measure of precision. A major consideration however, is the need to obtain sufficient number of sightings for analyses and the effort required to achieve such a sample size. Any future line-transect studies in the Mekong River (and other river systems) may consider a more robust survey design, whereby:

1. a 100m contour on land is drawn on either side of the river (the river plus the land area would then be the survey area);
2. a series of zig-zag transects across the survey area are designated to provide an appropriate coverage (which would prevent over-sampling of the edges);
3. boat surveys are conducted along the in-water sections of the transects (which would attempt to ensure all sections of depth gradient are surveyed equally); and
4. in narrow sections of river (<1000m), the zig-zag design would still be followed (rather than a straight line transect), to ensure the river edges are searched randomly.

The validity of using line-transect methodology to estimate population size of Irrawaddy dolphins in the Mekong River (and inappropriateness of direct counts), is confirmed through a comparison of estimates obtained by capture-recapture analyses of photo-identified individuals (Chapter 5). A total of 90 dolphins were photographically identified from February 2004-April 2005, which represents an absolute minimum number of dolphins in the river. Using a closed capture-recapture model using photo-identified individuals, the resulting population size estimates (including the proportion of unmarked dolphins in the population, and accounting for mortality and recruitment: Chapter 9) was 127 Irrawaddy dolphins ± s.e. 9.0 (95% CI = 108–146; CV=0.07). Although precise, this estimate is almost certainly an underestimation of the total population size, based on: (1) the fact that the discovery curve had not yet reached a plateau, and (2) dolphins inhabiting the Stung Treng critical area were not adequately sampled (see Chapter 5). The actual population size is probably between 127 (range=108-146; capture-recapture estimate) and 161 individuals (89–289; line-transect estimate).

An initial comparison between the effort required obtaining estimates for each methodology and associated precision (Table 6.15) confirms that photo-identification is one of the most cost effective survey methodologies, with resulting high levels of precision and confidence.

The comparison of survey techniques justifies the continued use of photo-identification studies, as an immediate priority for population monitoring. Comparisons with line-transect and photo-identification (Chapter 6) population estimates therefore indicate that at least 50-60% of dolphins in the Mekong River are missed during the direct count surveys. Direct count estimates are inaccurate and not recommended for future population monitoring. The probability of missing dolphins during direct count surveys could be obtained by either: (1) land-based observations (which importantly would need to be conducted outside dolphin-critical habitats); or (2) independent observation teams on the same survey boat. However, the bias associated with direct counts is variable, and generally not quantified.

Table 6.15. A comparison of the different surveys methods used to estimate total population size of Irrawaddy dolphins inhabiting the Mekong River.

Survey type	# Days	# Hours	Population estimate	CV
Direct Count (from 2001-2005)	119	553.2	68 (54-88) (May 2001)	--
Pool Count (from 2001-2005)	47	127.1	69 (57-84) (May 2003)	--
Photo-identification (from 2004-2005)	61	121.0	127 (95% CI=108–146) (2004-2005)	0.07
Line-transect (only in the Kratie to Khone Falls river stretch from 2003-2005)	66	320.9	161 (95% CI = 89-289) (2003-2005)	0.30

The argument for using photo-identification is strengthened by the small survey area (Kratie to Khone Falls), aggregation of dolphins in known critical areas, and the lack of immigration and emigration in the Khone Falls river section during the dry season. Line-transect estimates appear accurate when compared with downward biased capture-recapture estimates. However, the large number of sightings required for reliable and accurate line-transect analyses indicates that resources are better used to focus on photo-identification in critical habitats for accurate abundance estimation.

Further justification for the continued use of photo-identification over line-transect methodologies in the Mekong River is based on a comparison of their resultant CVs, and power to detect trends in abundance, as shown below

	5% pop. change	20% pop. change
Photo-identification (CV=0.07)	6 years	2 years
Line-transect (CV=0.30)	17 years	6 years

Line-transect sampling is not recommended for monitoring abundance of Irrawaddy dolphins in the Mekong River at the present time, primarily because:

1. a large number of sightings are required to obtain accurate and precise estimates of abundance;
2. the low power to detect trends in abundance compared to photo-identification;

3. based on five years of survey already conducted, dolphins appear to be restricted to the identified critical deep pool areas, where accurate and precise capture-recapture estimates can be obtained with significantly less resource investment using photo-identification than line-transect;
4. experienced observers need to conduct and analyse the line-transect surveys to ensure data is collected appropriately – which is currently beyond the capacity of local Cambodian monitoring efforts;
5. a significant amount of additional data can be collected on movements, associations and life-history through the use of photo-identification studies.

However, if adequate resources are available, as a secondary priority, standardised line-transect survey methodology would be useful for continued monitoring of distribution and area of occupancy within the Kratie to Khone Falls river section (discussed further in Chapter 4). Regardless of which methodology is used, all estimates indicate that the total population size of Irrawaddy dolphins in the Mekong River is very small (<180 individuals), confirming the need for urgent conservation action.

6.11. CONCLUSIONS

Chapter 6 aimed to provide baseline data on the population size of Irrawaddy dolphins in the Mekong River, using direct counts and distance- sampling techniques (a continuation of my thesis objective 4a: Chapter 1). A summary of the major conclusions from Chapter 6 are listed below.

- This study provides significant new information regarding the population size of the Irrawaddy dolphin population in the Mekong River and the appropriate survey methodology to continue the future population monitoring critical for management purposes.
- The Irrawaddy dolphin population is now primarily restricted to the Kratie to Khone Falls river section in the Mekong River. Abundance estimates from this area during the dry season are therefore representative of the total population size.
- The highest number of dolphins sighted during upriver direct count surveys was 68 (range: 54-88) in May 2001 and 67 (range: 59-81) in January 2004. The highest number of dolphins sighted during downriver pool counts was 69 (range: 57-84) in May 2003 and 66 (range: 58-83) in May 2004. Upriver direct counts generally obtained

slightly higher estimates than downriver pool counts but the results were not significantly different.

- Up to 22% of sightings (April 2004) were initially observed only by independent observers. This indicates that some proportion of dolphins were being missed by the primary observer team (these sightings were all located outside of critical areas).
- Based on habitat availability studies, dolphins regularly inhabit only 56 km^2, of the available 498 km^2 in the Kratie to Khone Falls river section.
- Line-transect analyses from 2003-2005 estimated 161 dolphins (range: 89-289: CV=0.30) inhabit the Mekong River as of April 2005. Adequate sighting sample size is important for precise and accurate line-transect estimates.
- No dolphins were sighted south of Kratie Township.
- With the highest level of precision obtained from line-transect abundance estimates (CV=0.30), it would take 17 years to detect a 5% per annum decline and 6 years to detect a 20% per annum decline.
- These analyses indicate that by the time a trend in abundance is detected, the population would have increased, or decreased, significantly. Therefore, if a declining population trend is detected statistically, the population is likely to be in significant trouble.
- Based on a combination of photo-identification and line-transect methodologies, the total Irrawaddy dolphin population in the Mekong River is probably between 127 (range: 108-146) and 161 (range: 89-289) individuals.
- Photo-identification also provides important information regarding dolphin movements, life history and habitat use.
- Irrespective of the differences between survey methodologies, the total abundance of the Irrawaddy dolphin population that inhabits the Mekong River is very small and the population is now facing a very uncertain future.
- Chapter 11: Table 11.5 summarises the main research and conservation implications from Chapter 6.

6.12. BOAT SURVEY RECOMMENDATIONS

- As a high priority, it is recommended that photo-identification studies are conducted, at a minimum, in March (first capture session) and April (recapture session) each year in the Kratie to Khone Falls river section.
- As a secondary priority if resources allow, a dedicated line-transect survey should be conducted at least once every year (March-May), to monitor dolphin distribution along the Kratie to Khone Falls river section.
- Direct counts are not recommended for population monitoring, as a result of the inaccurate and imprecise abundance estimates and variability in the proportion of dolphins missed by the observer team.
- Line-transect methodology is not recommended for current population monitoring of the Mekong dolphin population, as a result of the large number of sightings required, and necessity for a team of trained personel.

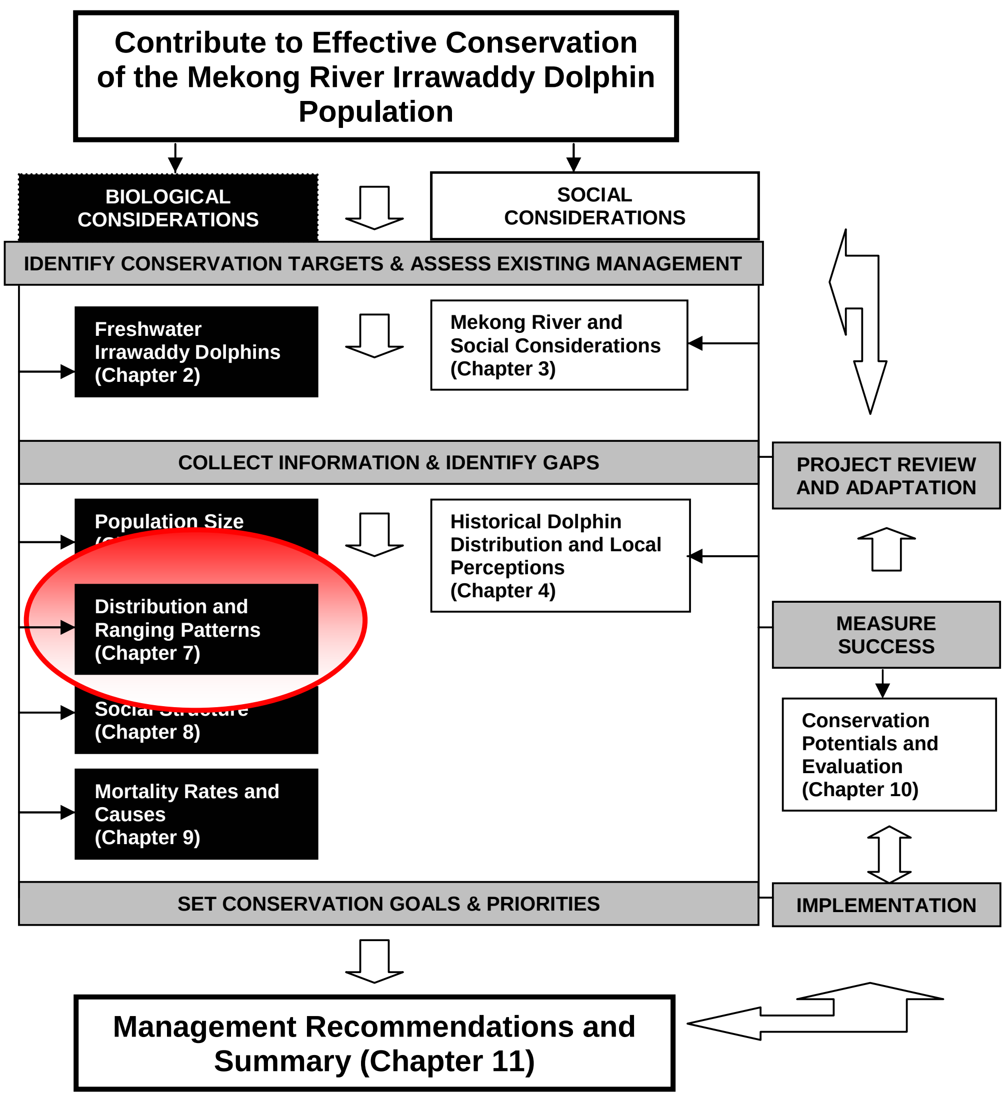
7. DISTRIBUTION AND RANGING PATTERNS OF IRRAWADDY DOLPHINS INHABITING THE MEKONG RIVER

An understanding of the habitat preferences of an endangered species, as well as identification of its critical habitats, is fundamental to enhancing the prospects for successful conservation. In Chapter 7, I investigate the distribution and ranging patterns of Irrawaddy dolphins in the Mekong River and discuss observed changes in distribution based on interviews and historical records. I also investigate individual ranging patterns based on photo-identification data collected throughout my study period.

An Irrawaddy dolphin from Kampi Pool, Kratie Province, with a small fish in its mouth.
Photograph by Laura Morse

7. DISTRIBUTION AND RANGING PATTERNS OF IRRAWADDY DOLPHINS INHABITING THE MEKONG RIVER

Chapter 7 investigates one of the biological considerations in the context of the '*collecting information and identifying gaps*' section of my conceptual framework. The aim of Chapter 7 is to provide baseline data on the distribution and ranging patterns of Irrawaddy dolphins inhabiting the Mekong River (thesis objective 4b: Chapter 1).



7.1. INTRODUCTION

An understanding of a species' distribution, habitat use and ranging patterns is important for conservation and management. The habitat use and ranging patterns exhibited by individuals may have major implications on the dynamics, demography and persistence of a population (McNab 1963, Swihart and DSlade 1985, Swihart *et al.* 1988, Hestbeck *et al.* 1991, Warkentin 1996). A variety of factors may influence the spatial and temporal changes of an individual's ranging patterns, including the availability and distribution of resources such as food and mates, (Ford 1983, Mace *et al.* 1983, Joshi *et al.* 1995), human disturbances (Bowyer *et al.* 1995) reproductive status (Bertrand *et al.* 1996, Ribble and Stanley 1998) and age (Cedurlund and Sand 1994).

The extent to which an individual ranges throughout an area is linked to its site fidelity (Warkentin 1996). Familiarity with a particular area conveys potential advantages in terms of dominance of an area for resources, knowledge of the spatial, daily and seasonal variation in resources, and enhanced ability to avoid predation (Gauthreaux 1982, Shields 1984, Dobson and Headrick 1995). Species and populations exhibiting high levels of site fidelity between years may be less adaptable to habitat degradation and loss and more vulnerable to population loss (Warkentin 1996).

Many studies have investigated the home ranges of delphinids, such as those on: Hector's dolphins (*Cephalorynchus hectori*) in New Zealand (Brager *et al.* 2002), bottlenose dolphins in California (Defran and Weller 1999) and the Moray Firth, Scotland (Wilson *et al.* 1997). humpback dolphins in Algoa Bay, South Africa (Karczmarski 1999) and Hong Kong (Hung and Jefferson 2004), marine tucuxi in southern Brazil (Flores and Bazzalo 2004) and Australian Snubfin dolphins in northern Australia (Parra 2006).

Irrawaddy dolphins occur in a variety of habitats, including coastal marine, brackish water lagoon and freshwater. However, within these habitats, very little is known regarding their specific habitat preferences or movements. Additionally, factors that may influence ranging patterns are unclear.

In this Chapter, I investigate the distribution and habitat use of Irrawaddy dolphins inhabiting the Mekong River, and compare the results to the published literature and local reports (Chapter 4). I also investigate individual ranging patterns through analysis of photo-identification data obtained from 2001 to 2005 (Chapter 5). This study represents the first attempt to estimate ranging patterns for an Asian river dolphin population, based on photo-identification data.

7.2. STUDY AREA AND METHODS

7.2.1. Distribution

Boat surveys and dedicated photo-identification studies were conducted throughout the entire lower Mekong River (including Tonle Sap Lake), from 2001 to 2005 (Chapters 5 and 6, Figure 7.1). To investigate the distribution of individual dolphins, I used all sighting data collected during this study period (which included associated data on position, depth, temperature and turbidity). Only minimal data were collected on the characteristics of the deep water areas throughout the Kratie to Khone Falls river section. A more detailed investigation into deep water area characteristics and dolphin sighting rates in various deep pools (including those not frequented by dolphins) is required in the future, but was outside the scope of my study. Dolphin distribution data were plotted using a Geographical Information Systems (GIS), with a bottom substrate theme obtained under licence agreement from the Mekong River Commission. The methodology I used to collect sighting data is described in detail in Chapter 6.

7.2.2. Ranging Patterns

To investigate the ranging patterns of individual dolphins, I used photo-identification data collected from 2001 to 2005 (Chapter 5). I use the term ‘range’ to define the area where an individual was sighted during this study (Parra 2006). Few sightings were obtained from the Stung Treng and Phum Kreing primary areas as a result of the low level of photographic effort (see Chapter 5). I selected the three most frequently sighted dolphins from each primary area (Figure 7.1) for analyses of ranging patterns, rather than the most frequently sighted individuals (Hung and Jefferson 2004) in order to minimise the bias caused by uneven sampling effort. Dolphins only use the Phum Kreing primary area during the wet season (Chapter 6). I present the dry season data for Phum Kreing individuals as evidence for the location of the dolphins during the dry season.

The methodology I used to photo-identify dolphins is described in detail in Chapter 5. Individual identification codes are based on the area in which the identified dolphin was first sighted: Kampi (KA), Phum Kreing (PK), Koh Pidau (GO), Tbong Klar (TK), Kang Kohn Sat (KKS), Koh Suntuk (KS) and Chiteal (CH) (Figure 7.2). The first dolphin sighted in the area was named ‘AREA’ 01. Subsequent dolphins were labelled consecutively. For example, KA01: Klasico, was the first dolphin to be identified at Kampi Pool and KA05: Rags, was the fifth dolphin to be identified at Kampi Pool. The Phum Kreing individuals were first identified at Phum Kreing, however, all moved to other areas (such as Kampi and Koh Pidau) during the dry season.

The most frequently sighted individual was KA01 (Klasico), who was first sighted when trapped in an irrigation canal near Phnom Penh. Klasico was released back into the river in December 2002 (Beasley 2002) and then swam back upstream to Kampi Pool (a total linear distance of 294 km), where it was resighted from 2003 to 2005. This single long distance movement was an outlier and removed from further analysis.

I had initially aimed to use either Minimum Convex Polygon (MCP) (Hayne 1949, Anderson 1982), or Kernel estimation methods (Powell 2000), to estimate ranging patterns. However, once the data were collected, these analyses were not possible because of:

1. the small number of sightings for each individual; and
2. the complex, linear study area.

Instead, I conducted a preliminary analysis that describes the total ranging area of a photo-identified individual based on the northern and southern limits of the sighting locations, bounded by the east and west river banks.

I term this range the '*maximum* range based on my sighting data' (rather than '*minimum* range'), because I acknowledge that it is unlikely that dolphins are using all of the area calculated, particularly during the dry season, as a result of habitat restrictions (such as islands, rocks and shallow water). However, importantly, I also acknowledge that dolphins are likely to be moving beyond the north/south boundaries of the photo-identification sighting data throughout the year. As a result, my definition of '*maximum range based on my sighting data*' could also have been termed '*minimum north/south distribution*'.

The total area encompassed by the north and south boundaries (excluding islands), was obtained using ArcGIS Desktop 9.1 with Hawth's Tools extension to calculate area. The data was projected into Universal Transverse Mercator (UTM) Zone 48 North.

7.3. RESULTS

7.3.1. Distribution of Dolphin Sightings

Boat surveys were conducted throughout the entire lower Mekong River (including Tonle Sap Lake) from 2001-2005, however dolphins were only sighted in the Kratie to Khone Falls River section (Figure 7.1). Within the Kratie to Khone Falls river stretch (excluding surveyed aras south of Kratie), a total distance of 11,416 km was surveyed by boat, over 901 hours (a total of 13,169 km was surveyed in total, 1,753 km being south of Kratie: Chapter 6). A total of 514 dolphin-sighting locations were identified (dry season=405, wet season=109). A total of 210 hours of photo-identification were conducted; 136 hours in combination with boat surveys and 74 hours conducted independently of boat surveys (Chapter 5).

As discussed in Chapter 4, dolphins do occasionally occur outside of the Kratie to Khone Falls river stretch during the wet season/end of dry season, based on:

1. the occurrence of two dolphins trapped in an irrigation canal after flood waters receded, 40km north of Phnom Penh in 2001 (both dolphins were subsequently released back into the river);
2. the occurrence of one dolphin found dead as a result of dynamite fishing more than 100 km upstream of the Srepok River in February 2005 (although it was first sighted in the area in December 2004: see Chapter 9);
3. one dolphin carcass that was discovered a few kilometres north of Kompong Som in 2003 (see Chapter 9, Figure 9.9); and
4. two dolphins that died after being accidentially caught in fishing gear in the Vietamese Mekong River, near the Cambodian/Vietnamese border (one in March 2002 and one in November 2005). However, it remains unclear if these dolphins moved upstream from the Vietnamese Delta, or downstream from the Kratie to Khone Falls River section.

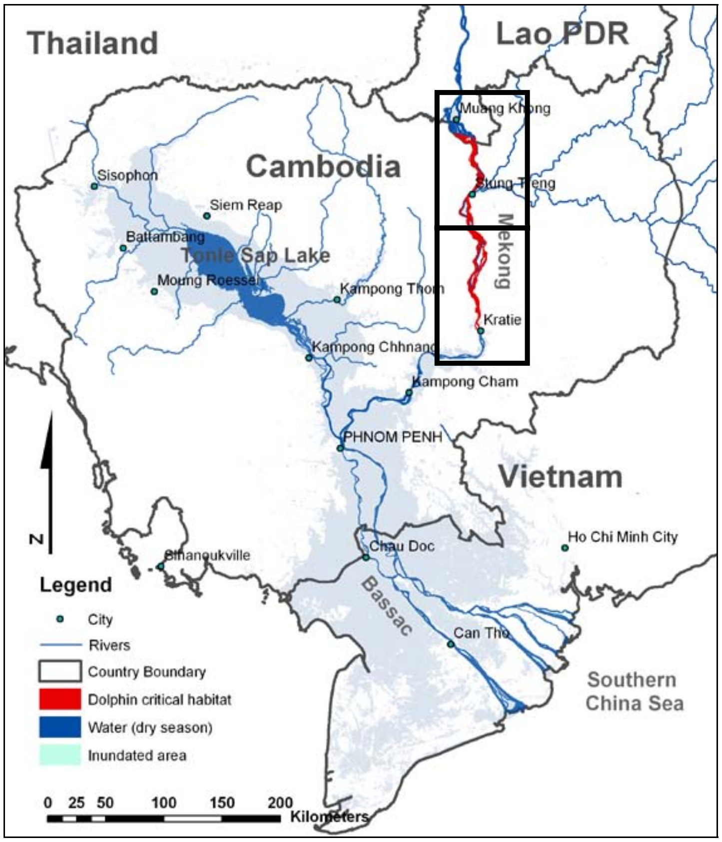


Figure 7.1. Map showing the study area where boat surveys were conducted. The area ranged from the Laos/Cambodian border (Muang Khong) south to the Vietnamese Delta (including Tonle Sap Lake). The Kratie to Khone Falls river section (shown in red), is the only area in the river where dolphins were sighted. The lower box represents Kratie Province, and the upper box represents Sung Treng Province. Map created by Matti Kummu.

The distribution of Irrawaddy dolphin sightings in the Kratie to Khone Falls river section is shown in Figure 7.2. Figure 7.2 illustrates that individuals are not distributed randomly along the river; rather they prefer critical deep pool habitats (*i.e.*, critical areas, Chapter 5), distributed along five primary areas. Five primary areas were evident; Kampi, Phum Kreing (used only during the wet season), Koh Pidau, Stung Treng and Chiteal (Chapter 6).

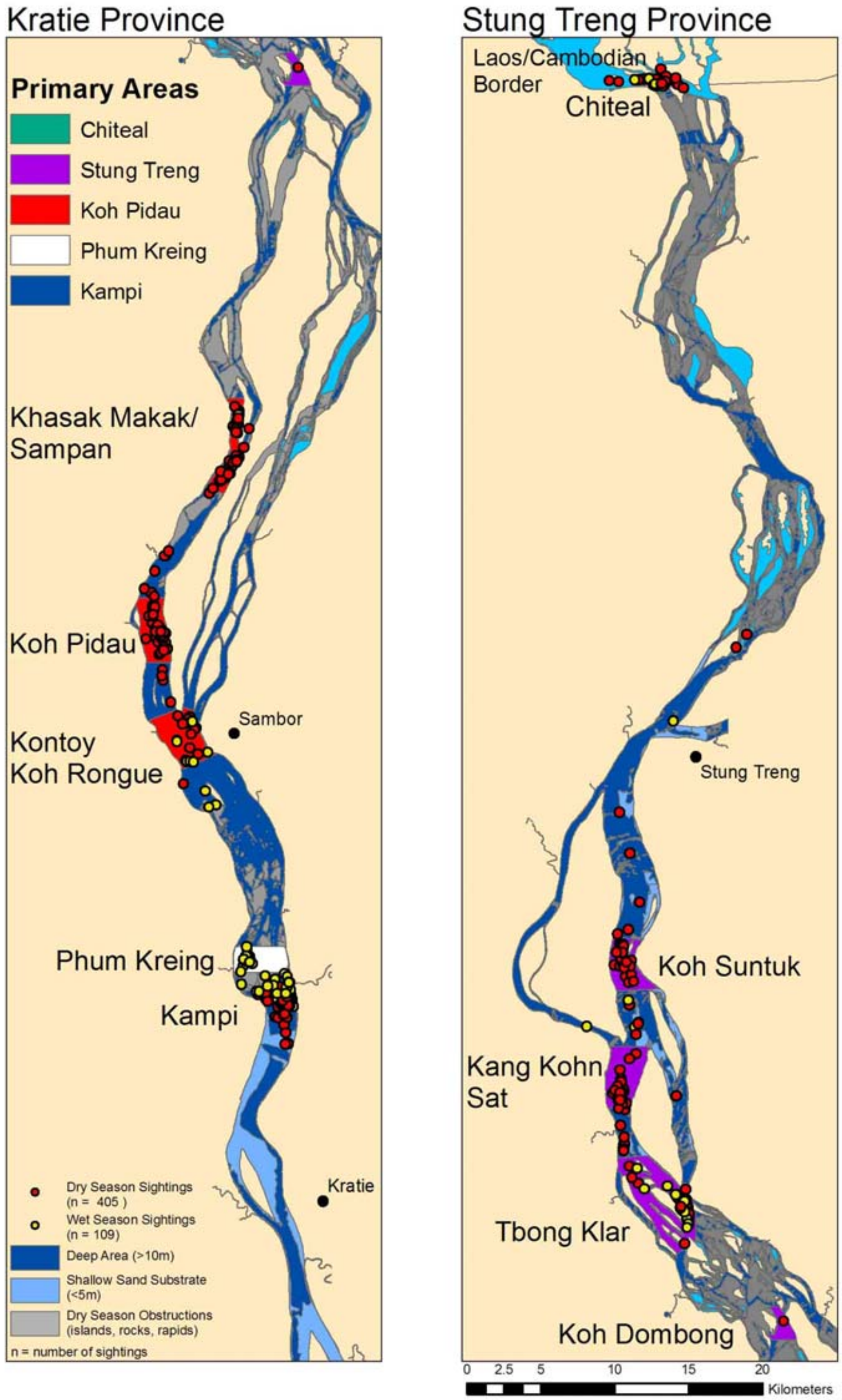


Figure 7.2. Distribution of Irrawaddy dolphins inhabiting the Mekong River, based on all dolphin sightings obtained between January 2001-April 2005. Kratie province is shown on the left map and Stung Treng Province, which is further north (see Figure 7.1) on the right map. Sightings are separated into dry season (red dots) and wet season (yellow dots). Chiteal primary area is located on the right map on the Laos/Cambodian border. Since it is a small area, the green colour is hidden by sighting dots and is therefore not visible. Maps created by Erin LaBrecque.

Total effort (boat surveys and dedicated photo-identification combined), was highest in 2003, and lowest in 2002 (Figure 7.3). Figure 7.4 illustrates the sighting locations separated by year. Acknowledging the differences in survey effort between years, there were no obvious changes in dolphin distribution over the five-year study.

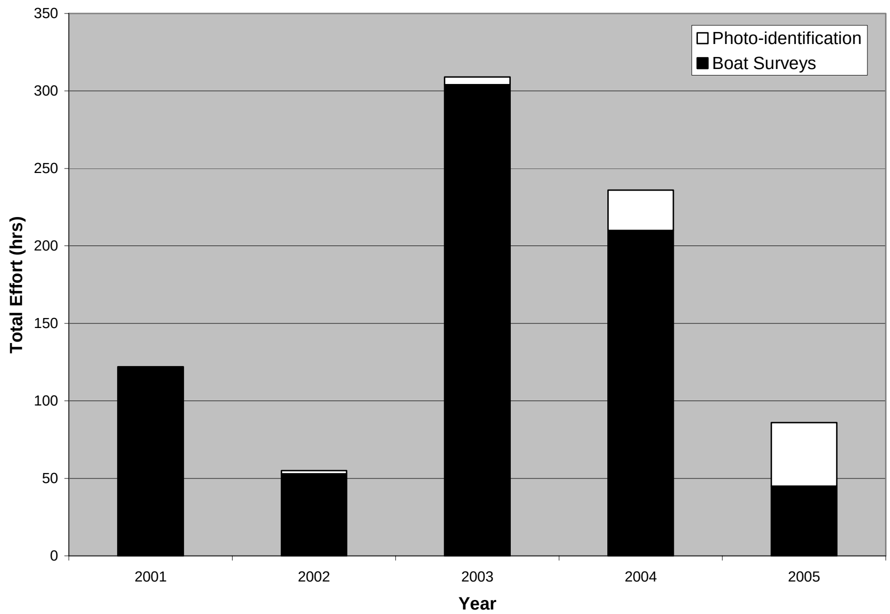


Figure 7.3. Total survey effort (boat surveys and dedicated photo-identification) in the Kratie to Khone Falls River section. No dolphins were sighted south of Kratie Township.

7.3.2. Environmental Characteristics of Sighting Locations

7.3.2.1. Water Depth

The average water depth where dolphins were encountered was 11.63 m (range=0.44-45.94, n=394) during the dry season, and 10.28 m (range=0.53-38.75, n=86), during the wet season. Dolphins were not sighted in water depths over 46 m, although the maximum depth of deep water pools reached 80-90 m (see '7.3.3 *Deep Pool Characteristics*').

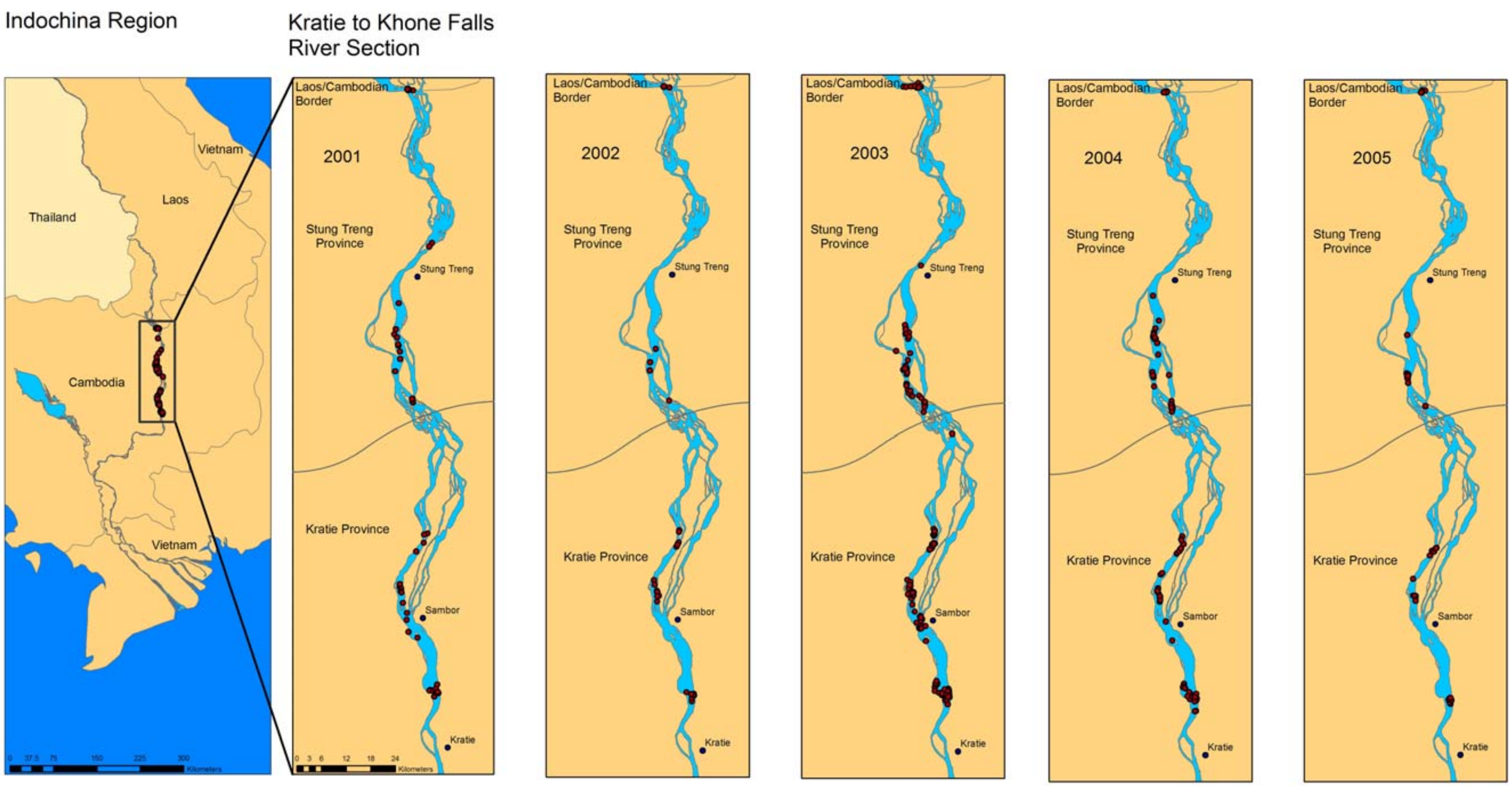


Figure 7.4. Distribution of all Irrawaddy dolphin sightings in the Kratie to Khone Falls section of the Mekong River from January 2001-April 2005. The sightings are separated by year. Map created by Erin LaBrecque.

7.3.2.2. Water Temperature

The water temperature at the locations where dolphins were sighted varied from a minimum of 26.3 $^oC \pm$ s.d. 3.11 (12.0-28.4, *n*=32) in January (end of the wet season), to a maximum of 32.8 $^oC \pm$ s.d. 0.96 (30.0-33.0, *n*=65) in May (height of the dry season) (Figure 7.5). Temperatures were not recorded from the deep pools that dolphins did not inhabit, an acknowledged inadequacy of my data collection protocol.

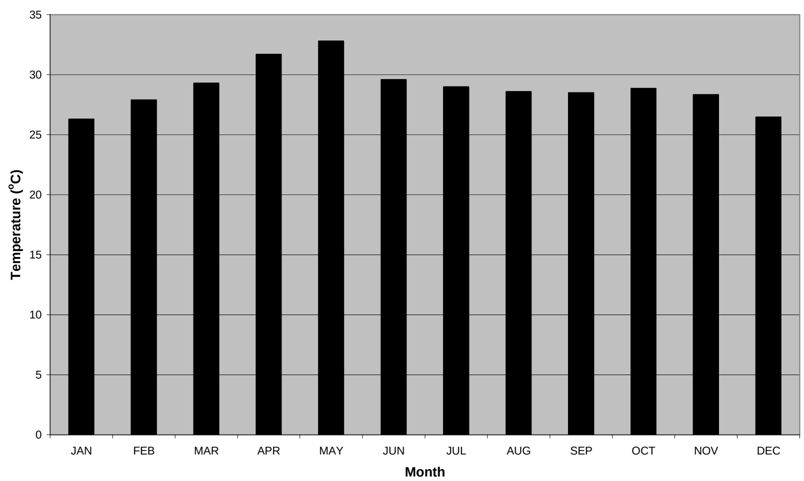


Figure 7.5. Average water temperature at dolphin sighting locations in the Kratie to Khone Falls river stretch from 2001-2005. Water temperature was highest in May and lowest in January.

7.3.2.3. Water clarity

At the location of dolphin sightings, water clarity (measured using a Secchi disk) varied from a minimum of 9.1 cm ± s.d. 2.40 (5.0-12.0, *n*=8) in August (middle of wet season), to a maximum of 122.0 cm ± s.d. 26.0 (70.0-200.0, *n*=96) in April (prior to the height of the dry season) (Figure 7.6). Once the rainy season began at the end of May/start of June, water turbidity increased significantly. No data on water clarity were recorded from the deep pools that dolphins did not inhabit, an acknowledged inadequacy of my data collection protocol.

7.3.3. Deep Pool Characteristics

Figure 7.2 illustrates habitat type during the dry season; dry season obstructions (islands, rocks, rapids), shallow sand substrate and deep water areas. Based on these substrates (which conform with my personal experience in the area), dolphins prefer to inhabit the deep water areas of the river. I attempted only minimal investigations into the characteristics of deep pools.

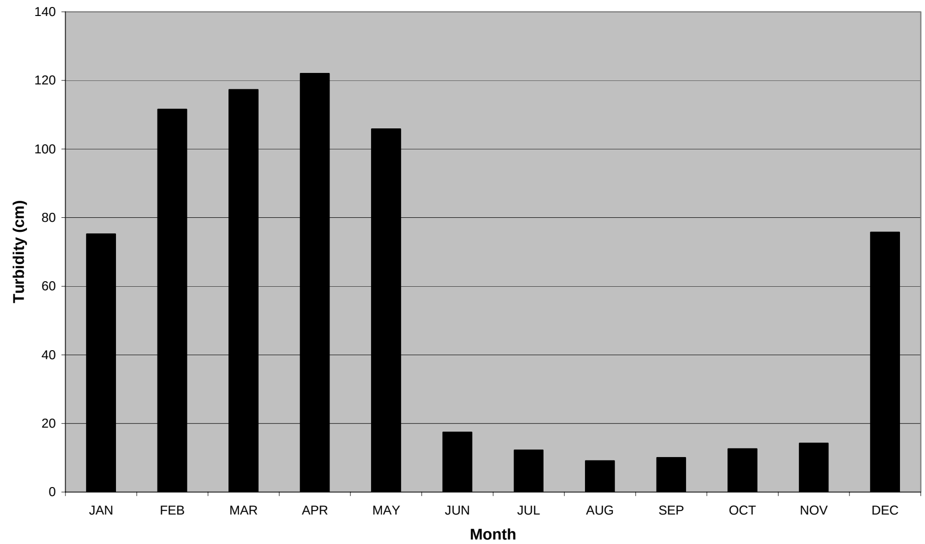


Figure 7.6. Average water clarity at the locations where dolphins were sighted in the Kratie to Khone Falls river stretch from 2001-2005. Water clarity was significantly reduced in August and greatest in April.

The maximum depth of a deep pool area in the Mekong River between 2001-2005 was 96 m (Dom Rei Pool, the deep water area between Khasak Makak/Sampan Pools and Koh Dombong Pool). Although we surveyed this area during all boat surveys (Chapter 6), no dolphins were sighted in this area (Figure 7.2).

Two types of deep water area were evident; areas with shallow sloping sides and medium depth (10-40m), and areas with very sharp sloping sides (similar to a channel) and greater depths (20-96m). My tentative conclusion is that dolphins prefer areas with shallow sloping sides and medium depth (e.g. Kampi, Koh Pidau, Tbong Klar and Chiteal Pools). Deep water areas with very sharp sloping sides included Chroy Banteay, Sampan, and Dom Rei Pools. Dolphins were only occasionally sighted in Chroy Banteay and Sampan Pools, and never sighted in Dom Rei Pool.

7.3.4. Ranging Patterns

Ninety-nine individual dolphins were photo-identified from 2001-2005, in all primary areas along the Kratie to Khone Falls river stretch (Figure 7.4) (Chapter 5). A total of 453 individual identifications were obtained during the dry season, and 103 identifications during the wet season.

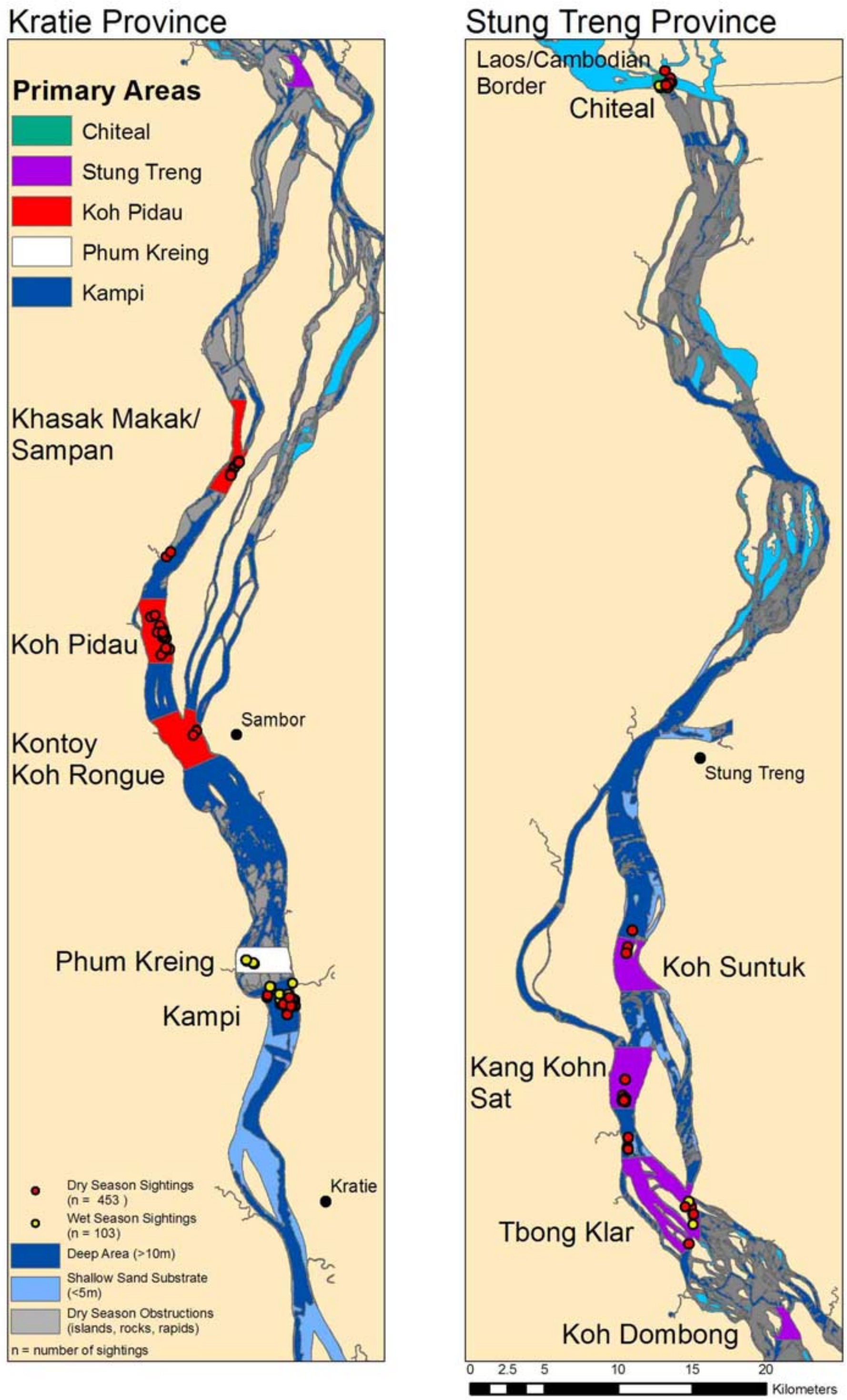


Figure 7.7. Locations of all individual Irrawaddy dolphins photo-identified in the Mekong River from 2001-2005. Most dolphins are represented more than once based on re-sightings. Sightings are separated into dry season (red dots) and wet season (yellow dots). Map created by Erin LaBrecque.

The number of days on which an individual was sighted varied from 1 to 29 times (Figure 7.8). The average number of sightings for each individual was 6 ± s.d. 5.1 (mode=1).

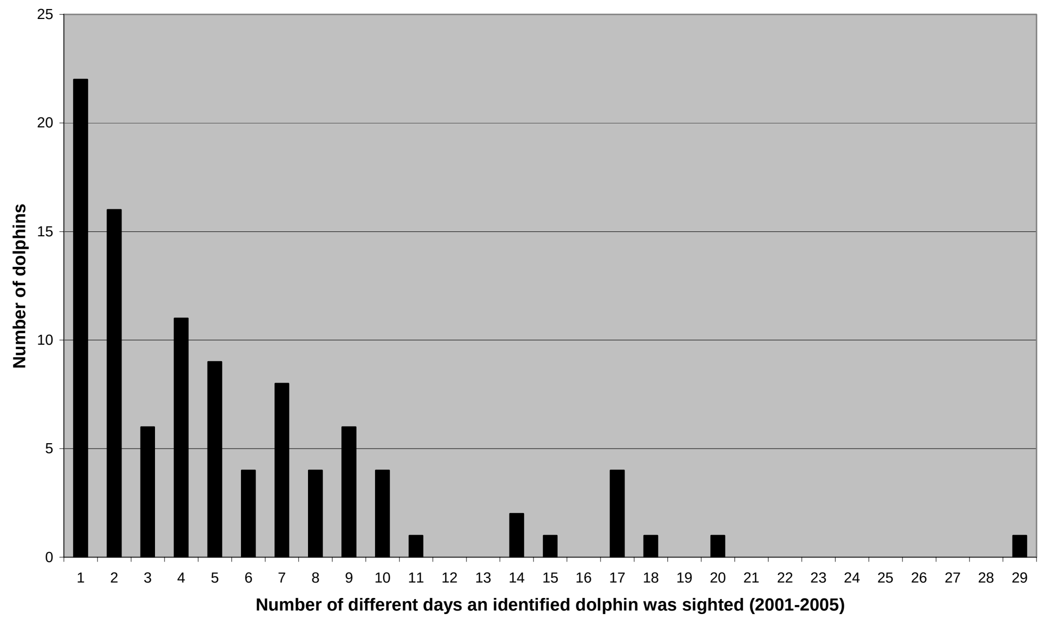


Figure 7.8. The number of different days an identified Irrawaddy dolphin was sighted in the Kratie to Khone Falls river stretch of the Mekong River, from 2001-2005

Figure 7.9 presents the sighting frequencies for the 15 individuals included in the ranging pattern analysis based on the three most frequently sighted dolphins from each of the five primary areas.

The average area used by these individuals in the dry season was 11.9 km^2 ± s.d. 15.41 km^2 (range=0.7-51.9 km^2); during the wet season, the area increases to 40.2 km^2 ± s.d. 37.28 km^2 (range=0.9-98.8 km^2).

The sample size was too small to compare ranging patterns between primary areas statistically. Based on an interpretation of the average ranging areas (shown in Figure 7.10), individuals from Stung Treng and Koh Pidau appear to range larger distances than individuals from Kampi. Phum Kreing and Chiteal during the dry season. This result likely reflects the relatively greater area of deep water habitat available in Stung Treng and Koh Pidau (Figure 7.2). Nonetheless, during the wet season, when water levels were high and habitat availability less restrictive, individuals from Kampi and Chiteal continued to exhibit minimal movements, suggesting that habitat may not be the primary factor restricting movements.

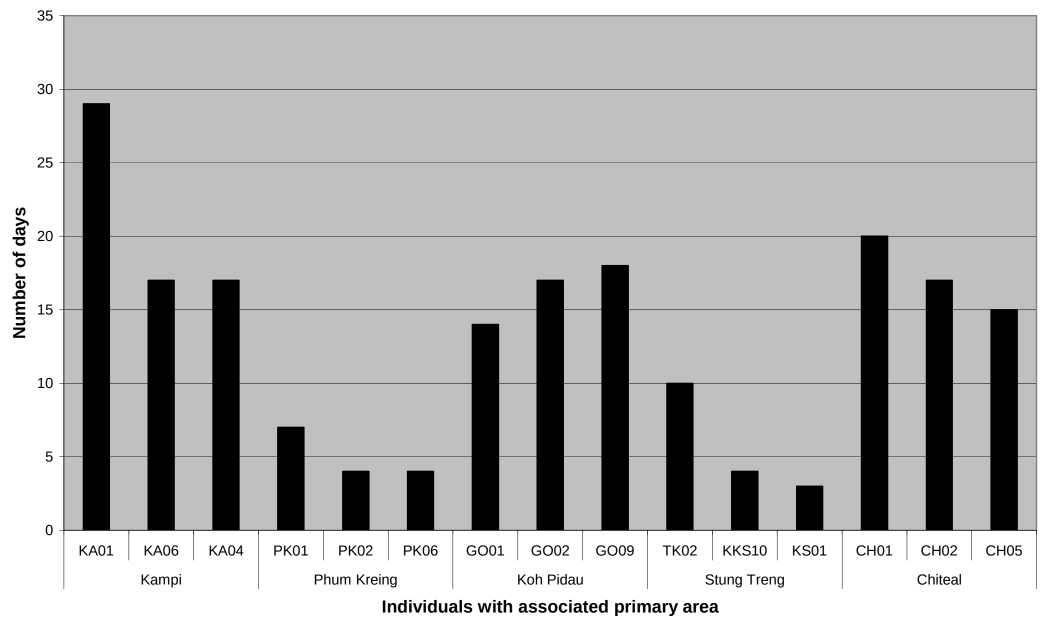


Figure 7.9. The total numbers of days each of the 15 individual dolphins that were included in the ranging pattern analyses were sighted in the Mekong River, from 2001-2005.

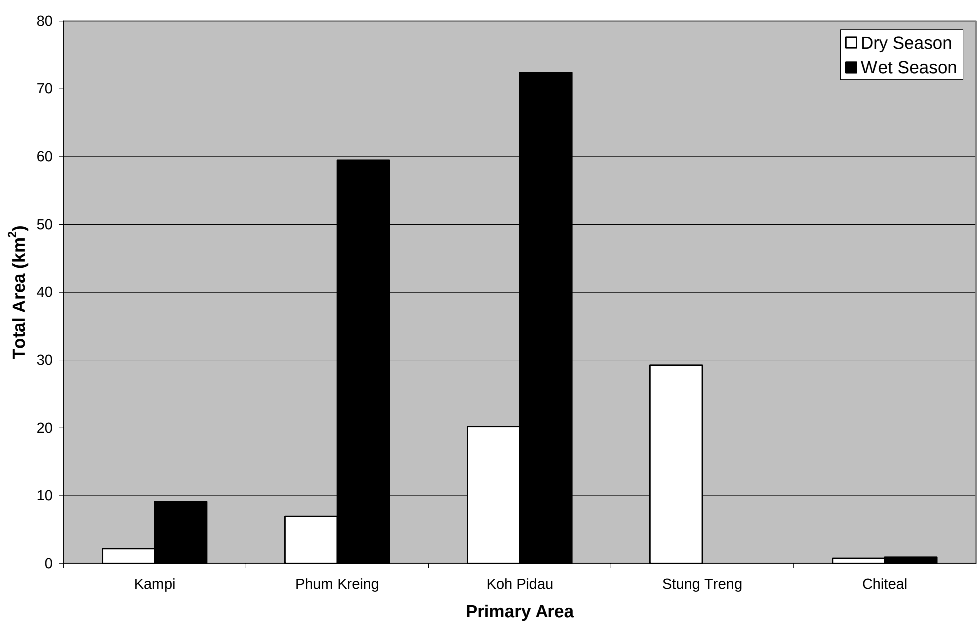


Figure 7.10. A comparison of the average area (total km^2) Irrawaddy dolphins ranged in the Kratie to Khone Falls river section, from 2001-2005. The 15 individual dolphins included in the analysis are grouped by primary area and separated into dry and wet seasons.

During the wet season, individuals from Koh Pidau area moved downstream to the Phum Kreing area, returning back to Koh Pidau the following dry season. Consequently, the wet season movements of the Koh Pidau individuals, and two of the Phum Kreing individuals (PK02, PK06), are relatively large, with a total average of 58.32–72.01 km^2 respectively.

Individuals from the Chiteal and Stung Treng primary areas were never observed to frequent other primary areas in the river throughout my study from 2001-2005. These individuals may therefore be isolated from each other, and from individuals in the Koh Pidau and Kampi primary areas (see Chapter 8). Figures 7.11-7.13 provide representative examples of the movements of individuals from Chiteal (CH01) and Stung Treng (KS01, and TK02). These movements were also representative of all other individuals from Chiteal and Stung Treng primary areas that were not formally included in the ranging pattern analysis.

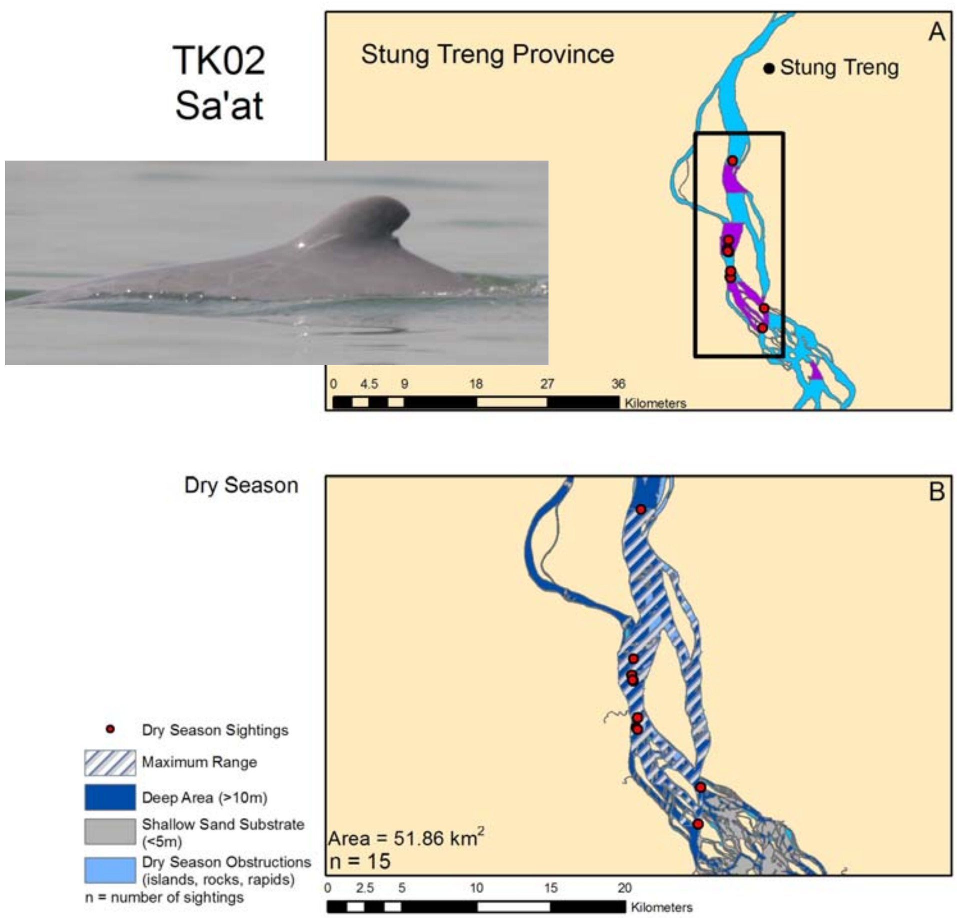


Figure 7.11. The ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, TK02: Sa'at, which was only observed to inhabit the Stung Treng primary area. Map A (top) illustrates all sighting locations of TK02 during my study. Map B (bottom) illustrates the dry season sighting locations (red dots). No sightings of TK02 were obtained during the wet season. Map created by Erin LaBrecque.

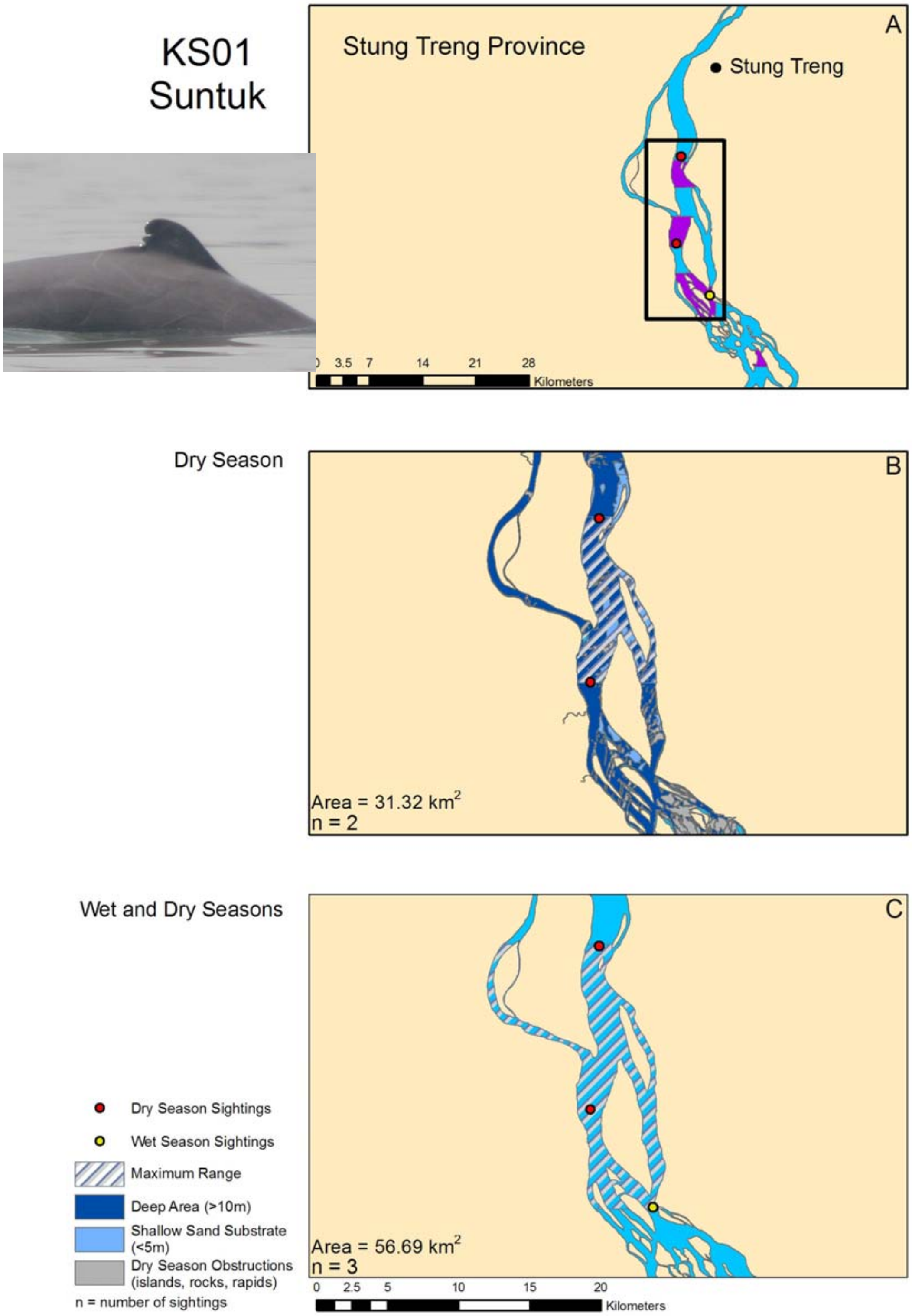


Figure 7.12. Ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, KS01: Suntuk, which was only observed to inhabit the Stung Treng primary area. Map A (top) illustrates all sighting locations of KS01 during my study. Map B (middle) illustrates the dry season sighting locations (red dots). Map C (bottom) illustrates both dry and wet season (yellow dots) sighting locations. Map created by Erin LaBrecque.

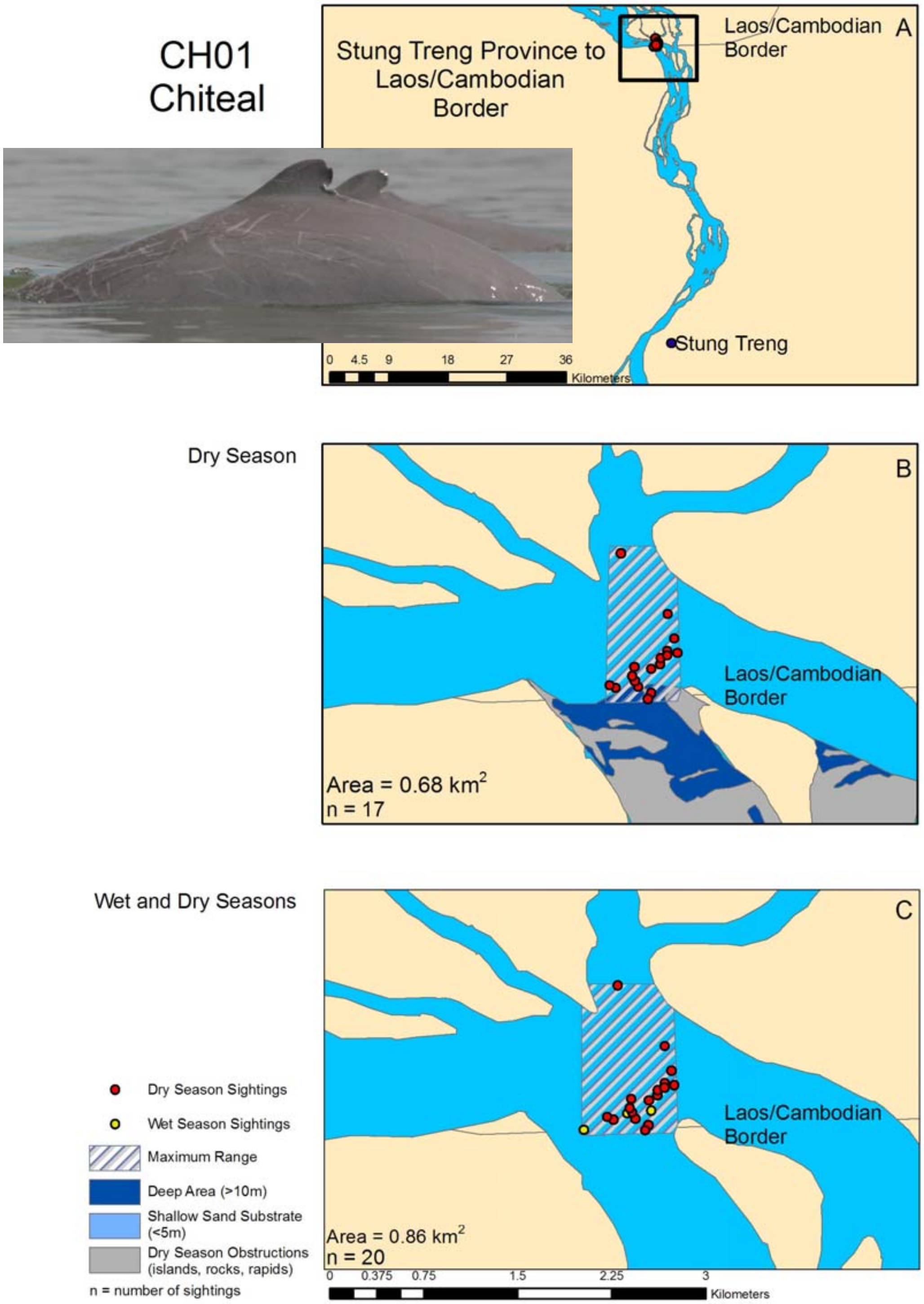


Figure 7.13. Ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, CH01: Chiteal, which was only observed to inhabit the Chiteal primary area. Map A (top) illustrates all sighting locations of CH01 during my study. Map B (middle) illustrates the dry season sighting locations (red dots). Map C (bottom) illustrates both dry and wet season (yellow dots) sighting locations. Map created by Erin LaBrecque.

The three identified individuals from kampi did not move to other primary areas during the dry season. However, during the wet season, all three individuals moved to Phum Kreing primary area. Figure 7.14 provides a representative example of the wet season movements of individuals from Kampi to Phum Kreing. This ranging pattern was also representative of al other Kampi individuals (n=31), that were not formally included in the ranging pattern analysis.

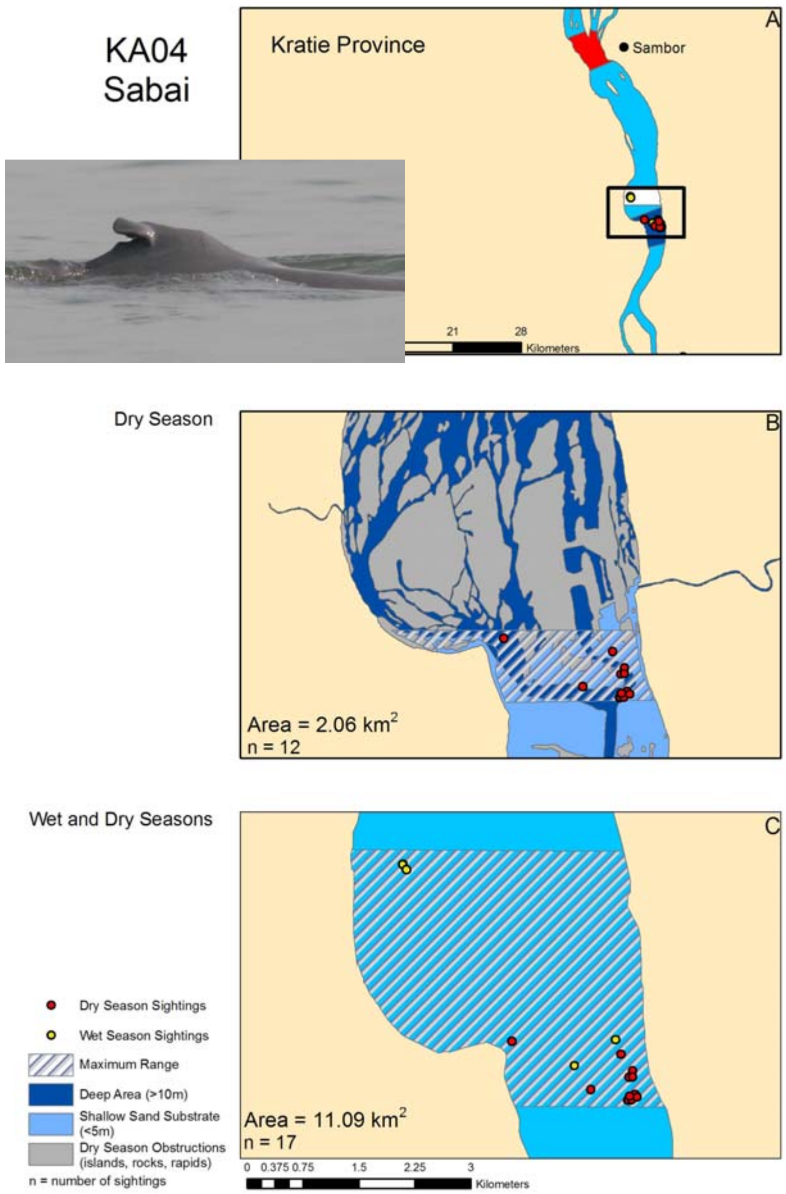


Figure 7.14. Ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, KA04: Sabai, which was only observed to inhabit the Kampi primary area. Map A (top) illustrates all sighting locations of KA04 during my study. Map B (middle) illustrates the dry season sighting locations (red dots). Map C (bottom) illustrates both dry and wet season (yellow dots) sighting locations. Map created by Erin LaBrecque.

All individuals from Kampi that were not included in the formal analyses of ranging patterns (*n*=31), except one (KA05: Rags), were recorded only in Kampi primary area during the dry season. KA05 was sighted at Koh Pidau primary area in the dry seasons of 2003 (March) and 2004 (May) (Figure 7.15), indicating that it possible for individuals to move between these areas during the dry season.

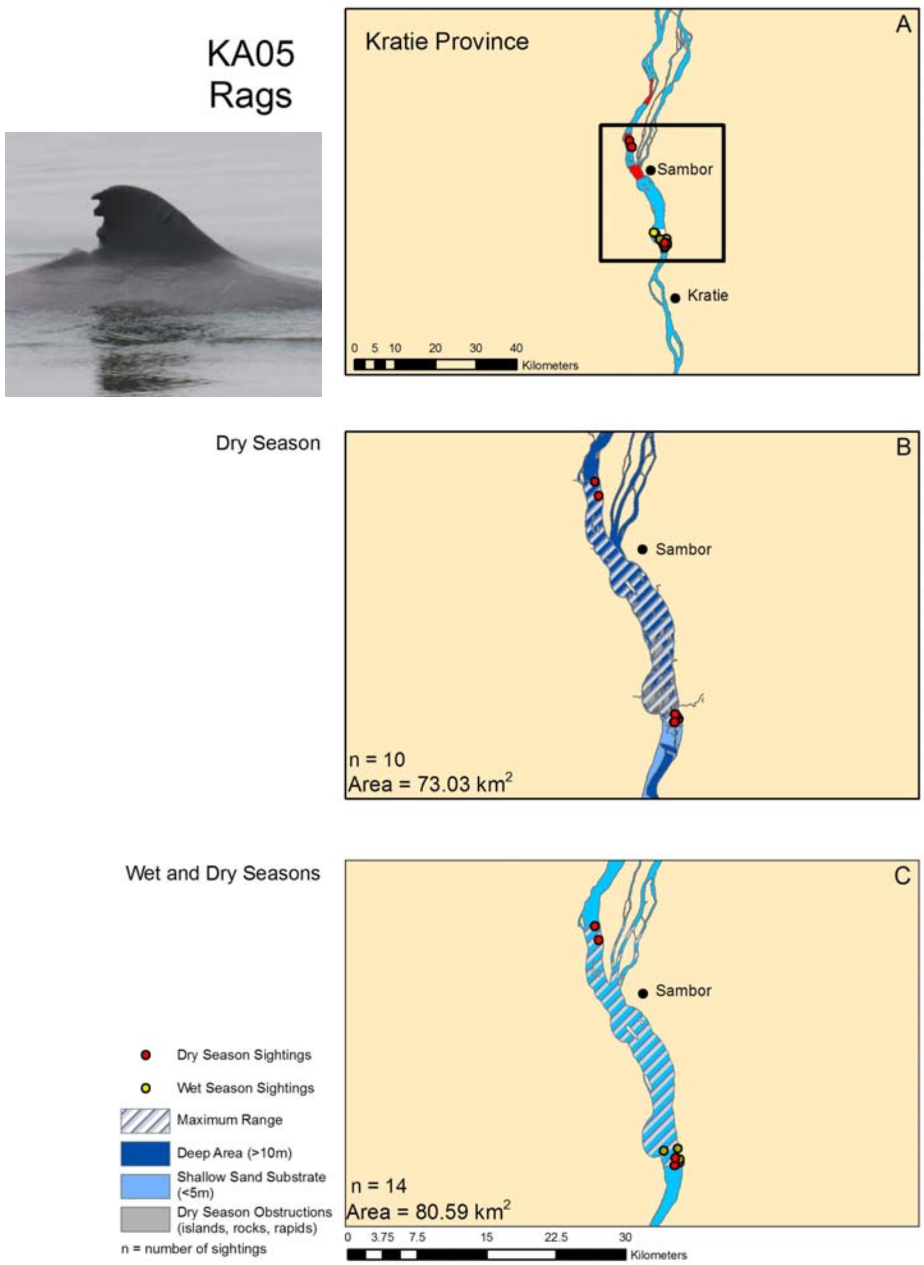


Figure 7.15. Ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, KA05: Rags, which was observed to inhabit both Kampi and Koh Pidau primary areas. Map A (top) illustrates all sighting locations of KA05 during my study. Map B (middle) illustrates the dry season sighting locations (red dots). Map C (bottom) illustrates both dry and wet season (yellow dots) sighting locations. Map created by Erin LaBrecque.

Individuals from Koh Pidau have not been observed to move to other primary areas during the dry season. This pattern was also characteristic of all other individuals not included in the formal analysis. During the wet season, however, all individuals (including those individuals not included in the formal analysis), moved downstream to the Phum Kreing primary area (as indicated by the yellow dots in Figure 7.16).

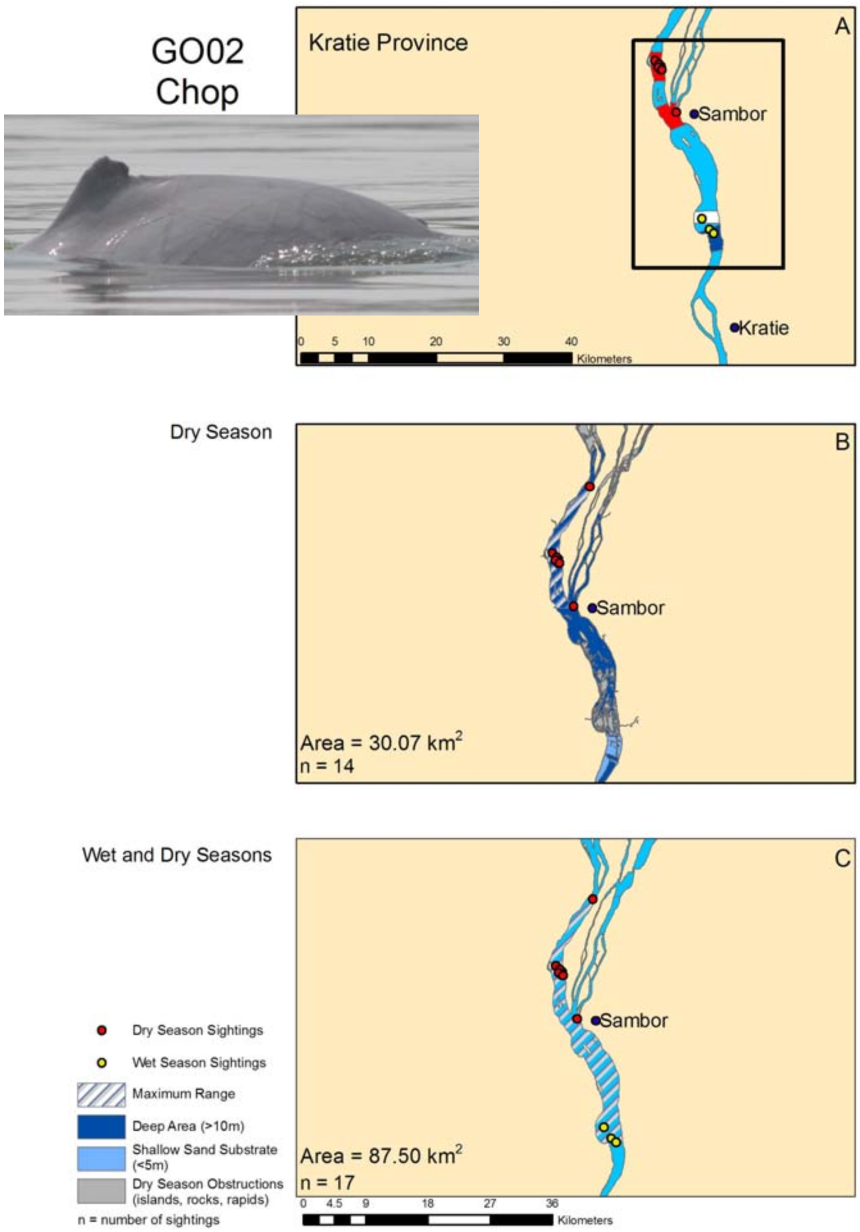


Figure 7.16. Ranging patterns of an identified Irrawaddy dolphin individual from the Mekong River, GO02: Chop, which was observed to inhabit only the Koh Pidau primary area. Map A (top) illustrates all sighting locations of GO02 during my study. Map B (middle) illustrates the dry season sighting locations (red dots). Map C (bottom) illustrates both dry and wet season (yellow dots) sighting locations. Map created by Erin LaBrecque.

7.4. DISCUSSION

7.4.1. Distribution and Habitat Preferences

I conducted dedicated boat surveys throughout the lower Mekong River (including Tonle Sap Lake). Dolphins were only sighted in the Kratie to Khone Falls river stretch. Chapter 4 provides information on historical dolphin distribution in the river based on previous scientific studies and interview reports. As discussed in Chapter 4, the dolphin population has declined significantly in range since at least the early 1970s. All evidence suggests that dolphins now primarily occur in the Kratie to Khone Falls river section. My dedicated boat surveys over five years confirm these reports and reaffirm the reliability of local knowledge regarding species ecology (discussed further in Chapter 4).

The limited published information available on habitat preferences of Asian freshwater dolphins suggest that freshwater dolphins prefer deep water areas of rivers (Anderson 1879, Beasley *et al.* 2002b, Kreb 2004) (discussed further in Chapter 2). My data confirm this pattern. Irrawaddy dolphins inhabiting the Mekong River also appear to prefer areas of the river between 10-45 m in depth. A lack of sightings in areas deeper than 46 m, suggest that dolphins do not favour these habitats. During the wet season, water levels increase laterally by as much as 20-30m. However, interestingly, the average depths of dolphin sighting locations remain similar during both dry and wet season. Dolphins therefore appear to move to areas within the river during the wet season, such as Phum Kreing, which are similar depths to the habitats used during the dry season.

Knowledge of the habitat preferences of endangered species significantly assists conservation. Species require adequate habitat and ecosystem functioning for their long-term persistence. If these requirements are known, positive steps can be taken to ensure essential components of the habitat are also conserved. As an example, the northern spotted owl (*Strix occidentalis caurina*) is a widely-publicised endangered species found in western North America (Taylor and Gerrodette 1993). As (Doak 1989) states

> *"there is concern for the fate of these owls because they require large tracts of old-growth conifer forest, the same forest that is most profitable to log (Doak 1989). Without these old growth forests, the owls are not able to survive and reproduce". pg 389.*

Preservation of these old forest tracts is now a high priority both for the persistence of the northern spotted owl, and also for conservation of other species inhabiting these areas (Chapter 2). It is clear from this preliminary study that Irrawaddy dolphins inhabiting the Mekong River prefer to use only relatively few deep pool habitats. A more detailed knowledge of the specific habitat preferences of freshwater Irrawaddy dolphins (e.g., bottom topography of pools, fish species present, environmental parameters), and preservation of these habitats would contribute significantly to their conservation and management.

7.4.2. Ranging Patterns

Irrawaddy dolphins inhabiting the Mekong River range over extremely small areas, with an average of 11.9 km^2 ± s.d. 15.41 km^2 (range=0.7-51.9 km^2) during the dry season and 40.2 km^2 ± s.d. 37.28 km^2 (range=0.9-98.8 km^2) during the wet season.

Kreb (2006) investigated ranging patterns of Irrawaddy dolphins inhabiting the Mahakam River based on focal follows of 58 dolphin groups. Average range was estimated to be 10 km long and 1.1 km^2 in area. Kreb did not present ranging pattern data based on photo-identification of individuals and acknowledged that focal follows are only possible for a short duration and therefore do not provide long-term movement data. However, initial indications are that individuals from the Mahakam Irrawaddy dolphin population exhibit similarly high site fidelity, to the Mekong population. No other ranging pattern studies have been published for an Asian freshwater dolphin population. Some movement studies have been conducted on freeze-branded boto from the 225 km^2 Mamiraua varzea floodplain lake system of Brazil, where it was estimated that 90% of botos within the lake were permanent residents (Martin and da Silva 2004). However, no estimate of individual range size was calculated.

These data confirm that conservation of the primary dolphin areas in the Mekong River should be a high priority. Preservation of these primary areas will significantly enhance the prospects of the survival of dolphins in the river, as well as benefit other flora and fauna and local communities that rely on the river for their livelihood.

7.5. CONCLUSIONS

- Distribution and habitat use of Irrawaddy dolphins inhabiting the Mekong River were investigated using boat surveys and photo-identification data from 2001 to 2005.
- Dolphins were only sighted in the Kratie to Khone Falls river stretch
- Individuals prefer five primary areas within the Kratie to Khone Falls river stretch: Kampi, Phum Kreing (used only during the wet season), Koh Pidau, Stung Treng and Chiteal.
- The average water depth in which dolphins were encountered was 11.63 m (range=0.44-45.94 m, n=394) during the dry season, and 10.28 m (range=0.53-38.75 m, n=86), during the wet season. Dolphins were not sighted in water depths over 46 m.
- Individuals exhibit extremely high site fidelity. The average area used by individuals in the dry season is 11.9 km^2 ± s.d. 15.41 km^2 (range=0.7-51.9 km^2). The average area used by individuals during the wet season, increases to 40.2 km^2 ± s.d. 37.28 km^2 (range=0.9-98.8 km^2).
- As a primary management focus, preservation of natural habitat within and surrounding the Kratie to Khone Falls river section is essential for conservation of the Irrawaddy dolphin population inhabiting the Mekong River.

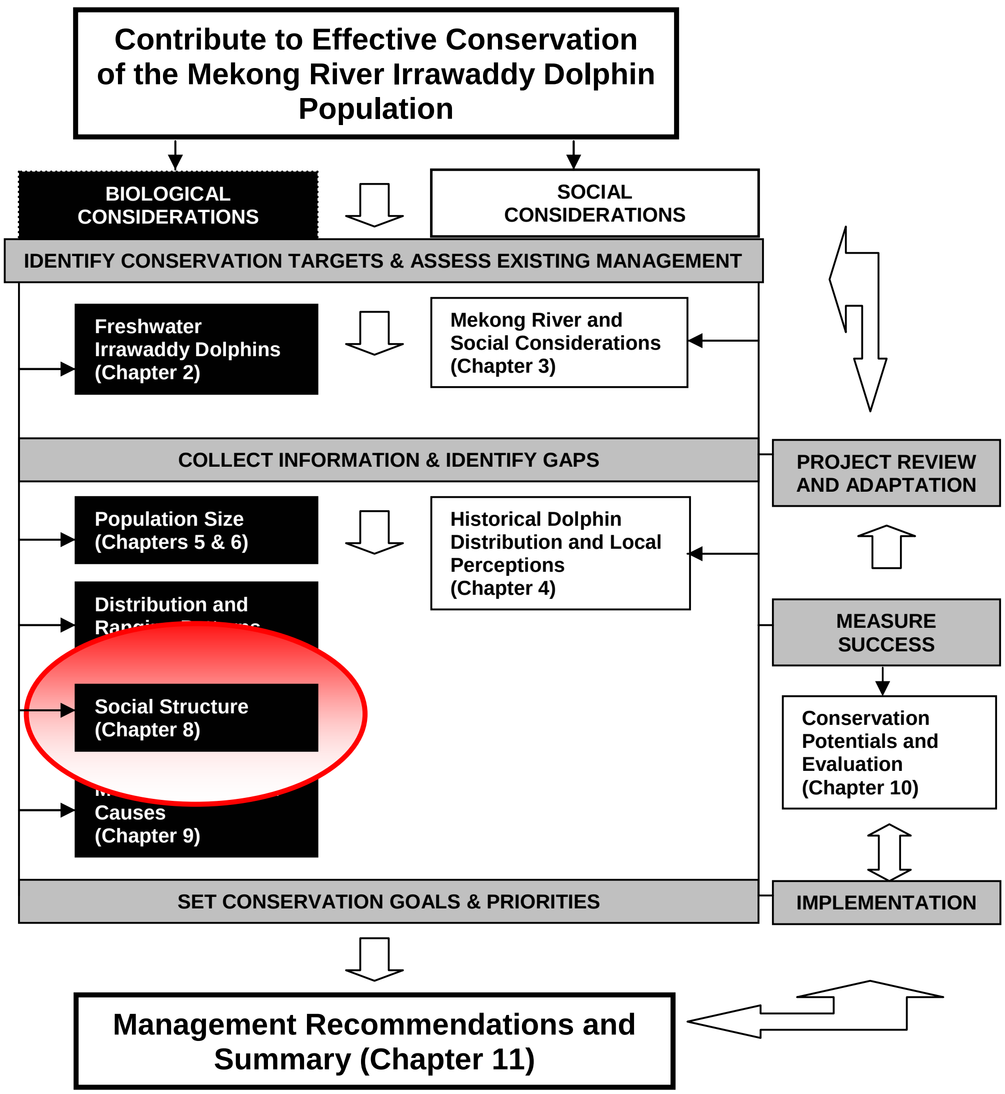
8. SCHOOL DYNAMICS AND SOCIAL STRUCTURE OF IRRAWADDY DOLPHINS INHABITING THE MEKONG RIVER

An understanding of a population's social structure has important implications for understanding the potential success and/or failure of a management strategy. In this chapter, I investigate the school dynamics and association patterns of the Irrawaddy dolphin population inhabiting the Mekong River. I assess the temporal variation in their association patterns and apply several mathematical models to determine the type of association that best describes their social structure. I compare the results of my study with other studies of the genus *Orcaella* and discuss the implications of these findings towards management of this *Critically Endangered* dolphin population.

A group of Irrawaddy dolphins from Kampi Pool, Kratie Province

8. SCHOOL DYNAMICS AND SOCIAL STRUCTURE OF IRRAWADDY DOLPHINS INHABITING THE MEKONG RIVER

Chapter 8 investigates a biological consideration in the context of the '*collecting information and identifying gaps*' section of my conceptual framework. The aim of Chapter 8 is to provide baseline data on the school dynamics and social structure of Irrawaddy dolphins inhabiting the Mekong River (thesis objective 4c: Chapter 1).



8.1. INTRODUCTION

Social structure is a key determinant of the population biology of a species. Social structure influences individual and population fitness, gene flow, spatial pattern and scale, and the effects of predation or exploitation by humans (Wilson 1975). Social structure has also been related through evolution to the cognitive and communicative abilities of animals (Byrne and Whiten 1988). Nearby conspecifics are vital elements of the environment. They compete for resources, mate with or take care of each other, cooperate with each other to obtain resources, or defend resources either against conspecifics or themselves against predators (Whitehead 1997). Thus, an understanding of social structure is an important element in the management and conservation of a species (Sutherland 1998).

In social mammals, the patterns of interactions between individuals form the relationships that underpin observed social structure (Hinde 1976, Whitehead 1997; 1999b, Whitehead and Dufault 1999). Hinde's (1976) classic studies of animal social structure based on observations of captive primates, provide a conceptual framework for the analysis of animal societies from an ethological perspective and can be applied to cryptic species, such as aquatic mammals. The fundamental elements for the examination of social structure are behavioural interactions between a dyad (two interacting individuals). In studies of cryptic or difficult-to-observe species, observations of interactions between individuals are often infrequent, or impossible to observe. Therefore, ethologists studying social organisation of such species assume the 'gambit of the group' (Whitehead and Dufault 1999): *i.e.*, they assume that animals which are clustered (usually spatially) are interacting with one another and then use membership of the same group to define association. These patterns of associations define relationships, which in turn determine social structure (Whitehead and Dufault 1999).

Interspecific differences and similarities in animal social systems reportedly result from:

1. ecological pressures, such as predation and prey distribution (Wrangham 1986, Wrangham and Rubenstein 1986);
2. social factors, such as aggressive and mating behaviour (Trivers 1972, Connor *et al.* 2000a); and
3. phylogenetic history (evolutionary relationships) (Struhsaker 1969, Parra 2005).

Recent studies have also illustrated significant intraspecific differences in social structure in cetaceans. For example, resident fish-eating killer whales live in stable pods. In comparison, although mammal-eating killer whales retain strong, long-term associations, these associations are only with few individuals and dispersal of both sexes from their natal pod commonly occurs

(Baird and Whitehead 2000). Some populations of bottlenose dolphins (*Tursiops truncatus*) form resident and socially-stable populations in sheltered and seasonally stable environments, such as Sarasota Bay, western Florida (Wells *et al.* 1987, Wells 1991; 2003) and isolated regions, such as Doubtful Sound, New Zealand (Lusseau *et al.* 2003). However, such stable social structures contrast with the species' in other areas, where they show weak levels of social stability and fission-fusion societies, although the degree of population isolation varies, e.g. southern California (Defran and Weller 1999), Galveston Bay, Texas (Brager *et al.* 1994), and Shark Bay, Australia (Connor *et al.* 2000b). Spinner dolphins (*Stenella longirostris*) exhibit fluid, fission-fusion societies in open-water habitats, such as off the main Hawaiian Archipelago (Norris and Dohl 1980, Wursig *et al.* 1994), but long-term group fidelity and social stability in populations from isolated atolls, such as Midway Atoll (the second-most atoll in the northwest Hawaiian Islands) (Karczmarski *et al.* 2005).

Karczmarski *et al.* (2005) propose that for small and isolated communities, the fission-fusion social structure (characteristic of various delphinid species) loses much of its fluidity, in favour of a considerably more stable society with long-term group fidelity and stable bisexual bonding[14]. Karczmarski *et al.* (2005) provide an insightful comparison of this social structure phenomenon between spinner dolphins and primate species, such as chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) (Boesch 1996, Boesch *et al.* 2002). Karczmarski *et al*. (2005) hypothesise that with: (1) deepwater food resources in close proximity, and (2) other sheltered atolls far away, it is energetically more beneficial for Hawaiian spinner dolphins from isolated atolls to remain 'at home' than to travel to other atolls. This situation results in stability of social structure, instead of variability.

I know of only one study that has investigated the social structure of an Asian river dolphin population. Kreb (2004) investigated the social structure of Irrawaddy dolphins inhabiting the Mahakam River of East Kalimantan. As explained in Chapter 2, the total population size of this subpopulation is thought to number only 48-55 individuals (Kreb 2004, Chapter 2). This population is reportedly closed to immigration and emigration to, and/or from coastal Irrawaddy dolphin populations (Kreb 2000). When investigating social structure, Kreb (2004) reported that individual dolphins showed clear preferences for association with certain individuals and had long-term preferred companions. Therefore, the hypothesis that small population size and restricted distribution favour a stable society appears to apply in this situation. The social structure of a population of Australian snubfin dolphins (the closest relative of Irrawaddy

[14] Both males and females associate together in the same group and form preferential companionships.

dolphins) found in Cleveland Bay, Queensland, Australia, is also characterised by strong long-term associations (Parra 2005).

Based on boat survey and photo-identification data (Chapters 5 and 6), the Mekong dolphin population is fragmented into four ‘communities’, or regional assemblages, or societies of animals that share ranges and interact socially, but do not represent closed reproductive units (Wells and Scott 1990, Karczmarski *et al.* 2005). These communities are separated by large distances of 30 km (Kampi and Koh Pidau), 50 km (Koh Pidau and Stung Treng) and 80 km (Stung Treng and Chiteal) (see Chapter 7).

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In this study, I investigate school dynamics and association patterns of Irrawaddy dolphins that inhabit the Mekong River. I also assess the temporal variation in their association patterns and apply various mathematical models to determine the type of association that best describes their social structure. I compare these results with other studies of the social structure of populations of the genus *Orcaella* and discuss the implications of these findings for the conservation and management of the *Critically Endangered* Irrawaddy dolphin population inhabiting the Mekong River.

8.2. MATERIALS AND METHODS

8.2.1. Photo-Identification of Individuals

A primary requirement for studies of social structure is that individuals are identifiable (Whitehead 1997). Individual Irrawaddy dolphins were photo-identified from the Mekong River during 2001-2005, as described in detail in Chapter 6. As explained in that chapter, boat survey procedures from 2002 onwards ensured that the observer effect was neglible, an important consideration for social structure studies, as animals may form larger or smaller groups, or increase/decrease their rates of associations or disassociations when disturbed (Foster and Rahs 1983, Kinnaird and O'Brien 1996).

8.2.2. Group Size

As discussed in Chapters 5 and 6, a dolphin ‘group’ was defined as a tight aggregation with one or more dolphins in close proximity (0-500 m), in apparent association and sighted independently of any other groups, moving in the same direction and often, but not always, engaged in the same activity (Mann 1999). Restricting the definition of a group to animals which are tightly clustered omits some interactions. In contrast, a group definition based on 'hydrological boundaries' (*sensu* Smith and Reeves 2000), would probably include non-interacting dyads (Whitehead 1997).

Following Smith and Reeves (2000), group size was estimated, based on 'low', 'high' and 'best' estimates of the number of animals (see Chapter 6: '*6.3.6 Sighting Data Recorded*'). All discussions in my thesis regarding group size relate to 'all' groups sighted throughout my study period and are not restricted to photo-identified groups (unless otherwise stated).

It was not possible to determine the sex of the majority of individuals in the population. Only three females were confirmed, based on their constant association with a newborn calf (see Chapter 6 for an explanation of age-class definitions). Association rates between sex classes are therefore not explored further.

8.2.3. Association Analyses

The use of photo-identification techniques implies that individuals were considered to be associated if they were photographed within the same group during an encounter (Karczmarski *et al.* 2005). There were no occasions during this study when in one day, an animal was resighted and photographed in two or more different groups.

Because of Irrawaddy dolphins' shy, erratic and inconspicuous surfacing behaviour and resultant difficulty in obtaining good quality photographs, not all individuals in any one group were photo-identified (Figure 8.1). To minimise this bias, only groups with ≥ 50% of individuals identified were included in the association analyses (Parra 2005). Additionally, to provide a balance between the representativeness of the data (including the maximum number of individuals) and its reliability (including individuals with maximum sighting frequencies), association analyses were limited to individuals identified on ≥ 4 days throughout the sample period (Brager *et al.* 1994, Chilvers and Corkeron 2002, Parra 2005).

As detailed in Chapters 5 and 6, the Irrawaddy dolphin population inhabiting the Mekong River comprised an estimated total population of 127-169 individuals (based on both line-transect and mark-recapture analyses). The proportion of individuals identifiable in the Mekong dolphin population was estimated to be 83% (see Chapter 6).

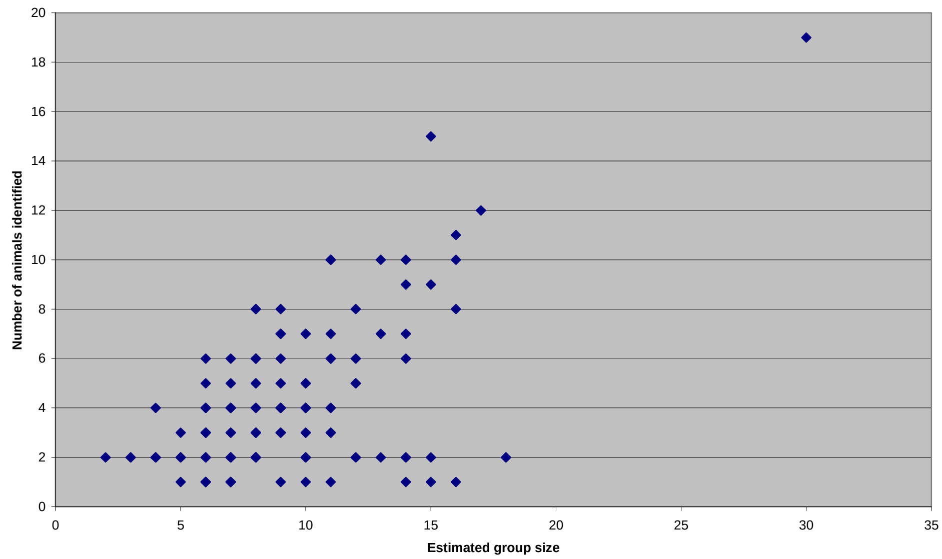


Figure 8.1. A scatterplot showing the relationship between Irrawaddy dolphin group size estimates in the Mekong River from 2001-2005 and the number of individuals photographically identified within each group.

Association analyses were conducted in MATLAB 6.5 using SOCPROG 2.2. (Whitehead 1999a). Two types of analysis were undertaken:

(1) the production, analysis and display of an association matrix; and

(2) an examination of temporal trends in association through the computation and display of lagged association rates (Whitehead 1995, Whitehead 1999b, Baird and Whitehead 2000).

Analyses were primarily conducted on the dry season data (when dolphins were restricted in distribution to particular deep water pools), as a result of the extensive sampling effort during this season (see Chapters 5 and 6).

Data from the wet season were minimal and therefore did not undergo a comprehensive analysis. However, preliminary wet season analyses were conducted using the Half-Weight Index (HWI: Whitehead 1997) on groups where ≥ 50% individuals were identified. As a result of small sample size, only individuals sighted on ≥ 2 days (range of 1-5 days) were included in the analysis. Wet season association results are reported, nevertheless, these should be viewed with caution as a result of the limited effort, and small number of identifications.

The association matrix is a measure of the relationship between each pair of individuals (Whitehead 1997). High values indicate that the individuals commonly associate and low values indicate that they rarely associate. To examine the proportion of time each dyad spent associating, a HWI of association was used. The HWI was preferable to the Simple Index (SI), since not all associates were identified (Cairns and Schwager 1987). The HWI was used to produce a symmetric association matrix (not shown) based on the following formulas:

Equation 8.1.

$$HWI = \frac{x}{x + \frac{1}{2}(yA + yB)}$$

where x is the number of schools that included both dolphin A and B, yA is the number of schools that included dolphin A, but not dolphin B, and yB is the number of schools that included dolphin B but not dolphin A.

Additional analyses using the Simple Index (SI) were conducted (Ginsberg and Young 1992), to enable comparisons with other studies that used this index (such as Hector's dolphins in New Zealand (Slooten *et al.* 1993) and killer whales (Baird and Whitehead 2000). The equation for the simple index is:

Equation 8.2.

$$SI = \frac{x}{x + yAB + yA + yB}$$

where x is the number of schools that included both dolphin A and B, yAB is the number of observation periods during which A and B are both observed in separate groups, yA is the number of schools that included dolphin A, but not dolphin B, and yB is the number of schools that included dolphin B but not dolphin A.

The association index results in values ranging from 0 (two dolphins never seen together) to 1 (two dolphins never seen apart). The sampling period option was selected as 'group in a sampling period'. The individuals were considered associated (association=1) in a sampling period of 2 days, if they were found in the same group. Individuals were considered not associated (association = 0), if they were never seen in the same group during the two day sampling period (Whitehead 2005). For each individual, the association output displayed:

1. the mean association index with all other individuals (excluding the individual with itself);
2. the sum of all associations including an individual with itself (which is similar but not identical to the 'typical group size' see Jarman (1974)); and
3. the maximum association (excluding individuals with themselves) (Jarman 1974, Whitehead 1999a).

The association matrix was displayed graphically in three ways. The first was an average-linkage cluster analysis that showed the average level of association between hierarchically formed clusters. Individuals were arranged on the *y* axis with the strength of associations presented on the *x* axis. The resulting cophenetic correlation coefficient (which ranges from 0 to 1) indicated the match of the dendogram to the matrix of association indices (Bridge 1993). The second was a principal component analysis, where each individual was plotted, so that the distance between individuals was proportional to one minus the square root of their association (strongly associated individuals were plotted together and weakly associated ones were plotted apart) (Digby and Kempton 1987). The third method was a sociogram, where the points representing the individuals were arranged around a circle and the thickness of lines between the points indicates the strength of the relationship (Whitehead 2005). Sociograms can be difficult to interpret with many identifications. Therefore, only individuals sighted on $\geq$6 days (n=21) were included in the dry season analyses and $\geq$2 days (n=18) in the wet season analysis, to facilitate visual interpretation of the sociogram.

To test whether the patterns of associations between individuals were significantly different from random (preferred/avoided associations), the observed association matrix was permuted 15,000 times following Bejder *et al*. (1998) as adapted from Manly (1995), with further adaptations by Whitehead (1999b). The null hypothesis was that individuals associate with the same probability with all other individuals (or among some set of them), given their availability (Whitehead 2005). As successive association matrices are not independent, the number of required permutations was determined by increasing the number of permutations until the *p* value stabilised, as too few permutations would have produced an incorrect *p* value (Bejder *et al.* 1998, Karczmarski *et al.* 2005).

8.2.4. Temporal Patterns of Analyses

Temporal trends in association were examined by computing and displaying lagged association rates (Whitehead 1995, Whitehead and Dufault 1998). The null association rate is the expected value of the lagged association rate if there is no preferred association (*i.e*., if the probability that A and B associate is independent of whether they have associated before) (Whitehead 1999a). Therefore, if the lagged association rate equals the null association rate then this indicates no preferred associations over the time lags examined. Because it was logistically difficult to photograph all individuals in a group in my study, the lagged and null association rates were standardised by dividing the lagged association rate by the number of associates recorded on each occasion (Whitehead 1995).

In order to obtain estimates of precision for the lagged association rates, I used a jackknife procedure. The analysis was run several times omitting one, or more, sampling periods each time (Sokal and Rohlf 1981, Efron and Tibshirani 1986, Whitehead 1999a). Groups were jackknifed in each sampling period, which resulted in five equally spaced jackknife error bars (± estimated standard error), giving the approximate precision of the plots and parameter estimates. However, these estimates of precision were approximate because the procedure is conservative and tends to underestimate precision (Efron and Tibshirani 1986); and assumes independence of jackknife groups, which may not be strictly true (Whitehead 1999a).

The temporal association patterns were then compared with mathematical models representing different social organisations, as proposed by Whitehead (1995):

1. *constant companions*: associations that stay together permanently over time;
2. *casual acquaintances*: associated individuals disassociate for some time and then reassociate; and
3. *rapid disassociations*: associates that disassociate very quickly within one time period (Whitehead 1999a).

The model that minimised either the adjusted Akaike Information Criterion (AIC), or quasi Akaike Information Criterion (QAIC) for small-sample bias was chosen as the best fit model (Burnham and Anderson 1998). Both the AIC and QAIC act as measures of model fit and complexity. The lower the value of the suggested parameter, the better the model is supported by the data. The difference between the QAIC of selected model and other models, gives an indication of how well the data support the less favoured model (Burnham and Anderson 2002). Measure of fit changes range between 0-2 (substantial support for the model), 4-7 (considerably less support), and >10 (essentially no support) (Whitehead 1999a).

8.3. RESULTS

8.3.1. Group Size

From 2001-2005, I encountered a total of 512 dolphin groups during boat surveys. No dolphin groups were sighted south of Kratie Township. The average group size during the dry season was 6.8 dolphins ± s.e. 0.20 (range 1-18, mode=6, median=6, *n*=405). Average group size during the wet season was 5.7 dolphins ± s.e. 0.41 (range=1-34, mode=3, median=5, *n*=107).

Seasonal group sizes were significantly different (T-test, P>0.001), with slightly higher group sizes during the dry season. A plot of group size versus the percent of total encounters showed that few single individuals, or group sizes larger than eight individuals, were sighted during the dry season. However, proportionally more single individuals were sighted during the wet season than during the dry season (chi-square = 9.43, P≤0.05: Figure 8.2)[15].

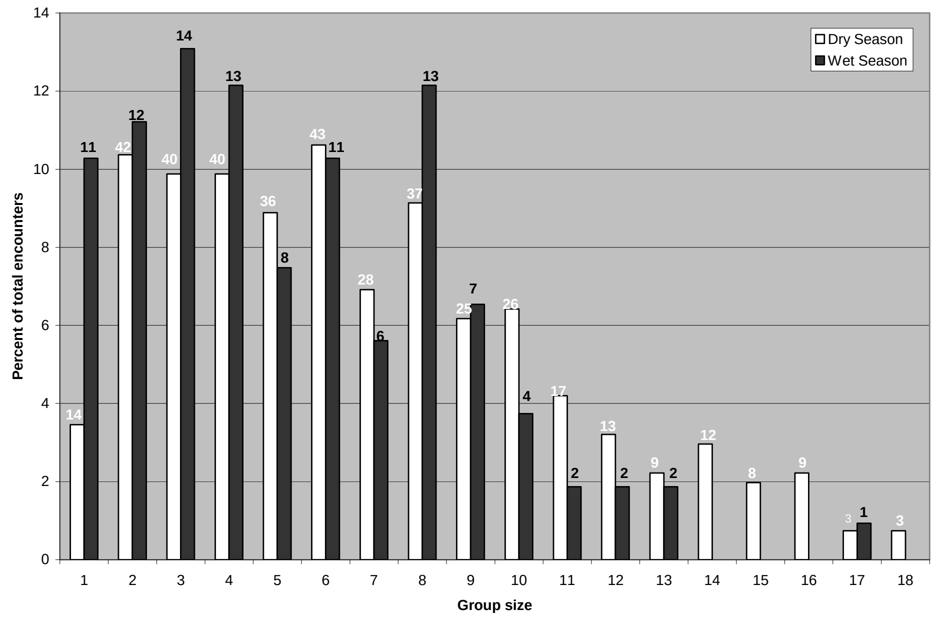


Figure 8.2. Comparisons of Irrawaddy dolphin group size in relation to the percent of total encounters during the dry and wet seasons in the Mekong River. In addition, a group of 34 individuals were sighted on 30 July 2004 at Phum Kreing critical area. This group was excluded from this figure, as it was a significant outlier. The numbers above each bar represent the number of groups encountered.

Group sizes throughout the study period were compared between the five primary areas: Phum Kreing (used only during the wet season) and Kampi, Koh Pidau, Stung Treng and Chiteal (see Chapter 7; Table 8.1).

[15] On 30 July 2004 (wet season), I sighted one large aggregation of 34 individuals at Phum Kreing primary area. These individuals consisted of three to four groups that occasionally interacted but were generally milling and feeding in the area. No other groups and/aggregations larger than 18 individuals were sighted during the study period.

Table 8.1. Irrawaddy dolphin group size in the five primary areas in the Mekong River during the dry and wet seasons.

Critical Area	Dry Season	Wet Season
Kampi	7.7 ± s.e. 0.43 (1-18, *n*=107)	6.3 ± s.e. 0.63 (1-16, *n*=26)
Phum Kreing	--[1]	6.8 ± s.e. 1.18 (1-34, *n*=28)
Koh Pidau	7.3 ± s.e. 0.32 (1-18, *n*=155)	3.6 ± s.e. 0.63 (1-10, *n*=19)
Stung Treng	5.8 ± s.e. 0.42 (1-17, *n*=93)	5.5 ± s.e. 0.74 (1-12, *n*=22)
Chiteal	5.6 ± s.e. 0.28 (1-9, *n*=52)	5.2 ± s.e. 0.82 (1-9, *n*=12)

1. Dolphins do not occur in the Phum Kreing primary area during the dry season.

There were statistically significant group size differences between the four primary areas (excluding Phum Kreing) during the dry season (One-way ANOVA df=3, P<0.001: Table 8.2). However, there were no statistically significant differences in group size between the five primary areas during the wet season (One-way ANOVA, df=4, P≥0.05). Tukey post hoc comparison test identified statistically significant differences between group sizes in all primary areas, except between Kampi/Koh Pidau and Stung Treng/Chiteal (Table 8.2).

Table 8.2. An examination of differences in Irrawaddy dolphin group size in the Mekong River between primary areas during the dry season. Highly significant differences in group size between primary areas are indicated by two stars (**), significant differences are indicated by one star (*) and areas showing no significant differences are indicated by 'ns'.

	Kampi	**Koh Pidau**	**Stung Treng**	**Chiteal**
Kampi	---------------	ns	P<0.001 **	P<0.05 *
Koh Pidau	ns	-------------	P<0.05 *	P<0.05 *
Stung Treng	P<0.001 **	P<0.05 *	--------------	ns
Chiteal	P<0.05 *	P<0.05 *	ns	------------

8.3.2. Dry Season Association Patterns

Between 2002-2005, I sighted and successfully photographed 131 dolphin groups (2001 data were excluded from analyses, as a result of only two individuals being photo-identified). As explained in Chapter 5, photo-quality and the proportion of individuals identified from each group increased through each survey year, as a result of increased quality of photographic equipment; and more time spent photographing dolphin groups (Figure 8.3: Chapter 6). As a result of the low photographic quality in 2002, these data were also excluded from further analyses. Thus, only photographic data from 2003-2005 were used to estimate Irrawaddy dolphin association patterns in the Mekong River.

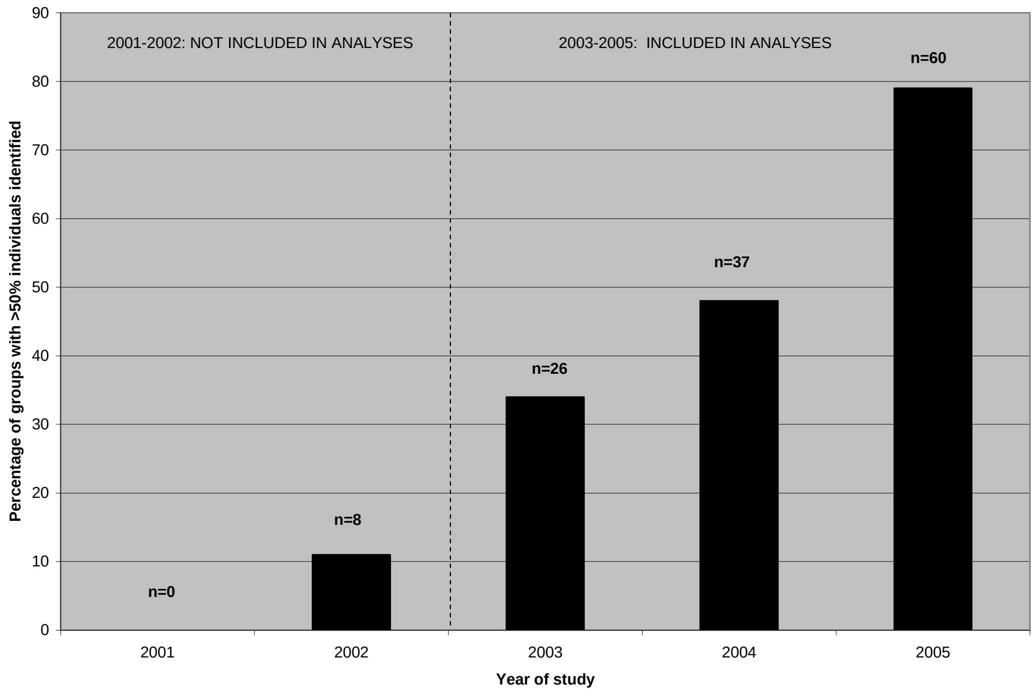


Figure 8.3. The percentage of Irrawaddy dolphin groups sighted in the Mekong river between 2001-2005, with ≥50% of individuals identified in the group. Data from 2001-2002 were excluded from the social structure analysis because of the minimal number of individuals identified (Chapter 5).

Using the 2003-2005 dry season data, I photo-identified a total of 51 individuals over 34 sampling periods (two-day sampling periods). Based on the pattern of the cumulative number of photographically identified individuals included in the association analysis (discovery curve) (Figure 8.4), most individuals in the population were identified, as shown from the discovery curve nearing a plateau in individuals identified (apart from Stung Treng primary area: see Chapter 5).

Accounting for the difficulty in photographing dolphins from the Stung Treng primary area, the nearing of a photo-identification plateau (and all new resights in 2005 being from the Stung Treng area) represents a population apparently closed to immigration and emigration; an assumption also supported by a lack of dolphin reports and sightings south of Kratie Township to the Vietnamese Delta (including Tonle Sap Lake), despite extensive dedicated interview and boat surveys (Chapters 4 and 6 respectively).

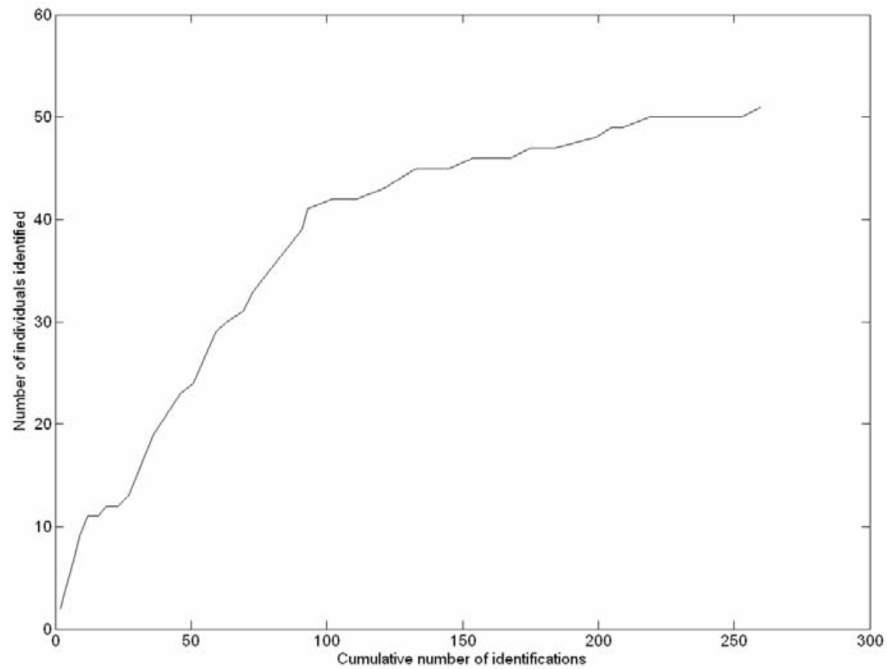


Figure 8.4. Discovery curve showing the cumulative number of individuals identified against the cumulative number of identifications (with only one identification of each individual counted during each sampling period).

Based on the output obtained from SOGPROG, the estimate of social differentiation was 1.0, indicating a well-differentiated society (<0.3: homogeneous, ca. >2.0 extremely differentiated). The estimate of the power of the social differentiation analyses was 0.7, indicating that the potential to differentiate the true social system was relatively high (0.0: poor result, ca. 1.0: perfect result). Identical values were obtained using the simple association index.

Both HWI and SI analyses were conducted to test association levels. The distribution of maximum HWI association levels observed for each individual shows that individuals were more frequently seen with a particular companion than would be expected if all individuals associated at random (HWI: Figure 8.5, SI: Figure 8.6). Ninety-eight percent of individuals showed relatively strong associations at HWI$\geq$0.5 (73% using SI), with the average maximum association rate being 0.72 ± s.d. 0.15 (Figure 8.5). Twenty-nine percent of individuals showed extremely strong associations of HWI$\geq$0.80 (20% using SI).

8.3.2.1. Average-linkage Cluster Analysis

A dendogram produced from an average-linkage cluster analysis shows that individuals form strong associations with more than one individual and spend more time with another individual, or group of individuals, than would be expected by chance (mean HWI>0.16 ± 0.07, Figure 8.7).

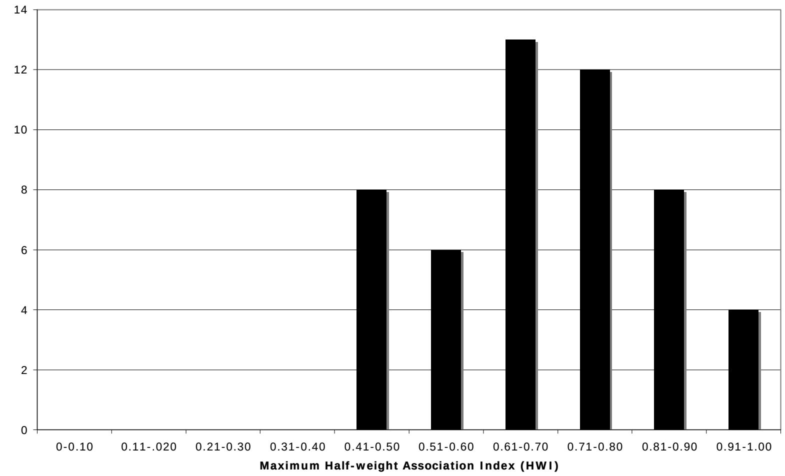


Figure 8.5. Distribution of maximum HWI of Irrawaddy dolphins in the Mekong River (individuals sighted on ≥ 4 days and in schools with ≥ 50% of individuals identified). The distribution of maximum association indices suggests that most animals formed strong associations with a particular companion.

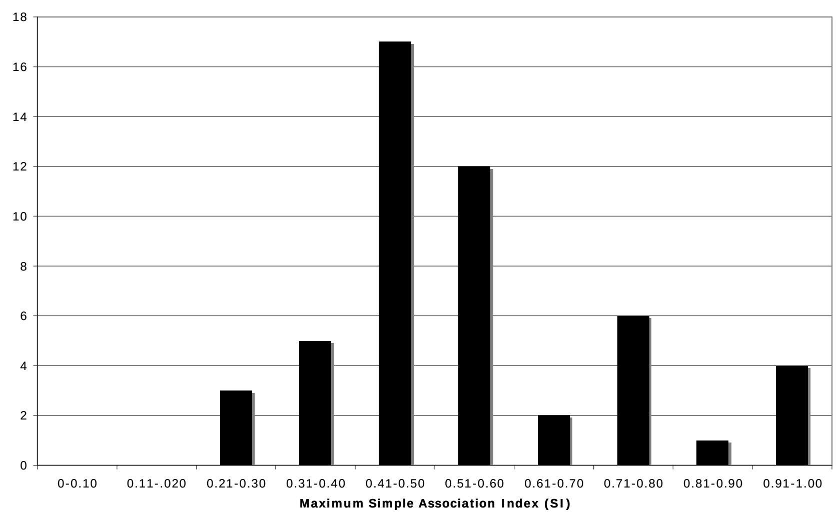


Figure 8.6. Distribution of maximum SI of Irrawaddy dolphins in the Mekong River (individuals sighted on ≥ 4 days and in schools with ≥ 50% of individuals identified). The distribution of maximum association indices suggests that most animals formed strong associations with a particular companion.

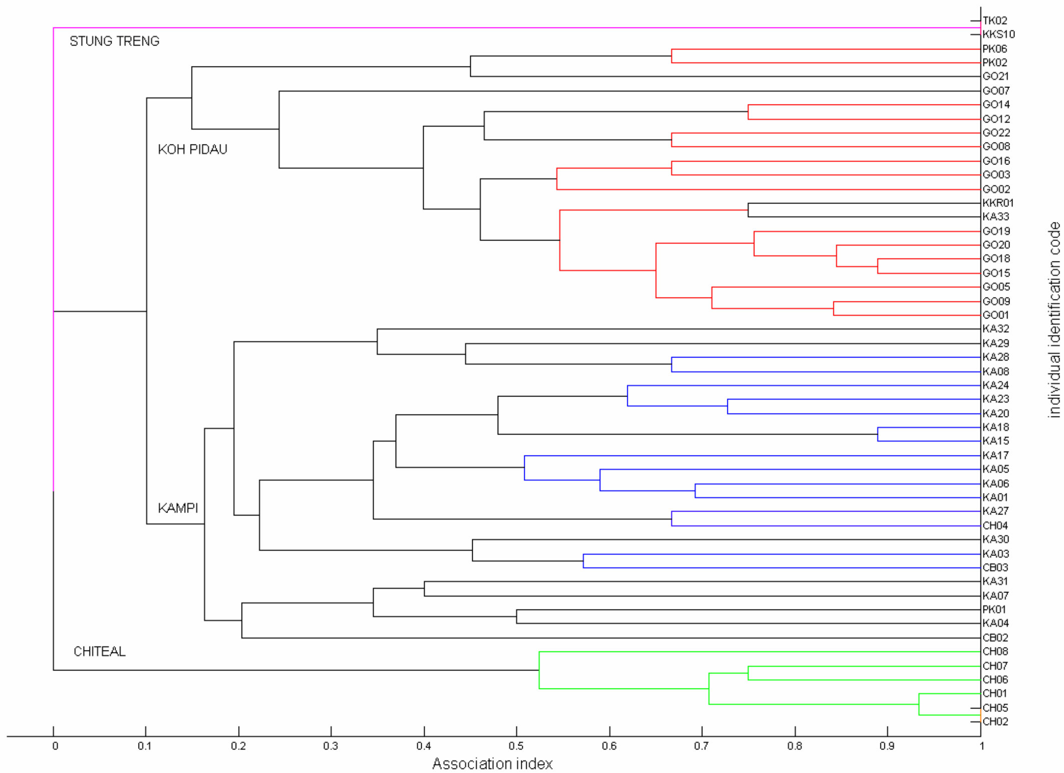


Figure 8.7. Average-linkage cluster analysis for associations between Irrawaddy dolphins in the Mekong River, using only individuals sighted ≥ 4 days and in groups with ≥ 50% of individuals identified. Associations higher than 0.50 are indicated by coloured branches. The four primary areas: Stung Treng, Koh Pidau, Kampi and Chiteal (see Chapter 7), are indicated on the dendogram and show distinct clustering during the dry season, particularly dolphins from Chiteal and Stung Treng primary areas. However, results from Stung Treng must be viewed with caution because of the small sample size (*n*=2)

The cophenetic correlation coefficient resulting from the cluster analysis was 0.82, indicating a good match of the dendogram to the matrix of association indices (1.0 indicates a perfect result and 0.0 a poor result). Figure 8.7 shows four distinct clusters within the dendogram: Chiteal (situated on the Laos/Cambodian border: CH); Stung Treng (TK and KKS); Koh Pidau (GO and KKR); and Kampi (situated near Kratie Township: KA and CB). There appears to be occasional association between some individuals from Koh Pidau and Kampi (as shown by the sociogram of the top 21 individuals identified). However, individuals from Chiteal[16] and Stung Treng were never observed associating with individuals from other critical areas (as also evidenced by the sociogram in Figure 8.8).

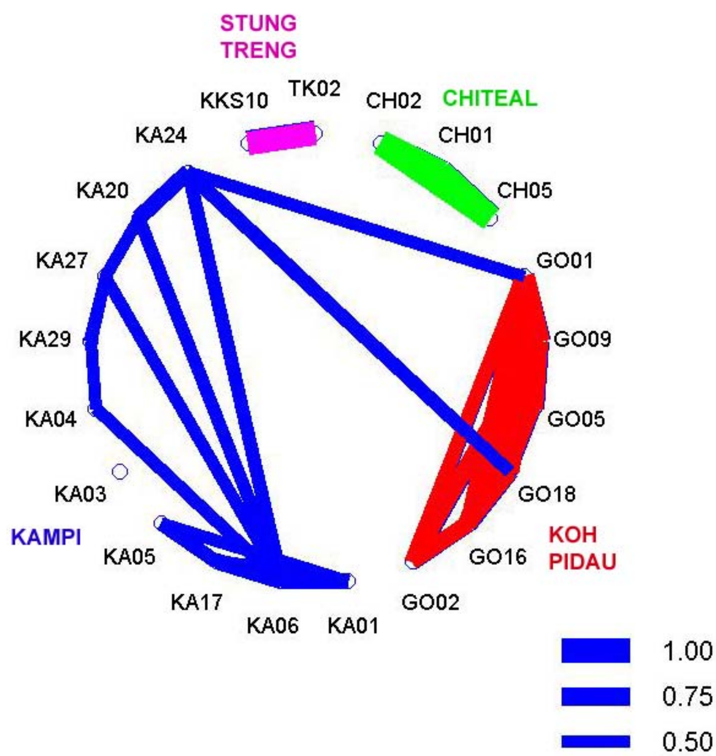


Figure 8.8. A sociogram of the association matrix of the top 21 individuals identified during the study period during the dry season. This sociogram shows that there appears to be no associations between the Stung Treng (KKS10/TK02) or Chiteal individuals (CH01/CH02/CH05) between themselves or individuals from other primary areas. However, results from Stung Treng must be viewed with caution because of the small sample size (*n*=2).

[16] One individual (CH04) from the Chiteal community has been known to move out of this area. CH04 was first sighted in Chiteal Pool during 2002. However, in 2003, CH04 was sighted in Kampi Pool and remained in this pool up to April 2005, when my study finished (see Chapter 7).

8.3.2.2. Principal Component Analysis

A Principal Component Analysis (PCA) also showed evidence of four distinct communities: Chiteal, Stung Treng, Koh Pidau and Kampi (Figure 8.9). Each point on the cluster analysis represents an individual, so that the distance between them is proportional to one minus the square-root of their association: therefore, strongly associated individuals are plotted together and weakly associated ones are plotted apart (Whitehead 2005). A total of 14 of the 51 eigenvalues were greater than one, indicating coordinates that explained more information than average (Whitehead 2005). No large negative eigenvalues were observed. Such values would indicate poor performance of the PCA (Whitehead 2005).

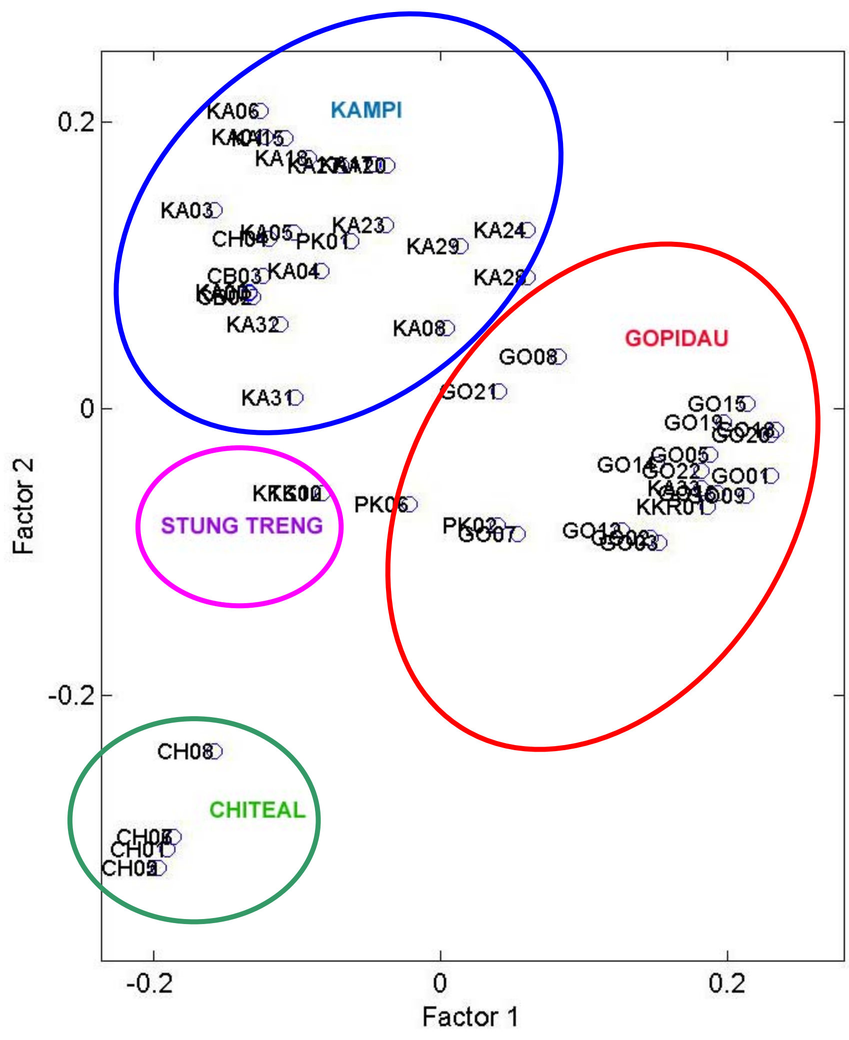


Figure 8.9. PCA of associations between Irrawaddy dolphins in the Mekong River. The PCA clearly shows the four primary areas: Stung Treng (KKS/TK), Kampi (KA/CB), Koh Pidau (GO/PK) and Chiteal (CH). Dolphins from these four primary areas also grouped together in the dendogram (Figure 8.7) (see Footnote 3. regarding an explanation of individual CH04 that associates with individuals from Kampi primary area).

8.3.2.3. Test for Preferred Associations

A test for preferred associations (Bejder *et al.* 1998) was conducted with the associations within samples permuted. A total of 15,000 permutations were conducted with 100 flips per permutation. Increasing to 20,000 permutations did not significantly change the resulting *p* value. The mean HWI association indices were significantly higher than indices generated from random data ($p \leq 0.001$), indicating that individuals showed a preference in their associations over the three years of the study. The mean sum of associations suggests that individuals formed non-random associations with up to 9 (8.87 ± s.e. 3.72) different individuals (see Figure 8.2).

Table 8.3. Results of permutation tests for preferred companionship of Irrawaddy dolphins inhabiting the Mekong River based on the 2003-2005 dry season data-set, following the Bejder *et al*. (1998) procedure. The highly significant P value (*P*<0.001) indicates that individuals showed a preference in their associations.

	Mean association index	**SD of mean association index**
Observed data	0.15747	0.21241
Random data	0.15761	0.20747
P value	<.001	<.001

8.3.3. Wet Season Association Patterns

Because of a lack of identified individuals during the wet season, only a preliminary investigation into the wet season association patterns was conducted using the HWI. Although data were minimal, they provide some indication of the potential associations during the wet season. A total of 37 individuals were identified over nine sampling periods, each of one day. No individuals were identified from the Stung Treng primary area during the wet season. Only two individuals were identified from Chiteal, 17 from Koh Pidau, and 18 from Kampi.

The estimate of the power of the social differentiation analyses was 0.0 ± s.e. 0.25, indicating poor differentiation of the true social system (0.0: poor result, ca. 1.0: perfect result). The mean HWI was 0.2 ± s.e. 0.11, sum of HWI was 9.7 ± s.e. 4.12 and the average maximum HWI was 0.9 ± 0.12. A very high average maximum HWI (0.9 ± s.e. 0.12) was obtained as a result of the low number of days (≥ 2) for identified individuals to be included in the wet season analysis.

The resulting sociogram provides indications that during the wet season, individuals from Chiteal remain isolated from Kampi and Koh Pidau individuals (no data were available on potential interactions between Stung Treng individuals). Nonetheless, there were indications that dolphins from Kampi and Koh Pidau interacted at higher levels in the wet season than observed during the dry season. Strong associations between some individuals were still apparent (Figure 8.10).

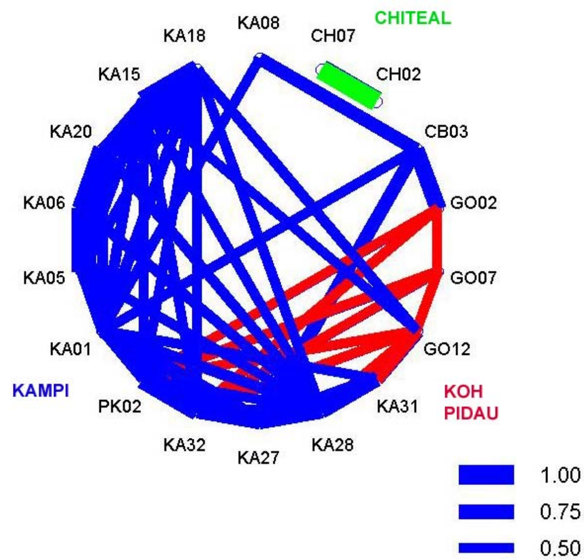


Figure 8.10. A sociogram of Irrawaddy dolphin association patterns from the Mekong River during the 2003-2005 wet seasons. Only groups where $\geq$50% of the group was identified were included in this analysis. The number of times that an individual was identified during the wet season ranged from two to five times. Only individuals with associations of 0.5 or greater are displayed on this sociogram. As a result of the small sample size the results should be viewed with caution.

A dendogram of wet season associations is shown in Figure 8.11. The results must be viewed with caution because even random data, with no preferred or avoided associations can produce a dendogram with apparent associations that are not indicative of the true social structure: (Whitehead 2005). There are indications that the Chiteal community remains isolated during the wet season. It also appears that at least some degree of association between individuals from Kampi and Koh Pidau primary areas occurs during the wet season, although there are some individuals from these two communities that never appear to associate. Further evidence for continued fragmentation of the Chiteal community and movements between Kampi and Koh Pidau communities during the wet season are found in Chapter 7.

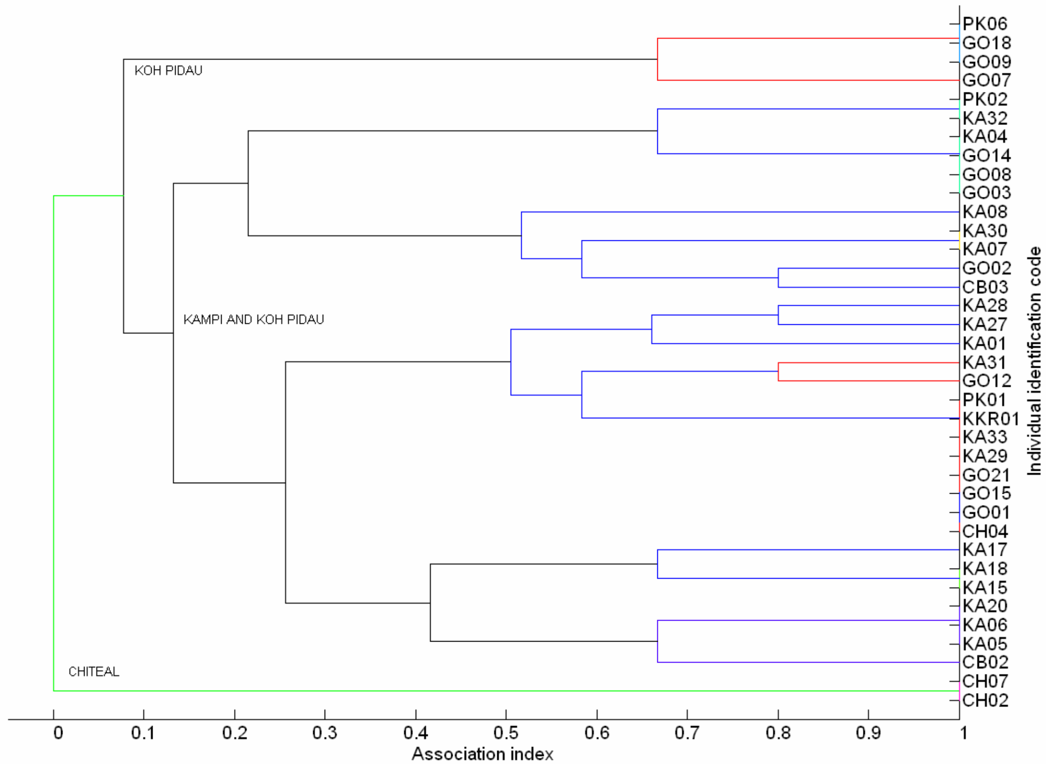


Figure 8.11. Average-linkage cluster analysis for associations between Irrawaddy dolphins in the Mekong River during the wet season, using only groups with ≥ 50% of individuals identified. Associations higher than 0.50 are indicated by coloured branches. The dendogram shows that the Chiteal community appears to remain isolated during the wet season. There are individuals from Koh Pidau and Kampi that associate with other communities and some that appear to have no association with other communities.

8.3.4. Dry Season Temporal Patterns of Analyses

The standardised-lagged association rates were: (1) stable over time, (2) higher than expected by chance alone, and (3) did not approach the random association rate (Figure 8.12). These results provide further evidence for preferential companionship and stable, long-term associations. Standard error bars were large, indicating low levels of precision. The model that best described these temporal association patterns was the constant companions model (Whitehead 1995), which indicates stable associations over time, changed only by birth and death (Karczmarski *et al.* 2005). No temporal analyses of wet season data were conducted as a result of the inadequacy of the data-set.

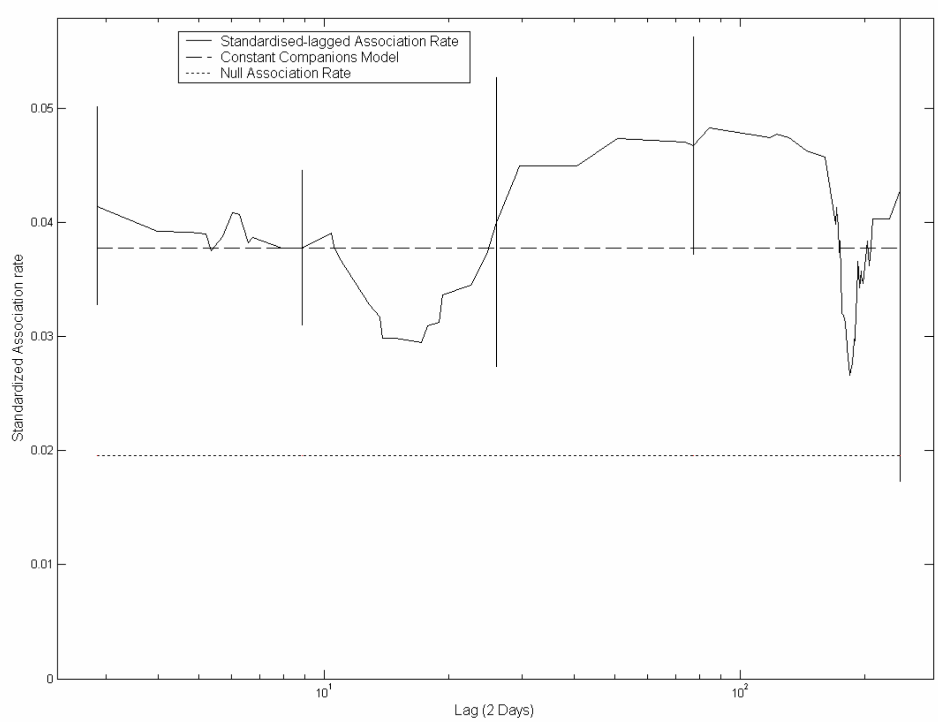


Figure 8.12. Standardised-lagged association rate for Irrawaddy dolphins inhabiting the Mekong River, using only individuals sighted ≥ 4 days and in groups with ≥ 50% of individuals photo-graphically identified. Standard error bars were estimated using jackknife procedures. The null association rate is the lagged association rate expected if individuals are associating at random. The constant companions model best explains the observed temporal association rates of Irrawaddy dolphins in the Mekong River. This model indicates a highly structured population with preferred companions and long-term associations.

8.4. DISCUSSION

8.4.1. A Stable Social Structure and its Potentially Influencing Factors

This study shows that Irrawaddy dolphins inhabiting the Mekong River live in a stable, highly-structured population of long-term associates, with strong geographic fidelity and no obvious fission-fusion. No data are currently available on the associations between males and females, as a result of the difficulty in establishing the sex of dolphins in the Mekong River (as is true of most small cetacean studies, if underwater viewing is not possible). The population appears closed to immigration and remigration and consists of four communities. Two of these communities appear isolated with no apparent association with other communities in the river (e.g. Chiteal and Stung Treng). Some individuals from the other two communities interact primarily when the water-level conditions allow (e.g. Kampi and Koh Pidau during the wet season).

The average group size for Irrawaddy dolphins in the Mekong River was 6.8 ± s.e. 0.20 individuals (range=1-18, *n*=407), compared with 4.4 ± s.d. 2.2 individuals (range 1-10, *n*=75) in the Mahakam River. The social structure of Irrawaddy dolphins in the Mekong River appears to be similar to that of the Mahakam population. Both populations are highly structured with preferred long-term associates. Kreb (2004) also studied group size of Irrawaddy dolphins inhabiting Balikpapan Bay, an estuarine bay located near the mouth of the Mahakam River, East Kalimantan. She hypothesised that 'bay' dolphins exhibit lower sociality. However, no photo-identification studies were conducted on the bay dolphins and therefore no comparison of association patterns between the bay and river populations was possible.

The only other comparison of *Orcaella* group size and social structure is from a small population (*i.e*., fewer than 100 individuals) of Australian snubfin dolphins in Cleveland Bay, Townsville, Australia. Average group size of this population was 5.4 individuals ± s.e. 0.35 (range=1-21, *n*=101). This population followed a temporal association model of constant companions and casual acquaintances, with strong social bonds and long-term associations (Parra 2005). Taken together, these data provide some indication that *Orcaella*, as a genus, exhibit strong social stability. The small group size encountered in the Mahakam River may be more a function of the very small population size (48-55 individuals: Kreb 2004), than the degree of sociality.

Various hypotheses have been developed to explain cetacean group formation and associations. These are discussed below in an attempt to understand the high degree of social structure observed in the Irrawaddy dolphin population inhabiting the Mekong River, and *Orcaella* as a genus.

8.4.1.1. Predator Avoidance Strategies

Predator avoidance has previously been reported to influence cetacean social structure (Norris and Dohl 1980, Connor 2000). Various strategies for avoiding predators by group living are reviewed in Connor (2000) and include:

1. dilution and encounter effects: e.g. individuals in a group experience a reduced attack rate compared with a solitary individual;
2. confusion effects: e.g. larger group sizes make it more difficult for the predator to track a single individual in a group and distinct individuals in a group, are generally more vulnerable to capture;
3. 'the selfish herd': e.g. individuals selecting a location in a group that renders them less likely to predation;
4. increased predator detection and vigilance;
5. sentinel behaviour e.g. where an alert non-foraging individual is stationed at a prominent place to keep watch over the group; and
6. predator inspection, pursuit and mobbing.

It is unlikely that the social structure of freshwater Irrawaddy dolphins is influenced by predators. Among the potential predators, only the Siamese crocodile (*Crocodylus siamensis*) inhabits the lower Mekong River and is listed as *Critically Endangered* (Platt and Van Tri 2000) and is now virtually extinct from the Mekong dolphins' range. Similarly, in the Mahakam River, two species of crocodiles are found: the false gavial (*Tomistoma schlegeli*) and the Siamese crocodile. These two crocodile species are reportedly not a threat to the dolphins because of their small body size (Kreb 2004). As mentioned by Conner (2000), although the killer whale presents a threat to more cetacean species than any other predator, individuals living in tropical rivers are the only cetaceans immune from killer whale predation (Jefferson *et al.* 1991). Large sharks do not inhabit either the Mahakam or Mekong river systems and no other predators are known.

8.4.1.2. Parasite Avoidance Strategies

Grouping may reduce the risk from non-socially transmitted parasites via the dilution effect (Mooring and Hart 1992). Cetaceans have previously been known to be parasitised externally by cookie cutter sharks (*Isistius brasiliensis*) (Jones 1971) and remoras (*Remora* sp.) (Connor 2000). However, neither of these two species are known to affect river dolphin populations.

Endo-parasites are also common in virtually all species of cetaceans. A comprehensive review of the variety of parasites in marine mammals and their impacts is outlined in Raga *et al.*, (1997), where it is concluded that parasites can play an important role in marine mammal populations, not only at the ecological scale but at the evolutionary one too. Despite dedicated carcass recovery and necropsy programs, no endo- or ecto- parasites are known for either the Mekong or Mahakam Irrawaddy dolphin populations'.

8.4.1.3. Prey Availability Strategies

Connor (2000) proposed strategies for group living related to prey availability as the defence of a feeding area or food patches (Wrangham 1980); and congregation of individuals in an area of high food availability. Prey availability was indicated as a factor potentially influencing social structure in the Mahakam population, where prey and dolphins are reportedly clumped in particular areas of the river (Kreb 2004). A similar situation of prey clumping occurs in the Kratie to Khone Falls river stretch of the lower Mekong River, where major fish aggregations have been reported in deep pool areas during the dry season, with at least 100 deep pools scattered along this river stretch (Viravong *et al.* 2005), and in Tonle Sap Lake during the wet season (Poulsen *et al.* 2002). In this same river stretch, dolphins are usually found in only nine out of the more than 100 deep pool areas (see Chapter 7). However, fish densities appear similar in deep water pools not inhabited by dolphins (Coates *et al.* 2003). It remains unknown why dolphins prefer only some deep pool areas or exhibit high site fidelity to these areas (see Chapter 7). Dolphins are also now virtually absent from Tonle Sap Lake during the wet season, although the lake has been described as the site of one of the most productive fisheries in the world (Coates *et al.* 2003) (see Chapters 4 and 7). Although an investigation into fish distribution was outside the scope of my study, as a result of the above considerations, it appears that prey availability strategies may not be a major influence on the dolphins' social structure in the Mekong River.

8.4.1.4. Phylogeny

In contrast to the above hypothesis, Parra (2005) proposes that *Orcaella* social structure may be influenced by phylogenetic rather than environmental factors. From 1999-2001, Parra (2005) investigated the social structure of the Australian Snubfin dolphin, which is the Irrawaddy dolphin's closest relative. Both species are also closely related to the killer whale. Parra (2005) also investigated the ecologically sympatric Indo-pacific humpback dolphin (*Sousa chinensis*). Both *Sousa chinensis* and *Orcaella heinsonhi* were studied in coastal waters of Cleveland Bay, adjacent to Townsville on the Queensland coast of Australia. The social structure of the Australian snubfin dolphin population consisted of 'constant companions and casual acquaintances', or individuals that formed long-term associations with some animals and occasional associations with others. In contrast, the Indo-pacific humpback dolphin population followed a 'casual acquaintances model', where associated individuals tended to dissociate over time (Parra 2005), similar to the fission-fusion societies observed in Indo-pacific humpback dolphins in other areas (Karczmarski 1999, Jefferson 2000, Keith *et al.* 2002) and various bottlenose dolphin populations (Defran and Weller 1999).

8.4.1.5. Co-operative Feeding Strategy

Among odontocetes, many species of delphinids, such as Hawaiian spinner dolphins (Norris and Dohl 1980, Wursig 1986) and dusky dolphins (Wursig and Wursig 1980), are known to feed cooperatively. Irrawaddy dolphins are closely related to the Australian snubfin dolphin and more distantly to the killer whale. The feeding behaviour of the Australian snubfin dolphin remains undescribed; however, killer whale foraging strategies have been extensively studied. Killer whales often forage in groups, where the benefits have been reported to include an increase in the rate at which prey is encountered; an increase in prey capture success; a decrease in prey handling time; and an increase in the ability of groups to defend prey during intergroup conflicts (Simila and Ugarte 1993, Baird 2000b).

No detailed accounts are known of Irrawaddy dolphin' foraging behaviour in the Mekong River, or anywhere else in their range. I did not conduct any studies on feeding ecology as part of my thesis. However, my unpublished observations of Irrawaddy dolphins in the Mekong River and throughout Asia indicate that they probably feed cooperatively, using bubbles and spitting water to disorientate fish and herding them either towards the water surface or conspecifics (Figure 8.13). Spitting behaviour has been observed in other Irrawaddy dolphin populations (both riverine and coastal) (Stacey and Leatherwood 1997), although rarely from the Australian snubfin dolphin (Parra 2005).

Based on my unquantified observations of Irrawaddy dolphins in the Mekong River over four years, I hypothesise that a major factor influencing the stable social organisation observed in Irrawaddy dolphins inhabiting the lower Mekong River is their cooperative feeding strategy, further related to their evolutionary history. Such a cooperative feeding strategy requires relatively large group sizes and strong social structures, such as exhibited by the genus *Orcaella*. Additionally, based on studies of spinner dolphin association by (Karczmarski *et al.* 2005), it is probable that fragmentation of the Mekong population and isolation of communities in the Kratie to Khone Falls river stretch further accentuates the social stability of the Mekong population. Irrawaddy dolphin' feeding behaviour should therefore be an important future research priority, if time and resources are available.

Figure 8.13. An Irrawaddy dolphin feeding in Kampi Pool, near Kratie Township. Irrawady dolphins are commonly seen spitting water in the vicinity of fish at the water surface (top). After a few moments of spitting behaviour, fish are often observed jumping in the air near the dolphin – seemingly disorientated (bottom). Photos by Laura Morse.

8.4.2. Research and Management Implications

From a research perspective, biopsy studies should be considered for genetic analysis to further investigate the social structure and level of genetic diversity within the Irrawaddy dolphin population in the Mekong River. Tissues samples are currently being obtained through the carcass recovery program. However, these samples are too few and often too decomposed to provide detailed information necessary to gain a comprehensive understanding of the status of the population throughout their current distribution. However, the potential negative impact of biopsy sampling on the remaining Critically Endangered population must be carefully considered before any such studies are undertaken.

From a management standpoint, there are three primary implications of my research. Firstly, it is critical that effective on-the-ground conservation efforts are focused on each of the four sub-populations and their associated critical habitats. The four sub-populations are widely fragmented and, as a result, are largely discrete and possibly closed behaviourally. Some sub-populations are small (e.g. Chiteal); however, conservation and management efforts should continue to be a high priority for each area.

Secondly, it is imperative to investigate management strategies that promote linkages (corridors) between the four primary areas. Potential strategies may attempt to reduce fishing gear use/boat activity between areas, and preservation of river-side ecosystems.

Thirdly, translocation programs to re-populate critical areas are probably not a viable conservation option. Translocation programs in which dolphins from one community (e.g. Kampi) are moved to a smaller community (e.g. Chiteal) are unlikely to be beneficial to the long-term survival of the population. In addition to the high probability of mortality during capture and transport (Fisher and Reeves 2005), the removal of one or more individuals from a socially-stable group may negatively affect:

1. the group that the individuals are taken from, e.g., any group hierarchy may be disturbed, potentially causing increased conflict to re-establish stability);
2. the individuals that are translocated to a new group, e.g., the new individuals may be behaviourally and/or socially unable to adapt or be accepted into a new social group; and
3. the new group that the individual(s) are translocated into, e.g., a stable group may be significantly disturbed by new individuals being introduced, particularly if dominance issues arise.

8.5. CONCLUSIONS

Chapter 8 aimed to provide baseline data on the school dynamics and social structure of Irrawaddy dolphins in the Mekong River (thesis objective 4c: Chapter 1). A summary of the major conclusions from Chapter 5 are listed below.

- Studies of a species' social structure have important implications for conservation and management. There is significant intraspecific behavioural variability within cetacean species; therefore it is important to understand social structure on a population scale to develop appropriate management actions.
- Average group sizes during the dry and wet seasons were 6.8 dolphins ± s.e. 0.20 (range 1-18, mode=6, median=6, n=405), and 5.7 dolphins ± s.e. 0.41 (range=1-34, mode=3, median=5, n=107) respectively.
- Analysis of association patterns of Irrawaddy dolphins from the Mekong River showed that individuals were seen with a particular companion significantly more often than would be expected by chance. Ninety-two percent of individuals show a maximum HWI association of $\geq$ 0.80 which indicates a highly structured population.
- Association analyses (e.g. Hierarchal Cluster and Principal Component Analysis) indicated four somewhat discrete dolphin sub-populations along the Kratie to Khone Falls river stretch. Two of these sub-populations (Chiteal and Stung Treng) apparently rarely associate with other sub-populations (Kampi and Koh Pidau), or with each other.
- The relationship between the lagged association rates and time lag suggests that the population is highly structured during the dry season, with the majority of individuals having preferred, long-term associates.
- Few data are available for comparison of wet season associations. The sample size from Stung Treng is particularly small. However, preliminary indications are that Chiteal and probably Stung Treng sub-populations remain isolated from other sub-populations, despite the fact that no barriers exist to dolphin dispersal throughout the river system during the wet season (e.g. there are few shallow, rapid areas or sand flats).
- There appears to be some degree of association between individuals from Kampi and Koh Pidau sub-populations during the dry season that increases during the wet season. Individuals from both sub-populations inhabit Phum Kreing primary area during July and August.
- The small and restricted population size of the Irrawaddy dolphin population in the Mekong River and potential to engage in cooperative feeding may be major factors influencing their strong associations.

- From a management standpoint, my research suggests that: (1) it is vital that conservation efforts are now focused on the four communities and associated critical habitats; (2) linkages between the four primary areas are promoted; and (3) translocation programs to re-populate critical areas are probably not a viable conservation option.
- Chapter 11: Table 11.6 summarises the main research and conservation implications from Chapter 8.

8.6. SOCIAL STRUCTURE RESEARCH RECOMMENDATIONS

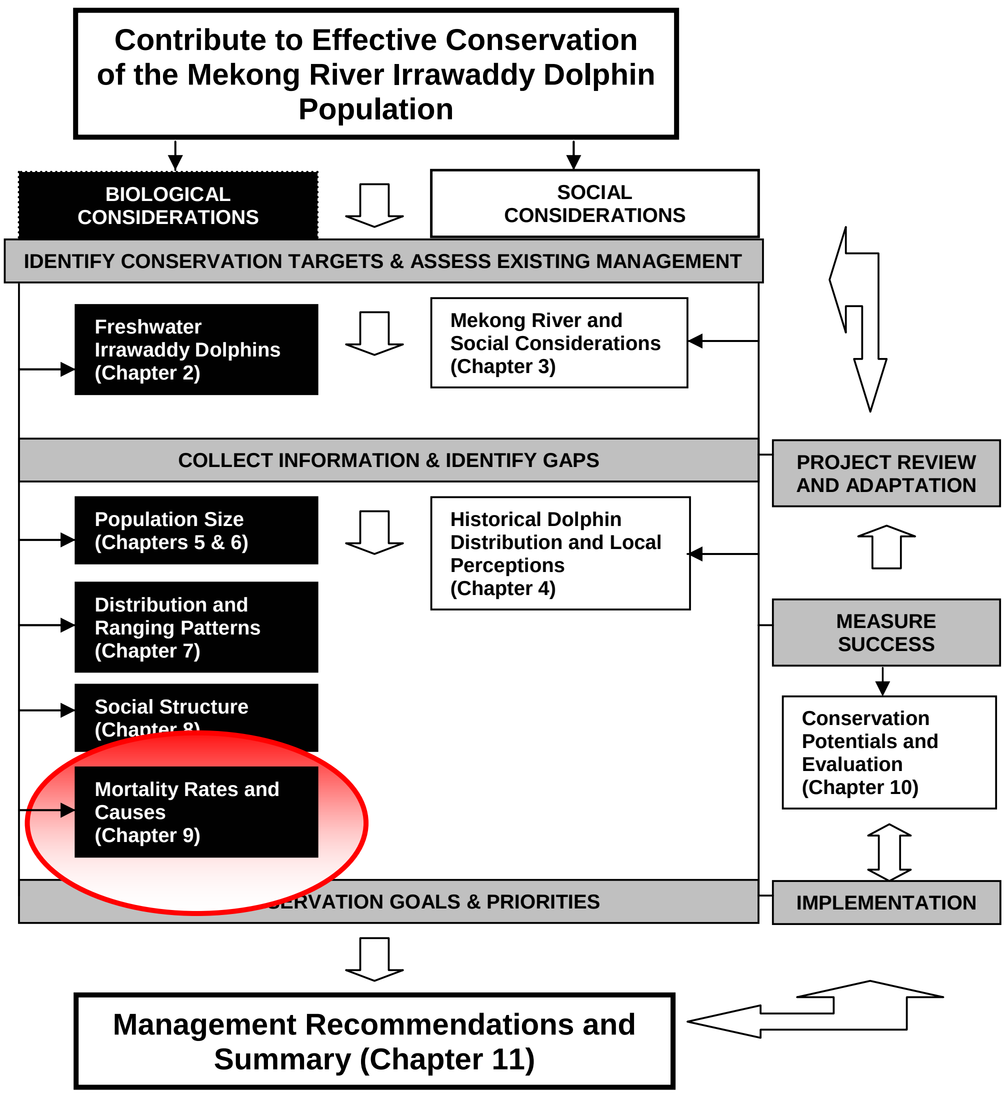
- Based on this study, research priorities include: (1) providing additional data on wet season associations, when individuals are able to move widely throughout the river system; (2) conducting detailed studies on behaviour in parallel with acoustic studies (particularly feeding behaviour); and (3) genetics.
- Photo-identification analyses compared data only from the dry season when dolphins are restricted to particular habitats as a result of low water levels. It would be beneficial to conduct further studies during the wet season to investigate wet season associations. There are indications that movements occur in the wet season and dolphins from at least Kampi and Koh Pidau communities are interacting (the degree of associations still remains unknown). In the event that individuals from Chiteal and Stung Treng are not associating with other communities during the wet season, the conservation status of these two management units is increasingly critical.
- Dedicated behavioural studies would assist in obtaining information about population structure and dynamics. Feeding behaviour is particularly interesting to investigate
- Importantly, genetic studies have significant potential to provide substantial information relevant to understanding population dynamics and structure.

9. MORTALITY RATES AND CAUSES AFFECTING SURVIVAL OF IRRAWADDY DOLPHINS INHABITING THE MEKONG RIVER

A dedicated marine mammal carcass recovery program can contribute to knowledge of trends in mortality rates and anthropogenic interactions, as well as providing information on stock identity, life history and contaminant levels. Such information is essential for developing effective management strategies for endangered populations. In this chapter, I provide significant new information about mortality rates of Irrawaddy dolphins in the Mekong River, based on results from the carcass recovery program undertaken throughout my study. I also discuss potential threats to this dolphin population which may also adversely impact on flora, fauna and local communities living along the river.

9. MORTALITY RATES AND CAUSES AFFECTING SURVIVAL OF THE IRRAWADDY DOLPHIN POPULATION INHABITING THE MEKONG RIVER

Chapter 9 investigates a biological consideration in the context of the '*collecting information and identifying gaps*' section of my conceptual framework. The aim of Chapter 9 is to provide baseline data on mortality rates and causes of death affecting survival of the Irrawaddy dolphin population inhabiting the Mekong River (thesis objective 4d: see Chapter 1).



9.1. INTRODUCTION

Data obtained from carcass recovery programs provide significant information relevant to the conservation and management of marine mammal populations. Some examples of well-known stranding programs are the Texas Marine Mammal Stranding Network, Texas, USA (Wilkinson and Worthy 1999) and the Manatee Carcass Retrieval Program, Florida, USA (Bonde *et al*. 2004). Systematic efforts to gather information from stranded animals have significant potential for improving management capabilities, as they provide information on mortality rates; stock identity; life history; population dynamics; and human/marine mammal interactions (Wilkinson and Worthy 1999). Few dedicated dolphin carcass recovery programs exist in Asia and only one is known for a river dolphin population **-** the Mahakam River of Indonesia (Kreb 2004).

One of the most successful and well-resourced stranding programs in Asia is conducted by the Hong Kong Agriculture, Fisheries and Conservation Department (through the Hong Kong Cetacean Research Project). This program focuses primarily on the finless porpoise (*Neophocaena phocaenoides*) and Indo-pacific humpback dolphin (*Sousa chinensis*) that inhabit the inshore waters of the Hong Kong Special Administrative Region (SAR) of the Peoples' Republic of China (Jefferson 2000, Parsons and Jefferson 2000). Dedicated programs also operate in Taiwan (Wang *et al.* 2002, Wang *et al.* 2003), Thailand (Chantrapornsyl *et al.* 1996, Chantrapornysl *et al.* 1999) and the Philippines (Smith *et al.* 2004).

I initiated a stranding program (the Mekong Dolphin Carcasses Recovery Program) to recover Irrawaddy dolphin carcasses from the Mekong River to complement abundance estimates obtained for this study (Chapters 5 and 6) (Gilbert and Beasley 2006). I aimed to determine mortality rates and potential causes of mortality. Additional information was obtained relevant to my study of Irrawaddy dolphin life history (Appendix V). Such information is essential for implementing appropriate management strategies and assessing the potential success of future conservation measures. In addition, the carcass recovery program has the potential to identify generic threats to the flora and fauna, and human communities living in the river basin.

9.2. STUDY AREA

The Mekong Dolphin Carcasses Recovery Program was conducted throughout:

1. the Kratie to Khone Falls section of the Mekong River (including the Laos/Cambodian border) and all associated tributaries;
2. the river section south from Kratie to the Vietnamese/Cambodia border;
3. Tonle Sap River; and
4. Tonle Sap Lake (Figure 9.1).

Additional information on recovered dolphin carcasses was gathered from Vietnam, when possible. As detailed in Chapter 2, dolphins do not occur in the Mekong River north of Khone Falls. Therefore, no boat surveys were conducted in this river section. The only area of potential Irrawaddy dolphin habitat that was not surveyed during my study (either by boat or through interviews) was the Sekong River of Laos, where Baird and Beasley (2005) reported that dolphins now rarely occur based on interview surveys (see Chapter 5).

9.3. METHODOLOGY

9.3.1. Carcass Reporting and Collection

The carcass recovery program began in January 2001, in association with interviews conducted to assess local perceptions towards dolphins and their conservation (Chapter 4). Local people living along the river were interviewed and asked if they had seen any dolphin carcasses or bones. This information provided initial indications of mortality rates and potential causes of mortality (as explained in Chapter 4). When conducting these interviews, a dolphin mortality report was recorded as ‘confirmed’ only if I observed pieces of bone, flesh or a photograph of the dolphin carcass. All other reports were listed as ‘unconfirmed’. If a person produced any part of the dolphin, small pieces of tissue were taken for genetic analysis and photographs were taken of the sample and the local person who owned the item. Most of the dolphin body parts were usually left with the owner, in recognition both of the reverence local people hold for dolphins (removing a cherished item risked causing bad relations: see Chapter 2), and of the necessity for continued cooperation with villagers for my project.

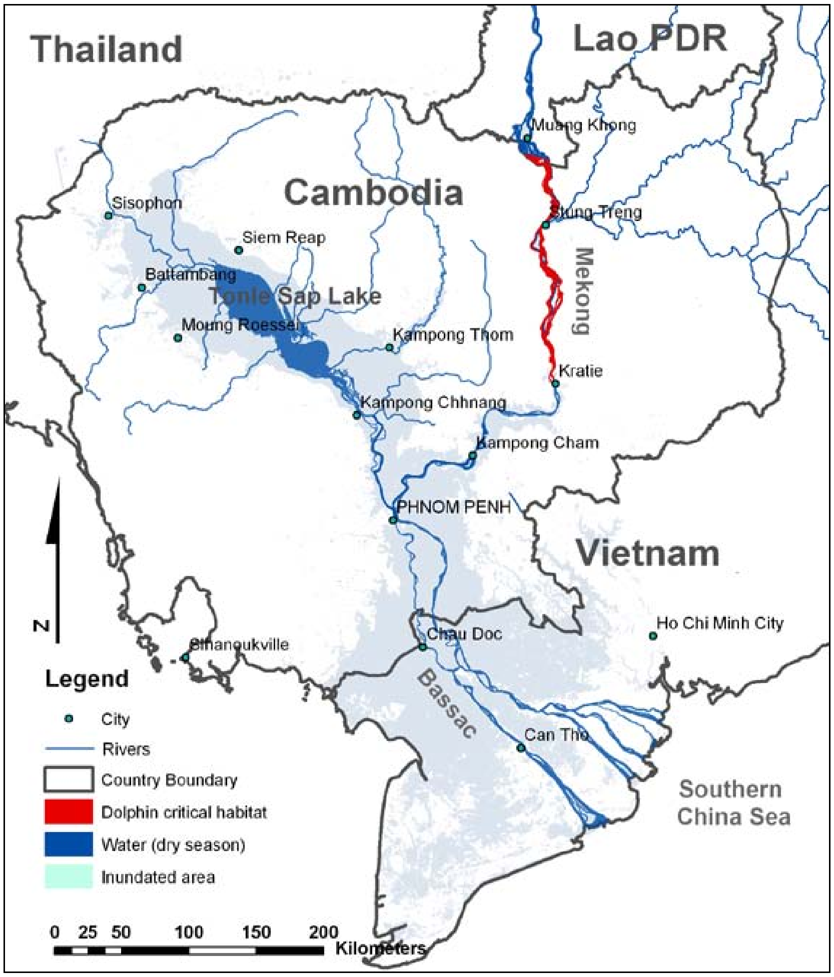


Figure 9.1. Study area for the carcass recovery program. The primary study area is the Kratie to Khone Falls River section (shown in red). From 2003 onwards, there was a high probability that most of the dolphins that died in this river section were reported to my project (see text for further discussion). Surveys south of Kratie were conducted during 2004–2005 to investigate mortality rates and causes throughout the known range of the population. Map created by Matti Kummu.

As explained in Chapter 1, in order to facilitate the collection of dolphin carcasses and provide an independent agency through which local communities could report dolphin carcasses, in 2002, I created a local organisation named the Mekong Dolphin Conservation Project: MDCP. I found that local communities were often wary of authorities including government departments in Cambodia and working as an independent organisation greatly improved the community's willingness to cooperate with my project activities.

In 2001 and 2002, the carcass recovery program was not well-known throughout the upper Cambodian Mekong River. Therefore, it is likely that a number of carcasses were unreported. At the end of 2002, I made significant efforts to increase public awareness regarding the programme and the importance of reporting dolphin carcasses by creating the MDCP;

distributing printed leaflets with contact numbers in the event a carcass was sighted; producing MDCP T-shirts for villagers who assisted with the program; and holding numerous discussions with heads of villages and local communities. Increased local awareness resulted in more carcasses being reported immediately after they were found. This practice enabled more accurate determination of causes of death and fresher samples to be collected. Nonetheless, some carcasses were inevitably unreported (particularly in the early years of my project) and my mortality estimates must be regarded as minimum estimates only. Until the start of 2004, there was no legislation prohibiting the possession or killing of dolphins (dolphin protected areas were developed in late 2004: see Chapter 2) and local people freely provided information and samples of bones, or pieces of dolphin flesh, to my research assistants.

If a dolphin carcass was reported, my research assistants and I immediately went to locate the body. We asked the relevant community members to assist in keeping the dolphin carcass on ice, if possible, until we arrived. From 2003 onwards, there were only a few occasions when a dolphin body was reported, but was not located.

Although many local people requested financial payment if they assisted in recovering a carcass, large sums of money were never paid because:

1. payments might have encouraged people to hunt dolphins directly to provide revenue;
2. fishers might have decided not to release dolphins alive if caught in fishing gear, if the alternative option was to let the dolphin die and then receive payment; and
3. payments might have set a precedent such that local people would refuse to assist the project in the future without some form of payment (a significant problem if local attempts were made to continue the program if international financial support ceased).

Only small expenses, such as fuel or phone costs, were covered, up to a 10,000 riel (US$2.40) limit. This limit was always strictly adhered to and widely publicised, to discourage rumours that our project was buying dolphin carcasses. A MDCP T-shirt was given to people who assisted in recovering a carcass. Local people felt proud of their contribution towards dolphin conservation and often wore the T-shirt. This practice also increased local awareness about the project and stressed the importance of reporting dolphin carcasses.

Once the carcass was located, the first consideration was to determine whether it could be taken back to the Fisheries Office in Kratie Township for a full necropsy (Figure 9.2). If the carcass was too large, or too decomposed, it was necropsied on-site. A necropsy kit was kept on the survey boat at all times, in case a dolphin carcass was found during boat surveys.

Once the carcass had been recovered, all local people who were watching or involved in the carcass recovery would be clearly informed of the purpose of gathering the carcass; what would be done with the carcass; and what samples would be collected and for what reason (e.g. studies on population structure, age, stomach contents).

This communication significantly assisted in dispelling false rumours about why our project was interested in the carcass, particularly when a foreigner was present (initially some villagers believed that we intended to sell the dolphin carcass to other agencies or individuals); and increasing local awareness about dolphin conservation and the importance of reporting dead dolphins.

9.3.2. Information Gathered from Carcasses

Permission for my project to collect dolphin carcasses and conduct dolphin necropsies was granted by the Cambodian Ministry of Agriculture, Forestry and Fisheries. Necropsy of the dolphin carcass always followed the same procedure. The following information and samples were collected, whenever possible. However, the variety of samples and the information collected were reduced for decomposed specimens:

- *Body length and other body measurements*: All length measurements were taken in a straight line and recorded on a standardised data sheet (which included a diagram of measurements to be taken: Appendix VI).
- *Weight:* Weight was measured using 100 kg scales. The entire dolphin was typically placed on the scales, using a wooden board to balance the carcass (Figure 9.3). The weight was checked by weighing all individual body parts (e.g. head, tail, internal organs), once the carcass had been necropsied. On all occasions, weight obtained from the intact carcass was recorded as the total weight, since, as a result of blood loss, some weight loss occurred when the body parts were weighed (*sensu* Arnold and Heinsohn (1996).
- *External photographs***:** Photographs were taken of all external features and parts of the body, including external wounds or markings. Photographs of the dorsal fin were particularly important to facilitate potential matching with the photo-identification catalogue (Chapter 5).
- *Age Class (i.e., newborn, calf, juvenile or adult)*: A dolphin was classified as a newborn if it was 90–110 cm long; the umbilicus was unhealed; and foetal folds were present. A dolphin was classified as a calf if it was 111–159 cm in length; and the umbilicus was

healed. Juveniles were classified as 160–190 cm long[17]. Adults were classified as any dolphin greater than 191 cm (based on new data obtained on approximate age at sexual maturity: Appendix VI). In my analyses, the only necropsied juvenile was classified with the adults, to clearly separate newly-born young from all other age classes.

- *Sex:* Sex was identified through careful examination of the genital region and internal organs. If it was not possible to locate male or female reproductive organs, the sex was recorded as unknown.
- *Blubber samples* were taken for contaminant analyses. Samples were wrapped in aluminium foil and then frozen.
- *Skin and muscle samples* (Chapter 3) were taken for genetic analyses (see Appendix I) and stored in 20% DMSO.
- *Internal samples* of liver, kidney and lung were taken for contaminant studies and investigation of parasites.
- The *stomach* and *reproductive organs* were removed for diet and life-history studies respectively.
- Three *teeth* from the middle of the jaw were removed from every carcass for age determination.
- *Skull and postcranial skeletal material* were collected from every carcass recovered (newborn/calf, juvenile and adult). Carcasses were flensed, stored in water and then further cleaned manually after two to three months. These items were used for taxonomic studies (Appendix I and II) and to assess minimum length and weight at physical maturity, based on skull fusion.

All data were recorded using standardised datasheets, one datasheet for each dolphin carcass. All skeletal material is housed at the Kratie Fisheries Office, Kratie Township and all tissue samples at the Wildlife Conservation Society Office, Phnom Penh.

[17] The lower limit of 160 cm was based on Tas'an *et al.* (1980), who reported a seven month old Irrawaddy dolphin measuring 153 cm in total length, from tip of snout to notch in tail fluke. This dolphin weighed 45 kg.

Figure 9.2. MDCP team members measuring the total length a newborn dolphin carcass (OBRE04-28/09), that was discovered in Chiteal Pool during September 2004. This newborn dolphin was estimated to be only a few days old. The foetal folds are still clearly present (indicated by arrows). The cause of death was unknown.

Figure 9.3. A newborn dolphin discovered in September 2002 near Kampi Pool (OBRE02-08/09). The carcass was weighed using 100 kg scales. This specimen was classified as a newborn (as opposed to a calf), as it had obvious foetal folds (indicated by the arrows) and the umbilicus was unhealed.

9.3.3. Location of Deaths

The exact location where each confirmed and unconfirmed carcass was initially discovered was recorded on a standardised data sheet. The position was obtained using a global positioning system (GPS). In the event a dolphin carcass was reported but not recovered, the closest known position was recorded based on location of area as shown, or described by a witness.

9.3.4. Cause of Death

Cause of death was recorded for each reported dolphin carcass, whenever possible. For most specimens, local people allegedly did not know why the dolphin had died and most carcasses were found at the river-side, or floating downstream. For a small number of carcasses, local people reported that the dolphins had been captured in gillnets (normally large-mesh nets). Occasionally, the net that caught the dolphin remained at the site and was available for inspection and collection. All external wounds, apparent net indentations (often located at the anterior of the pectoral flippers: Figure 9.4, or around the tail) and/or unusual markings were photographed. A full necropsy examination allowed examination of internal signs of death, such as parasites (none was ever found), or other ailments that may have resulted in the dolphin's death. In the event that the cause of death could not be confirmed, the reason for the death was listed as unknown, although possibilities based on anecdotal reports and observations were always recorded.

Potential discharge of mercury from gold mining activities into tributaries and subsequently into the mainstream of the Mekong River were implicated in the deaths of dolphins in Kratie Province. Investigations into the possible role of environmental contaminants in the deaths of these dolphins were conducted in collaboration with Environment Canada, Burlington, Ontario, and the Canadian National Laboratory for Environmental Testing, which analysed blubber and liver samples for mercury contaminants (Tom Murphy and Derek Muir unpublished report included in Gilbert and Beasley 2006).

9.4. ESTIMATES OF MORTALITY LIMIT

To investigate the allowable human-caused mortality for marine mammal populations in the U.S (under the U.S Marine Mammal Protection Act), a mortality limit (termed the Potential Biological Removal: PBR) was developed (Wade 1998). As Wade 1998 states,

> *'It is concluded that any marine mammal population with an estimate of human-caused mortality that is greater that its PBR has a level of mortality that could lead to the depletion of the population'.*

To investigate whether the level of human-caused mortality of Irrawaddy dolphins may be resulting in a population decline, I calculated the allowable PBR for dolphins in the Mekong River according to Wade (1998):

Equation 9.1 $PBR = N_{MIN}\ 1/2R_{MAX}F_R$

where:

- PBR = Potential Biological Removal
  The PBR is "*maximum number of animals, not including natural mortalities that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population*" (Wade 1998).
- N_{MIN} = the minimum population estimate of the stock. For calculations of N_{MIN} used in this study: N_{MIN} = is based on the line-transect and capture-recapture estimates of population size (161 dolphins, CV=0.30; and 136 dolphins, CV=0.07 respectively), calculated as the lower 20th percentile of a log-normal distribution as:

Equation 9.2

$$N_{MIN} = \frac{N}{\exp (z \sqrt{\text{In}(1+CV(n)^2})}$$

- Where z = a standard normal variate and thus equals 0.842 for the 20th percentile (Wade 1998).
- R_{MAX} = one-half of the maximum net productivity rate of the stock at a small population size (I used the default of 0.04 for cetaceans). The value of R_{MAX} takes into account cetacean life history, including age-specific mortality (survival) rates, fecundity rates, age at sexual maturity and longevity (Wade 1998), and
- F_R = a recovery factor between 0.1 and 1. The recovery factor is normally set a default of 0.5, and 0.1 for endangered populations. I used 0.1 because the Irrawaddy dolphin population in the Mekong River is listed as *Critically Endangered* by IUCN (Smith and Beasley 2005).

This model does not include the Allee effect, whereby the net production rate declines as population size reduces (Wade 1998). Because of the very small size of the Irrawaddy dolphin population in the Mekong River, this effect may become an increasingly important consideration in the future. In addition, the model does not explicitly take into account the age and sex structures of the population. Wade (1998), however, reports that this simplification should not make a difference to estimates of N_{MIN} or F_R, as long as the human-caused mortality is relatively random with respect to age and sex.

The sex and age composition of the carcasses retrieved were therefore important considerations. Based on the polygamous mating structure of most delphinids (possibly including Irrawaddy dolphins, although see Chapter 8), a higher mortality of females relative to males will contribute significantly to population decline (Wade 1998). Additionally, as a result of the high newborn mortality in the Mekong population, the age structure was potentially biased towards a higher proportion of adults, than would normally be expected in a non-depleted population.

Figure 9.4. A large adult dolphin (OBRE01-12/05) that was photographed by a local person at the location where it was found stranded. The dolphin (2.26 m long and 130 kg) was reported to have been caught in a large mesh size gillnet at Tbong Klar Pool, Stung Treng Province. The indentations from the net can be clearly seen around the head, behind the ear and at the base of the flippers, extending around the body.

9.5. RESULTS

9.5.1. Mortality Rates, Seasonality and Age/Sex Composition

From January 2001 to April 2005, a total of 54 dolphin carcasses were confirmed. These comprised 27 adults, 23 confirmed newborns/young calves and four confirmed but of unknown age (Figure 9.5, Table 9.1). At least 43% of the confirmed deaths were newborns/young calves (young calves were all less than 120 cm in total length).

Increased efforts to raise local awareness of the importance of reporting dolphin carcasses were made in late 2002. Figure 9.6 shows the increased number of mortalities reported and subsequently confirmed from 2003 onwards. From 2003 to April 2005, 38 dolphin carcasses were confirmed and recovered and three carcasses were unconfirmed (31 carcasses from 2003–2004). The 38 confirmed carcasses consisted of 17 adults and 21 newborns/young calves, which represented an average mortality rate of 13 confirmed deaths a year, consisting of six adults and seven newborns/young calves per year (Table 9.1).

Table 9.1. Total confirmed and unconfirmed dolphin mortalities in the Mekong River from January 2001 to April 2005.

Year	Confirmed deaths	Unconfirmed deaths	Confirmed adults	Confirmed newborns/young calves	Confirmed unknown age
Pre 2001	8	-	4	-	4
2001	3	-	2	1	-
2002	5	1	*4	1	-
2003	15	3	10	5	-
2004	16	-	5	11	-
(Jan - Apr) 2005	7	-	2	5	-
TOTAL	**54**	**4**	**27**	**23**	**4**
TOTAL 2003 - April 2005	**38 (31)**	**3 (3)**	**17 (15)**	**21 (16)**	**-**
AVERAGE / YEAR 2003 – April 2005	13 (15.5)	1 (1.5)	6 (7.5)	7 (8)	-

* One animal recorded as a juvenile (OBRE02-01/04) is listed with the adults to differentiate it from newborns/young calves.
* Data obtained from 2003 onwards is considered to be reliable and close to representative of the majority of dolphins that died in Mekong River. Totals and averages are presented for January 2003–April 2005 in the light grey shaded area. Confirmed totals include one carcass that was reported from the Vietnamese Mekong River (photographic evidence was available).

The newborn death rate is very high compared to population estimates (Chapters 5 and 6), and only one juvenile was recovered from 2001-2005. These data indicate that there is low recruitment to the population, and subsequently the population age structure may be skewed towards consisting of primarily adults.

Newborns/young calves were recovered during all months of the year, except May, July and December (Figure 9.7), suggesting that calves are born throughout the year in the Mekong River. Figure 9.7 suggests apparent peaks in births during February to March (start of the dry season) and September to November (end of the wet season). Adults were recovered in all months of the year apart from July (start of the wet season) (Figure 9.7).

Sex was confirmed in 29 of the 45 confirmed carcasses (64%) from January 2001–April 2005. Of the 13 adults, six were male and seven were female. Of the 17 newborn/young calves, nine were male and seven were female. There was no obvious gender bias in the number of males and females carcasses recovered, based on the sample collected (Figure 9.8).

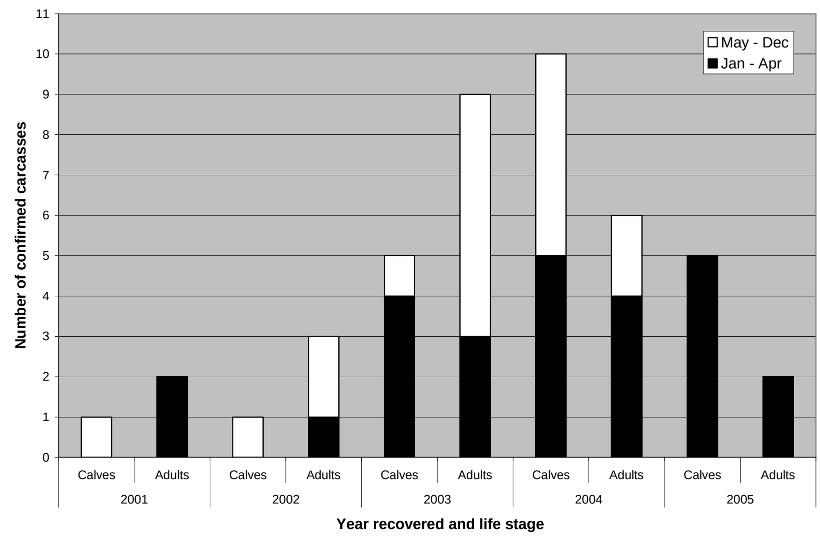


Figure 9.5. The number of adult and newborn/young calf Irrawaddy dolphin carcasses recovered from the Mekong River each year. The bars are separated into January - April and May – December, to facilitate comparisons with 2005 data, which was only collected until April. Newborn/young calf mortalities reached a maximum in 2004, with ten carcasses recovered. No data are available for this analysis from May 2005 onwards (although see Appendix VII).

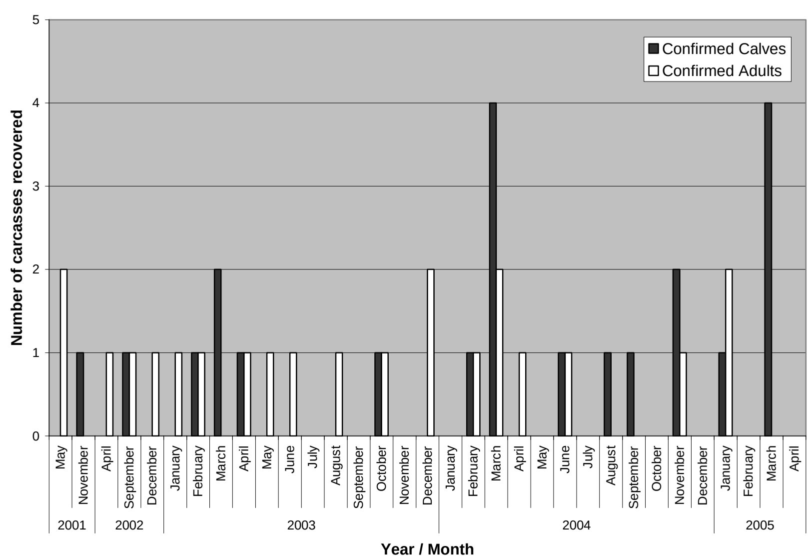


Figure 9.6. The number of adult and newborn/young calf Irrawaddy dolphin carcasses recovered from the Mekong River between 2001 and 2005. Note that only a few carcasses were reported in the first few years of the study. Therefore, only the months where carcasses were recovered are shown on the bar chart. All months are shown from 2003 onwards. From 2003 onwards, the highest numbers of carcasses per month were recovered in March of each year. These carcasses primarily consisted of newborns/young calves.

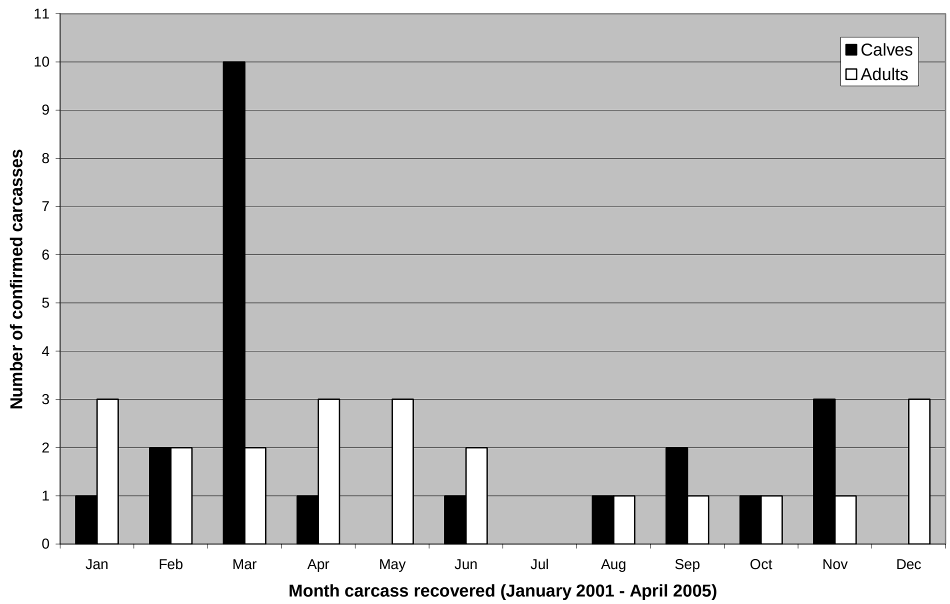


Figure 9.7. The number of adult and newborn/young calf Irrawaddy dolphin carcasses salvaged from the Mekong River and confirmed for each month from January 2001-April 2005 combined. Carcasses of newborns/young calves were recovered every month except May, July and December. Carcasses of adults were recovered every month except July. An adult female carcass recovered on 02 August 2003 was carrying a near term foetus (73 cm).

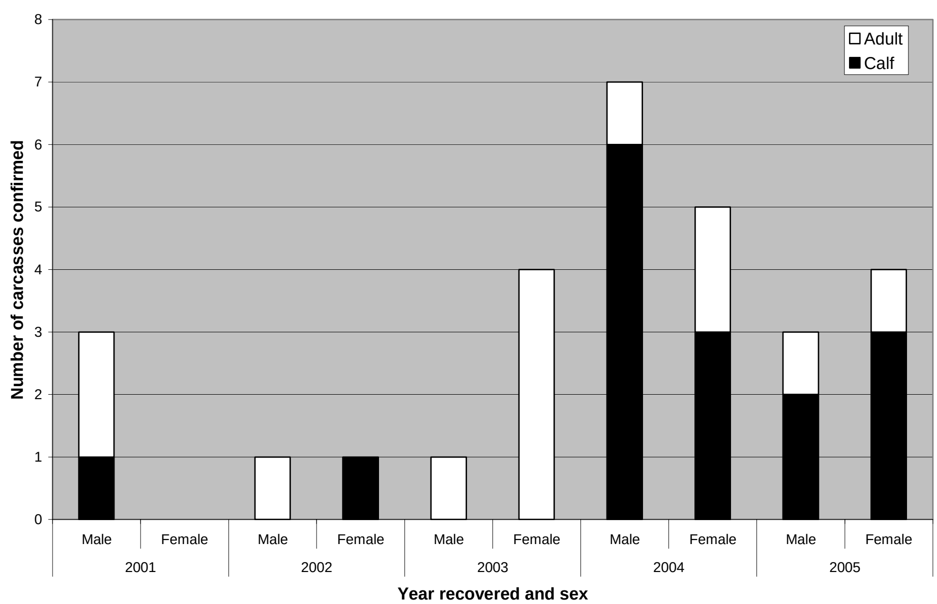


Figure 9.8. Known sex of Irrawaddy dolphin carcasses collected in the Mekong River (*n*=29), separated by year. Based on these data there were no apparent trends in rate of stranding for either sex or age composition (*i.e.*, adult or calf) of carcasses. Although five calves were recorded in 2003, their sex could not be determined.

9.5.2. Location of Dolphin Deaths

Most dolphin deaths were reported from the upper Cambodian Mekong River (including Chiteal Pool on the Laos/Cambodian border: Figure 9.9). Three carcasses were recovered from other regions of the river: including one carcass from the Srepok River, Mondulkiri Province, a second carcass 20 km north of Kompong Cham, Kompong Cham Province, and a third carcass from the upper Vietnamese Mekong River, near the Vietnam/Cambodian border.

Two dolphins were also found alive, trapped in a tributary in Kandal Province (approximately 270 km south of Kratie Township), close to Cambodia's capital city of Phnom Penh. Both dolphins were successfully released back into the mainstream Mekong River (Beasley 2002).

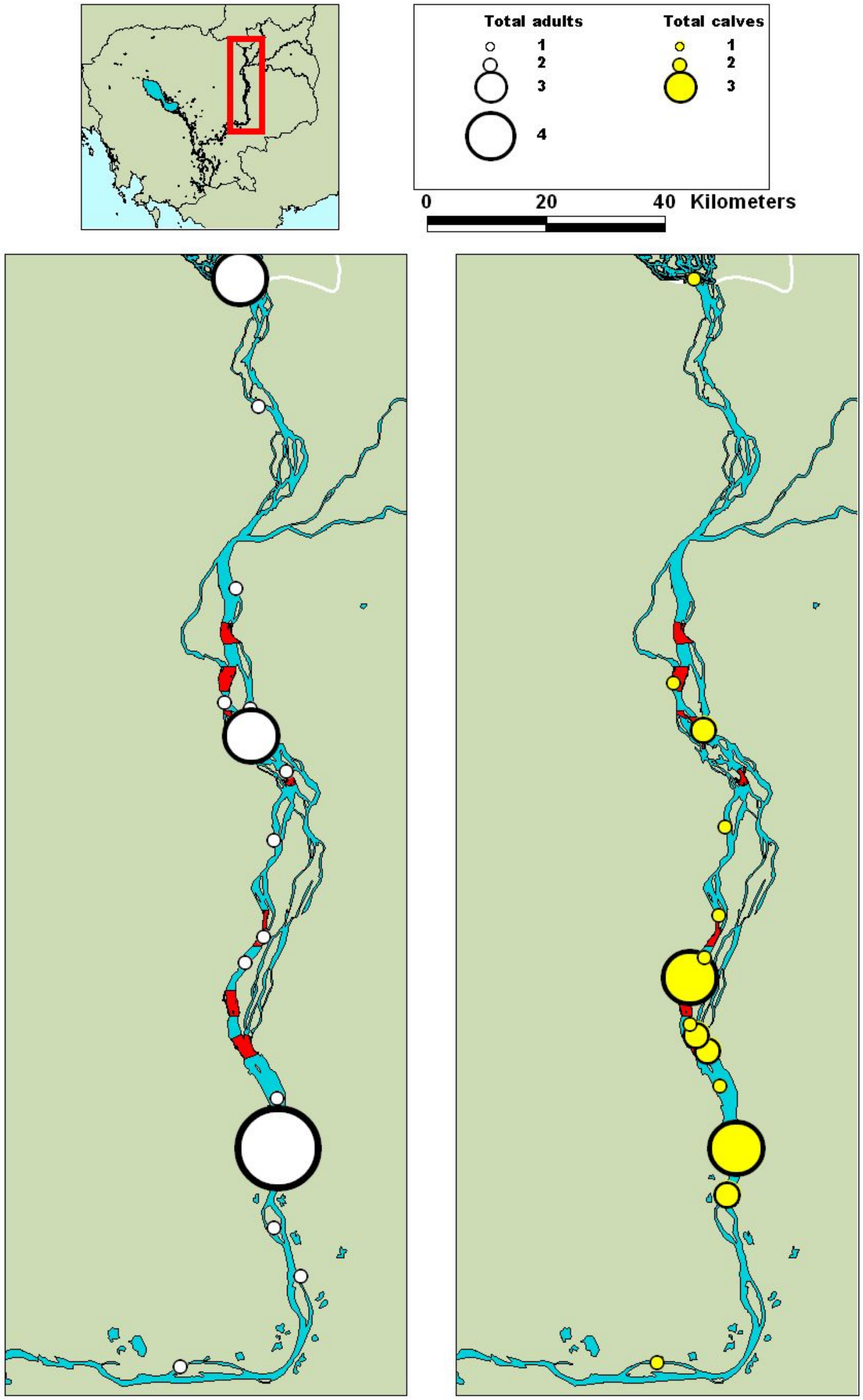


Figure 9.9. Distribution of confirmed Irrawaddy dolphin carcasses found in the upper Cambodian Mekong River between 01 January 2001 and 31 December 2005. The size of each circle has been scaled to represent the number of dolphins found dead within a radius of 2km. This map was produced by WCS Cambodia Program and is also shown in Gilbert and Beasley (2006): Appendix VII.

9.5.3. Cause of Death

Since 2001, anthropogenic factors were confirmed in the deaths of 14 (60.9%, *n*=23) adult dolphins (a minimum of 2.8 anthropogenic deaths/year). Twelve adult deaths (52% of the total adult carcasses) were apparently as a result of entanglement in large mesh gillnet fishing gear (mesh size between 6-14 cm, *n*=4). One animal was deliberately killed by explosives, apparently used as a result of concerns for access to fishing rights by dolphins' being in the area (OBRE05-25/01[18]:) and another was reported to have been shot (OBRE01-11/05). No calves exhibited evidence of human involvement in their deaths. One calf was reportedly trapped in a bamboo fence and was unable to free itself. Although extensive scratches were apparent over its body, entrapment could not be confirmed as the cause of death.

Gold-mining operations use mercury for extracting gold from sediment. To test whether dolphins have accumulated mercury in their organs, ten liver samples (three adults and seven calves) were analysed for inorganic mercury by Environment Canada, Burlington, Ontario and the Canadian National Laboratory for Environmental Testing (Table 9.2). Samples were found to contain mercury concentrations in the range 0.87-3.71 µg/g (wet weight), which are low compared to level; founds in other dolphin species (see Table 9.2). However, one exception was one adult female (OBRE03-22/12), which was found to have considerably higher concentrations of liver mercury of 67 µg/g. Liver mercury residues were consistently lower in calves compared with adults. Blubber samples from five adult dolphins were also analysed for mercury concentrations. Samples were found to contain mercury concentrations in the range 0.06–0.86 µg/g (wet weight), with the exception of the adult female (OBRE03-22/12), which had a concentration of 2.66 µg/g (wet weight) (Appendix VII: Derik Muir *pers comm*).

The adult female with high mercury concentrations was found at Chroy Banteay Pool, Kratie Province. She had very worn teeth (indicative of an old dolphin) and an empty stomach. There were no signs of accidental entanglement and it was possible that she aborted a foetus prior to death, based on apparent expulsion of her uterus, which was confirmed by a registered veterinarian who attended the necropsy. It is not known why this dolphin had much higher mercury concentrations than the other dolphins examined. This dolphin was not identifiable through the existing photo-identification catalogue (see Chapter 5). Jefferson *et al.* (2006) note that it is known that concentrations of contaminants increase with age in male cetaceans. In females, they increase until sexual maturity (when they decrease through pollutant transfer to young) and finally increase again later in life. This age relationship may explain why the mercury levels were low for the seven calves examined (Table 9.2).

[18] OBRE=*Orcaella brevirostris:* YY-DD/MM=date of stranding)

Table 9.2. Summary table of inorganic mercury residues in Irrawaddy dolphin liver and blubber tissue from the Mekong River, plus comparative data for other cetacean species from Japan, China and the Mediterranean[1].

Dolphin specimen number	Age class	Liver mercury ug/g (ppm)	Blubber mercury ug/g (ppm)
OBRE03-02/08A	Adult		0.86
OBRE03-11/06	Adult		0.52
OBRE03-22/12	Adult	67.00	2.66
OBRE04-13/03	Adult	3.71	0.21
OBRE04-10/11	Adult	2.84	0.06
OBRE04-18/03	Calf	0.87	
OBRE04-20/03	Calf	1.33	
OBRE04-22/03	Calf	1.61	
OBRE04-17/08	Calf	1.19	
OBRE04-28/09	Calf	1.36	
OBRE04-09/11	Calf	1.16	
OBRE04-22/11	Calf	1.49	
striped dolphin (*Stenella coeruleoalba*) in Japan (Honda *et al.* 1983)	--	485.00[2]	
Indo-pacific humpback dolphins in Xiamen (Huang *et al.* 1999)	--	272.00[2]	
Indo-pacific humpback dolphins in Hong Kong (Parsons 2004)	--	275.00	0.30
Bottlenose dolphins from the Tyrrhenian Sea, Mediterranean (Leonzio *et al.* 1992)	--	3986.00[2]	

1. Mercury values vary strongly with species and age, an important consideration when interpreting the results.
2. It remains unclear if these measures are from the liver or blubber. However, based on a comparison of values, they are likely to be liver measures.

There is no evidence of additional causes of dolphin deaths in the Mekong River. However, the appearance of skin lesions on some individuals from Koh Pidau region (based on photographic evidence), indicates that there is some potential for disease to be a contributing factor.

Dolphin-watching tourism occurs in two locations on the lower Mekong River. Although direct collisions between boats and dolphins have not been documented, it is possible that the reproductive success and calf survival are compromised by daily boat harassment (as has been shown for bottlenose dolphins experiencing dolphin-watching tourism in Shark Bay, Western Australia: Bejder *et al*. 2006). However, there is no evidence from Figure 9.9 that an increased number of newborn dolphin carcasses were found in the dolphin-watching areas .

9.6. ESTIMATES OF SUSTAINABLE ANTHROPOGENIC MORTALITY

The mortality limit was calculated using the line-transect population estimate: 161 (95% CI= 89–289; CV=0.30) (Chapter 5) and capture-recapture population estimate: 127 (95% CI=108–146; CV=0.07) (Chapter 6) to estimate N_{MIN}. Minimum population estimates (N_{MIN}) of Irrawaddy dolphins in the Mekong River were therefore 129 and 126 individuals respectively. Table 9.3 presents the resulting matrix of the allowable human-caused mortality limit.

Table 9.3. The allowable Potential Biological Removal of Irrawaddy dolphins from the Mekong River from anthropogenic mortality

Survey type	**N_{MIN}**	**F_R**	**R_{MAX} 0.04 (default value for cetaceans)**
Capture-recapture	129	0.1	0.26
	129	0.5	1.29
	129	1.0	**2.58**[2]
Line-transect	126	0.1	**0.25**[1]
	126	0.5	1.26
	126	1.0	2.51

1. The most conservative estimate of allowable anthropogenic mortality.
2. The least conservative estimate of allowable anthropogenic mortality.

Minimum estimates were used from line-transect and capture-recapture abundance analyses (Chapters 5 and 6), with the maximum net productivity value of 0.04 (default value for cetaceans) and recovery factors of 0.1 (endangered population) to 1.0 (relatively secure population).

The results indicate that for the N_{MIN} estimates, the level of anthropogenic mortality the populaton can withstand is $\leq$ 2.6 per annum. However, for an endangered population, a 0.1 recovery factor should be used, which yields an allowable anthropogenic mortality of < 1 dolphin/year.

9.7. DISCUSSION

This study provides the first estimates of mortality rates for the Irrawaddy dolphin population inhabiting the Mekong River and potential causes of these mortalities. Valuable information on *O. brevirostris* life-history was also obtained (Appendix VI). These results are directly applicable to the development of management strategies for the remaining dolphin population.

9.7.1. Newborn Mortalities and Survival Rates

The high mortality rate of newborns/young calves in the Mekong River is of major concern. From January 2001–April 2005, 23 of the 54 carcasses (43%) recovered were newborns/young calves. The cause of these deaths remains unknown but should be investigated as a matter of priority. As mentioned in Chapter 5, based on the low recruitment and adult mortality, the population was seemingly declining by at least 4.8%/year, as of April 2005.

Only two calves born in the Mekong River (born at Chiteal Pool in January 2004) are known to have survived more than four months over the entire study period (although this is likely to be an underestimation resulting from the difficulty in approaching mothers with newborns). If it is assumed that the newborn carcasses recovered (n=23) are representative of the total number of potential newborns, 92% of newborns are dying before weaning. Cetaceans are characterised by low adult mortality and fecundity, but relatively higher infant mortality (Mann and Watson-Capps 2005). Nonetheless, newborn/calf mortality of dolphins in the Mekong River appears much higher than for most oceanic dolphin populations studied (Table 9.4). No comparative data is known from other river dolphin populations.

Table 9.4. A comparison of newborn mortality rates in the Mekong River with other well-studied cetacean populations.

Country	Locality	Species	Newborn Mortality	Reference
Cambodia	Mekong River	Irrawaddy dolphin	43% of all carcasses recovered from 2001-2005 (92% of all newborns)	This chapter
Hong Kong	Coastal waters	Indo-Pacific humpback dolphins	53.2% of all carcasses recovered from 1995-2004	Jefferson *et al*. (in press)
Australia	Shark Bay	Indian Ocean Bottlenose dolphins	29% of all newborns[1]	Mann *et al*. (2000)
USA	Sarasota Bay, Florida	Bottlenose dolphins	19% of all carcasses recovered	Wells *et al.* (1987)
USA	Bahamas	Atlantic spotted dolphin (*Stenella frontalis*)	24% of all carcasses recovered	Herzing (1997)
USA	Atlantic coast (Massachusetts to South Carolina)	Bottlenose dolphins	17.7–26.6% of all carcasses recovered	Mead and Potter (1990)
USA	South Carolina	Bottlenose dolphins	39.9% of all carcasses recovered from 1992-1996	McFee and Hopkins-Murphy (2002)
USA	Texas	Bottlenose dolphins	20% of all carcasses recovered	Fernandez and Hohn (1998)
Thailand	Songkhla Lake	Irrawaddy dolphin	37.5% of all carcasses recovered from 1990-2001	Beasley *et al.* (2002b)

1. Survival analysis of calf mortality from birth to age three revealed a high first-year mortality (29%), with mortality declining in the second (18%) and third (3%) years (Mann *et al.* 2000).

2. These deaths were reportedly associated with poor body condition. The percentage of deaths was higher in provisioned (some dolphins accept fish handouts from humans) (56%) compared to non-provisioned females (24%) in the first year of life, with no significant difference for the second or third years (Mann *et al.* 2000).

9.7.2. Location of Deaths

Figure 9.9 shows areas where dolphin carcasses have been found. The lack of human settlement from Stung Treng north to the Laos/Cambodian border may have resulted in fewer carcasses being reported in these areas. The location of the carcasses when found may not be truly indicative of where individuals died (as a result of downstream drifting). However, it is unlikely that these carcasses have drifted more than a few kilometres before being discovered, as a result of the high level of fishing activity along the river.

The location of the dolphin carcasses provides further evidence that the Irrawaddy dolphin population is now largely restricted to the upper Cambodian Mekong River, between Kratie Township north and Khone Falls (Chapters 6 and 7). Nonetheless, three dolphins were recovered outside this area at Srepok River, Kompong Cham, and the Vietnamese Mekong River. Two dolphins were also trapped alive in a tributary near Phnom Penh in 2001 (and subsequently released back into the river: see Chapter 4). These reports confirm that at least occasionally during the wet season, some dolphins move outside the Kratie to Khone Falls area. Based on the results obtained for Chapter 8, it is likely that any dolphin movements out of the Kratie to Khone Falls river stretch are now very infrequent.

9.7.3. Causes of Death

9.7.3.1. Entanglement in Gillnets

Based on results from my carcass recovery programme, gillnet mortality (primarily large-mesh sizes) is a known factor responsible for adult dolphin deaths. Gillnet entanglement was confirmed for 52% of dolphin deaths (all adults) in the Mekong River. This entanglement rate is comparable with other freshwater Irrawaddy dolphin populations. In the Mahakam River, it was reported that between 1995 and 2001, 74% of dolphins (n=35) died as a result of gillnet entanglement in large-mesh gillnets (7.5–17.5 cm) (Kreb 2005). In Songkhla Lake, 13 of the 29 (45%) carcasses recovered from 1990–2001, were associated with gillnet entanglement (Beasley *et al*. 2002), although no mesh size information was available.

Most species of marine mammals interact in some way with fisheries. Individuals of almost all species are known to have been killed in fishing operations (Northridge and Hofman 1999). Small coastal cetaceans are particularly susceptible to entanglement mortality (Pichler *et al*.

2003), as are river dolphin species. Mortality through gillnet entanglement was described as the most important short-term risk factor to the vaquita (*Phocoena sinus*), one of the world's most endangered cetaceans found only in the upper Gulf of California, Mexico (D'Agrosa *et al.* 2000). The total vaquita population was estimated to number 567 individuals (95% CI = 177 – 1,073) in 1996 (Jaramillo-Legorreta *et al.* 1999). Incidental mortality of 39 vaquitas per year was reportedly caused by entanglement in both large- and small-mesh size gillnets (D'Agrosa *et al.* 2000). To mitigate mortality, D'Agrosa *et al.* (2000) recommended:

1. an immediate ban on the use of all gillnets within vaquita habitat; and
2. provision of an alternate source of income for local residents (e.g. creating infrastructure such as fish storage and processing plants to support and improve alternative fishing techniques that are less dangerous to the vaquita, such as longlines for fishing for sharks and rays). However, the subsequent effect on sharks and rays would probably be a concern for these elasmobranch populations.

The New Zealand endemic Hector's dolphin is a coastal cetacean species that is declining as a result of unsustainable levels of bycatch (Dawson 1991b; a, Cameron *et al.* 1999, Slooten *et al.* 2000, Pichler *et al.* 2003). The Hector's dolphin occurring in the waters of the North Island of New Zealand has been proposed as a distinct sub-species - the Maui's dolphin, *C. h. maui* (Baker *et al.* 2002) - and has been listed as *Critically Endangered* by the IUCN (Slooten and Taylor 2000). Fisheries bycatch is a major cause of population decline (Pichler *et al.* 2003). Management actions have been taken in some local areas. These include the creation of the Banks Peninsula Marine Mammal Sanctuary, in Akaroa Harbour, South Island, in 1988, and the use of acoustic pingers voluntarily by gillnet fishers in Canterbury, South Island (although adherence is unclear and concerns are evident with pinger use in general) (Pichler *et al.* 2003). Other actions involve gear restrictions (e.g. banning amateur set netting within 4 nm (7.5 km) of coastline in high density North Island Hector's dolphin habitat), and observer programs, such as north and south of the Banks Peninsula Marine Mammal Sanctuary for both inshore gillnetting and trawling (Pichler *et al.* 2003).

Although pingers have been trialled to reduce cetacean bycatch in several countries, their success is highly questionable (Dawson *et al.* 1998, Stone *et al.* 2000, Culik *et al.* 2001) Major problems for their use in developing countries include:

1. the remote location of many subsistence fisheries;
2. the high cost of maintenance for local fishers through the need to purchase batteries;
3. the lack of enforcement and associated uncertain compliance with their use; and
4. potential habitat displacement of dolphins from preferred habitats from the constant noise associated with pinger use.

The only prudent management path that does not require robust data on bycatch rate is to use the precautionary principle (e.g. avoid the use of fishing methods implicated in dolphin entanglements until population recovery is demonstrated) (Pichler *et al.* 2003). In the Mekong River, it is unrealistic to expect that an immediate ban on gillnet fishing can be applied throughout the dolphins' range, resulting from the wide use of gillnets amongst the majority of subsistence riverine communities, and the loss of local food security if communities are unable to catch fish.

It is imperative that management strategies are put in place immediately to minimise accidental gillnet entanglement, while acknowledging the needs of subsistence communities. Such strategies may include determining the specific reasons for dolphin entanglement; trialling new gear types/gear modifications that reduce the threat of accidental dolphin entanglement while not significantly reducing subsistence fishers catches; developing conservation areas in cooperation with local communities; and trialling diversification of livelihood projects to minimise fishing activity (Chapter 10). These strategies are discussed further in Chapter 11.

9.7.3.2. Deaths through Destructive Fishing Practices and Direct Catch

Dolphin deaths by direct catch for oil and meat during the 1950s-1960s, as well as resulting from dynamite fishing and being shot for target practice after the Khmer Rouge regime (1974-1979), were widely reported by interviewees (Chapter 4). Contemporary incidents of dolphin deaths through dynamite fishing have been confirmed (e.g. one dolphin killed in the Srepok River in 2005) as well as many reports of direct catch of dolphins by Khmer-Islam minorities south of Kratie Township. Regulations currently exist in the lower Mekong River prohibiting destructive fishing practices. Management strategies need to build on strengthening the effectiveness and compliance with these regulations – and developing additional regulations if required. Such strategies may include strengthening national legislation to minimise destructive fishing practices, increasing enforcement and patrols, and developing conservation areas in cooperation with local communities. These strategies are discussed further in Chapter 11.

9.7.4. Potential Causes of Dolphin Death

9.7.4.1. Contaminants

The causes of newborn/calf mortalities in the Mekong River remain unknown. However, based on existing literature, there is a high probability that contaminants may be responsible for the newborn/calf mortalities. Symptoms of contamination from many pollutants that interact with the environment are evident in cetaceans because they are long-lived and exist near the top of the food chain (Whitehead *et al.* 2000). Contaminants found in cetaceans include heavy metals (such as mercury, lead and cadmium), organochlorines (such as PCBs, DDTs and dioxins), and polycyclic aromatic hydrocarbons (O'Shea 1999, Whitehead *et al.* 2000).

There are numerous small gold-mines along the Mekong River and its tributaries in Kratie Province. As a consequence of poor mining practices, resulting from a lack of effective government regulation and a lack of training amongst gold miners, increasingly serious impacts on natural resources, human health and rural livelihoods have resulted (Sieng 2004). Therefore, mercury poisoning is a potential contaminant affecting newborn survival. In mammals, mercury poisoning can result in neurological damage, immunosuppression and foetal abnormalities (Parsons 1998). Indo-Pacific humpback dolphins in Hong Kong had average mercury concentrations in liver samples of 92.8-141.7 µg/g (ppm) dry weight (28.1-42.9 µg/g (ppm) converted wet weight) (Parsons 1998, Jefferson 2000). As was found in my study, these results showed evidence of increasing levels in larger, older individuals. The levels of mercury recorded in Irrawaddy dolphins from the Mekong River (0.87-67 µg/g (ppm): wet weight), were much lower than those recorded for Indo-Pacific humpback dolphins in Hong Kong. This result would be expected resulting from the industrialised development occurring in Hong Kong coast, compared to the relatively undeveloped shores of the Mekong River.

Organochlorines persist in aquatic environments due to their chemical stability, persistence and toxic properties (e.g., dichlorodiphenyltrichloroethane: DDT) and chemical inertness (e.g., polychlorinated biphenyls: PCBs) (de Kock *et al.* 1994). Marine mammals appear to be especially vulnerable to the toxic effects of organochlorines as a result of their low capacity to metabolise these compounds (Tanabe and Tatsukawa 1992, Tanabe *et al.* 1994, Tanabe *et al.* 1997). Studies of the effects of organochlorines have also been conducted on other marine mammal species. A study on contaminants in harbour seals (*Phoca vitulina*) in Puget Sound, Canada, noted that reproductive success was lower and juvenile mortality higher in the southern area of the Sound, where seals had higher levels of PCBs (Calambokidis *et al.* 1984). Similarly, Helle (1980) found a correlation between reduced reproductive rates and high levels of organochlorine contaminants (PCBs) in ringed seals (*Phoca hispida*) in the Baltic Sea. Reijnders (1984) hypothesised that organochlorines affected hormonal balance, after finding contaminants caused reduced fertility in harbour seals from the Wadden Sea.

Only one published study is known that investigates levels of persistent organic pollutants in an Irrawaddy dolphin population. Kannan *et al*. (2005) found organochlorine pesticides, and polybrominated diphenyl ethers, in tissues of Irrawaddy dolphins collected from Chilka Lake, but in lower concentrations than reported for other Asian coastal and riverine dolphins. (Kannan *et al.* 2005) recommended that efforts should be made to reduce the sources of contamination by DDTs and hexachlorocyclohexanes (HCHs) in the lake, as a priority

Based on studies conducted in other countries of Asia, there is a high probability that organochlorines are present in the lower Mekong River, probably resulting from agricultural practices and/or the use of chemicals during the Vietnam War (1960s to 1975) (Tanabe *et al.* 1994, Minh *et al.* 1999, O'Shea 1999, Smith *et al.* 2001).

Management strategies that investigate contaminants as a potential cause of dolphin mortality should be a high priority. I conclude that although the levels of mercury currently appear low in Irrawaddy dolphins from the Mekong River, continued rigorous sampling and analyses for all contaminants in Irrawaddy dolphin tissue samples, should be conducted, as well as investigations into potential sources of contaminants along and adjacent to the lower Mekong River (e.g. gold-mines and agricultural practices).

9.7.4.2. Other Causes of Dolphin Death

In the Mekong River, dolphin deaths through vessel strikes were not evident in recovered carcasses. This is in contrast to the Mahakam River, where vessel strikes are significant causes of dolphin death (5% of deaths: Kreb 2004). Further threats to the dolphin population in the Mahakam River were listed as direct capture for oceanaria (now prohibited in the Mahakam River), increased industrial activities, boat traffic, chemical pollution (mercury and cyanide from gold mining operations) and decreasing fish populations (Kreb 2004).

An indirect threat that should be considered when investigating dolphin mortality in the Mekong River is dolphin-watching tourism. Although no direct collisions between tourism boats and dolphins are known, there is concern regarding the effect of prolonged daily harassment of dolphins by tourism boats, including boat noise. Bejder *et al*. (2006) provide strong evidence for habitat displacement and reduced reproductive success of bottlenose dolphins, caused by tourism boat harassment in Shark Bay, western Australia.

Other potential threats to dolphins in the Mekong River include disease, boat collision (direct deaths), reduced fish stocks (reduced ability to forage in preferred areas), boat noise (which may damage the dolphins' sensitive hearing), and inbreeding depression (reduced fitness caused by critically low population numbers). Continuation of the carcass recovery program will be imperative to continue investigations into mortality rates and causes, particularly to establish the cause of newborn death. The extremely high newborn mortality rate is likely to be resulting in virtually no recruitment to the population, and subsequently a declining population.

9.8. ESTIMATES OF MORTALITY LIMIT

Management actions can be triggered by criteria such as a population falling below 50–85% of carrying capacity, declining trends in abundance, and/or estimating allowable level of human-caused mortality when mortality is known (Wade 1998). In the last case, mortality above the allowable limit should trigger management actions beyond basic monitoring (Wade 1998) and is often a preferable method to alternatives such as population monitoring (Chapters 5 and 6). My calculation of the PBR confirmed that the current anthropogenic mortality rate of Irrawaddy dolphins in the Mekong River is unsustainable. The challenge of reducing the Irrawaddy dolphin mortality rate is significant. As mentioned by Wade (1998),

> "*estimating incidental mortality in one year to be greater than the mortality limit calculated from a single abundance estimate survey does not prove the mortality will lead to depletion; it identifies a population worthy of careful future monitoring and possibly indicates that mortality-mitigation effects should be initiated*".

Data have been collected over a five-year period and there are indications that the Mekong dolphin population is experiencing a population decline. Effective management actions must therefore follow a precautionary principle and be implemented immediately, before being confirmed by a significant downward trend in population numbers, when the population may already be facing local extinction. The difficulty in obtaining a significant trend was shown by the photo-identification studies conducted as part of this study (Chapter 5). Management strategies must aim to continue the carcass recovery program to monitor the population and effectiveness of strategies, as well as reduce anthropogenic mortality to zero.

9.8.1. Considerations Regarding Implementing Management Actions

From 2004 onwards, the public profile of Irrawaddy dolphins in the Mekong River had grown significantly, both nationally and internationally. This publicity had both positive and negative ramifications. By 2004, many local people were afraid to report a dead dolphin to local authorities, or even to our independent project, a significant contrast to the early-years of the project (2001-2003), when many local people freely provided information.

One of the main catalysts for this fear was when a local man from Kampi Village, Kratie Province, was sent to jail for 2-3 weeks in February 2003, by the Kratie Provincial Governor for accidentally catching a dolphin in a 7 cm gillnet, set across a small tributary just north of Kampi Pool. Although the Governor had good intentions, I considered this arrest to be unfair to the local fisher because there were no official regulations against catching or killing dolphins in Cambodia at the time, local communities were not aware that individuals would be sent to jail for accidentally catching a dolphin, and the dolphin was accidentally caught by the fisher's net and it was apparently dead when he arrived to check his net. The local fear of reporting dolphin carcasses evoked by this arrest was evident in May 2003, when another adult dolphin carcass (based on fusion of the skull: OBRE04-17/02) was discovered cut into small pieces, placed into sacks and hidden on a small island near Kampi Pool. If this carcass had been directly caught for food or medicinal purposes, the body would have been taken back to the village. Thus, it is likely this dolphin was accidentally caught and the net owner tried to hide the body as quickly as possible. During the recovery of another carcass (OBRE05–19/03) in Kratie Province in March 2005, many people reported that they had seen the carcass floating downstream, but were afraid to collect and report it to authorities. It is understandable that local subsistence fishers will be reluctant to report carcasses, if they may be fined or jailed. Strategies must therefore be developed to ensure continued local cooperation with reporting and carcass collection.

The success of my carcass recovery program relied almost entirely on the support and cooperation of local communities living alongside the river. The proposed dolphin conservation plan (Chapter 11), will reportedly ban fishing of any kind inside designated conservation areas. If local communities are not involved in the designation and demarcation of these conservation areas and the development of appropriate regulations, these restrictions will potentially be a further catalyst to distance many local communities from dolphin conservation efforts in the Mekong River. The proposed prohibition of gear types within these conservation areas that have no effect on dolphins or sustainability of fish stocks (such as small hook line-fishing, cast-nets and fish traps) is unnecessary and represents only a draconian management measure that does not consider the livelihoods of subsistence communities in the area.

After working on the dolphin population for five years and interacting with virtually all local communities, I am convinced that establishing conservation areas with little or no community involvement in their designation and management has minimal chance of success. This is particularly evident in the upper Cambodian Mekong River, where the area is remote, fisheries offices have few resources or personnel to patrol the area, and communities rely almost entirely on fisheries for their livelihoods. I believe that a more realistic approach to long-term dolphin and fisheries conservation and management is to:

1. increase awareness of the importance of dolphin and fisheries conservation;
2. strengthen the capacity of local communities to manage important fishing areas;
3. provide local tenure for important fishing areas to prevent outsiders fishing in those areas (with the provision for no gillnet zones in critical dolphin/fishery areas);
4. trial gear modification experiments; and
5. assist with livelihood diversification options (such as land-based fish culture, small livestock production and agriculture and community-based ecotourism).

Importantly, an agreement that individuals will not be sent to jail or fined if they report a dolphin carcass (whether they caught it or not), may encourage local communities to continue reporting dolphin carcasses when encountered, especially if failure to report resulted in jail sentences or fines. Wide publication of fisheries regulations (including immunity from prosecution if reporting a dolphin carcass) by relevant government departments and an independent organisation, such as MDCP, to recover and process carcasses, will be critical to the success of the carcass recovery program and dolphin conservation along the Mekong River.

9.9. CONCLUSIONS

Chapter 9 aimed to provide baseline data on the mortality rates and causes of Irrawaddy dolphins in the Mekong River (thesis objective 4d: see Chapter 1). A summary of the major conclusions from Chapter 9 are listed below.

- This study provides the first estimates of mortality rates for the Irrawaddy dolphin population that inhabits the Mekong River and potential causes for these mortalities
- A total of 54 dolphin carcasses were recovered and/or confirmed from 2001 to April 2005. The mean annual adult mortality was six dolphins. There was no obvious gender bias in carcasses recovered (46% male and 54% female).
- Forty-three percent of all carcasses recovered were newborns. Only two newborns are known to have survived longer than 6 months during my study.

- All but three dolphin carcasses were recovered from the Kratie to Khone Falls river stretch.
- The cause of the high number of newborn deaths remains unknown.
- It is assumed that resulting from low recruitment, the population is skewed towards primarily consisting of adults. This skewed age structure may result in the high number of newborns (although the majority appear to be dying within the first week), compared to population estimates.
- Entanglement in gillnets and direct deaths through destructive fishing practices (e.g. dynamite fishing) are known causes of anthropogenic mortality.
- Fifty-two percent of adult deaths were confirmed to result from entanglement in large mesh fishing gear.
- Other potential indirect causes of dolphin mortality are contaminants (newborns), disease, boat harassment and noise, boat collision, reduced fish stocks, and inbreeding depression.
- Mercury levels were low in all dophins except for one adult female (although 58% of samples were from newborn dolphins).
- The allowable Potential Biological Removal (PBR) from anthropogenic mortality (Min Pop = 129, F_R=0.1, R_{MAX} 0.04) is less than one (0.26) individual/year.
- Irrawaddy dolphin mortality rates in the Mekong River are high and apparently unsustainable.
- It is essential that effective management actions are put in place immediately to reduce human-caused mortality to zero.
- Through the carcass recovery program, new data were obtained on Irrawaddy dolphin life-history (Appendix VII).
- Management actions should be conducted in close collaboration with local communities for long-term conservation efforts to have any chance of success.
- Chapter 11: Table 11.7 summarises the main research and conservation implications from Chapter 9.

9.10. RECOMMENDATIONS FOR MORTALITY STUDY AND MITIGATION

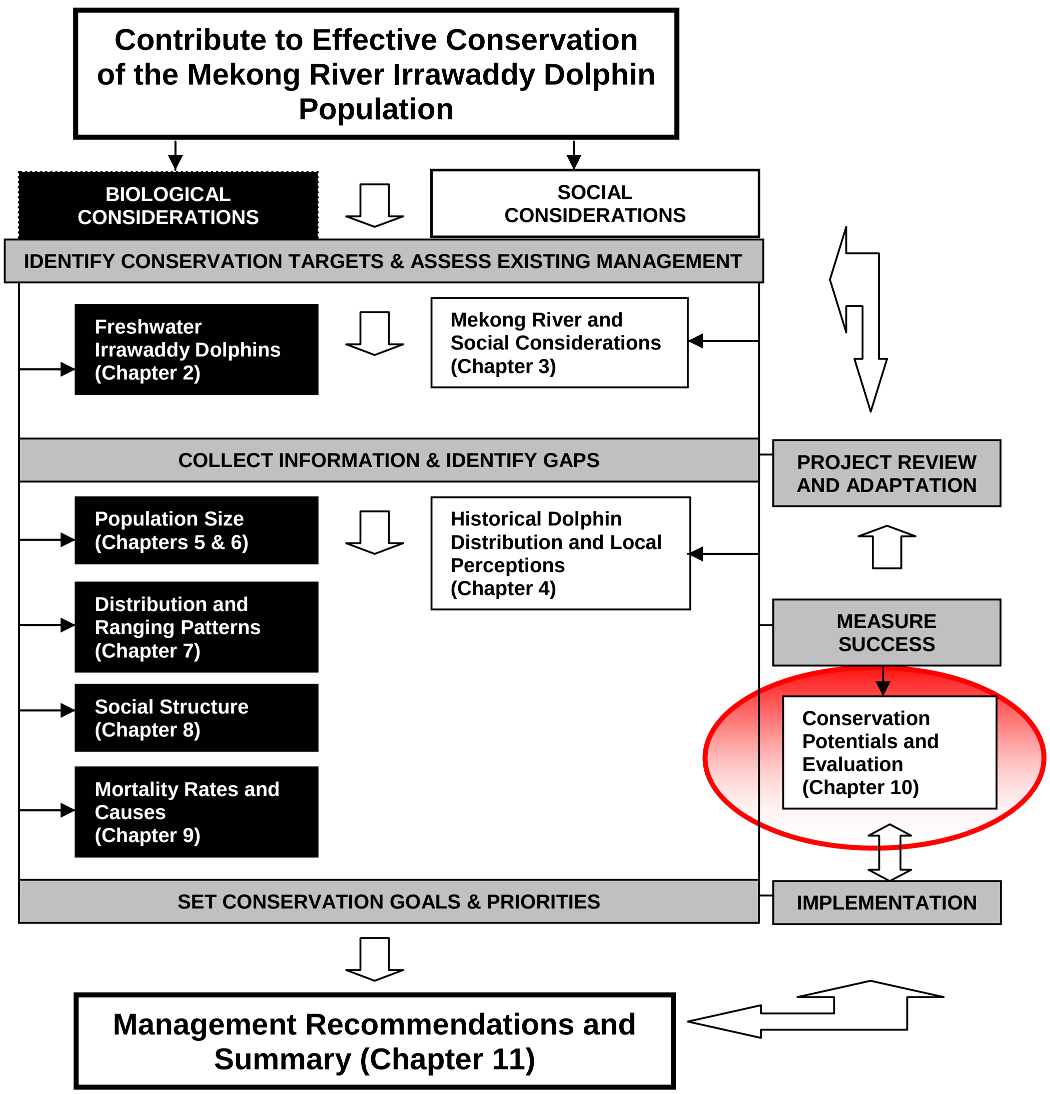
- The carcass recovery program needs to be strengthened, with all carcasses being examined by a qualified veterinarian and appropriate samples taken for analyses.
- To reduce accidental gillnet mortality, the use of gillnets should be discouraged in locations where dolphins are found (*i.e.*, dolphin primary habitats) as a matter of priority, preferably in close cooperation with adjacent communities.
- A secondary priority would be to discourage gillnet use throughout the remainder of the Kratie to Khone Falls river section, if this proves feasible and socially viable to do so.
- If a decision is made to develop protected areas, provision of alternative livelihoods to reduce fishing pressure in the river should be a priority (e.g. land-based native fish culture) (see Chapter 10).

10. ENCOURAGING COMMUNITY SUPPORT FOR IRRAWADDY DOLPHIN CONSERVATION: RURAL DEVELOPMENT, LIVELIHOOD DIVERSIFICATION AND TOURISM

Successful long-term conservation of endangered species and habitats adjacent to human settlements requires the support and cooperation of those communities. In this chapter, I describe an integrated conservation development project, Dolphins for Development that was trialled to increase the cooperation of local communities to conserve Irrawaddy dolphins in the Mekong River. I discuss the potential effectiveness of this project and introduce 'Community Conscious Conservation' as a concept to guide species and habitat conservation in Cambodia and perhaps other developing countries.

10. ENCOURAGING COMMUNITY SUPPORT FOR IRRAWADDY DOLPHIN CONSERVATION: RURAL DEVELOPMENT, LIVELIHOOD DIVERSIFICATION AND TOURISM

Chapter 10 investigates social considerations in the context of the '*implementing*' section of my conceptual framework. The aims of Chapter 10 are to investigate social considerations that influence conservation strategies, and trial an integrated conservation development project conservation initiative (thesis objective 5: see Chapter 1).



10.1. INTRODUCTION

10.1.1. Conservation Strategies

Conservation of endangered species is a crisis discipline. An endangered population faces one or more major threats, causing numbers to decline. With limited resources available, management strategies must be implemented effectively and efficiently, to halt population decline. Conservation situations are complex and dynamic, differing between species and countries. As Baird and Dearden (2003) state "*the site specific strategies of necessity will likely range across the entire spectrum of management approaches from the strictly protectionist to the overtly developmental*". Conservation managers are therefore responsible for developing management strategies applicable to their particular situation.

Until the early 1980s, conventional wisdom held that central governments should manage all conservation efforts in developing countries (Barrett *et al.* 2001). Most attempts at conservation of species and ecosystems involved creating protected areas and attempting to prohibit local human-use of and access to these areas (Terborgh 1999). Little attempt was made to compensate local communities for lost livelihoods or for restrictions to areas of traditional access. Restrictions frequently led to disputes and to considerable resentment and hostility of communities towards management agencies (Hough 1988), as well as expensive and ineffective management. In many cases, protected areas have failed to sustain the wildlife populations that they were designed to protect, while at the same time having a negative impact on the food security, livelihoods and cultures of local people (Ghimire and Pimbert 1997, Roe and Elliott 2004). Rural communities in developing countries are particularly vulnerable to the establishment of protected areas and possible exclusion from the area, since their livelihoods are often dependent on resources found in these areas (Rodgers 1989, Gadgil 1990, Mishra *et al.* 1992) and unlike in developing countries there is frequently no social security. Even if protected areas are established effectively, communities often settle adjacent to park boundaries, which lead to further confrontations between humans and wildlife.

Conserving large-bodied species, such as large carnivores and herbivores near human settlements, often involves costs to resident peoples (Mishra *et al.* 2003). These costs may include:

1. livestock predation by large carnivores: e.g. predation of livestock by snow leopard (*Panthera uncia*) in Spiti Valley, Himachal Pradesh, India (Oli *et al.* 1994, Mishra *et al.* 2003);

2. financial losses as a result of crop and property damage by large herbivores: e.g. crop damage caused by Nilgai deer (*Boselaphus tragocamelus*) and wild boar (*Sus scrofa*) in Sariska Tiger Reserve, Rajasthan, India (Sekhar 1998); and/or
3. injury, or loss of human life caused by wildlife: e.g. Sumatran tigers (*Panterhera tigris sumatrae*) caused 146 human deaths near protected areas in Sumatra, Indonesia, between 1978 and 1997 (Nyhus and Tilson 2004).

The above factors also relate to dolphin conservation because dolphins may be perceived as predators on local fisheries, and financial losses may occur if protected areas are established that excludes local people from fishing in particular areas.

It is now widely acknowledged that community participation is crucial to the long-term success of conservation strategies (Alpert 1996). To encourage local coexistence with wildlife, there is a need to estimate and offset the economic costs of wildlife conservation, and importantly, to make wildlife conservation beneficial to people (Prins 1992, Prins *et al.* 2000).

The feasibility of community-based conservation initiatives (Barrett *et al.* 2001, Berkes 2004), and the usefulness of establishing protected areas (Wilke *et al.* 2006) are still hotly debated. Recent attempts have been made to investigate strategies and incentives to increase local community cooperation with endangered species' conservation, primarily in terrestrial protected areas (Ferraro and Simpson 2001). These conservation incentives lie on a spectrum from indirect to direct, with respect to their conservation objectives (Ferraro and Kiss 2002), as discussed below**.**

10.1.1.1. Indirect approaches

Indirect approaches to conserve biodiversity include:

1. payments to encourage other land-use activities that protect habitat and supply biodiversity as a by-product, such as ecotourism, e.g., a community trust fund was established from revenue generated from mountain gorilla ecotourism at Bwindi Impenetrable Forest, Uganda. This fund was used partly for community development (Hamilton *et al.* 2000); and
2. payments to encourage economic activities that direct human resources away from activities that degrade habitats, such as integrated conservation and development programs (ICDPs) or 'conservation by distraction' (McShane and Wells 2004b), e.g., conservation of wildlife in Africa involves providing local employment and provision of community facilities such as dispensaries, schools, bore holes and roads in

exchange for the communities' support for conservation (Alpert 1996, Newmark and Hough 2000).

10.1.1.2. Direct approaches

Direct approaches to conservation of biodiversity include:

1. land purchase**:** e.g. land is purchased from local people for parks or reserves;
2. easements: e.g. owners agree to restrict land use in exchange for a payment;
3. concessions: e.g. conservation organisations bid against companies or developers, for the right to use government-owned land; and
4. lease or 'resource conservation agreements**'**: e.g. incentive-based alternatives that provide private landowners with compensation for conserving and managing wildlife habitats (Main *et al.* 1999, Ferraro and Simpson 2001, Ferraro 2002).

These direct approaches are more commonly used in developed countries than in developing countries (Ferraro and Simpson 2001, Ferraro and Kiss 2002)

Although various projects have been initiated to encourage community benefits, their success has been varied. Integrated Conservation Development Projects (ICDPs) offer the opportunity to promote socio-economic development, and conserve nature (Robinson 1993). ICDPs were first developed in the late 1990s (Brandon *et al.* 1998), and quickly became popular with NGOs and international funding agencies (Christensen 2004). This popularity was short-lived, as opponents of the concept stated that "*protecting biodiversity is fundamentally incompatible with economic development of any kind*" (Terborgh 1999). Questions were also raised regarding the contribution of ICDPs to biodiversity conservation from both ecological (Robinson 1993) and social perspectives (Ghimire and Pimbert 1997, McShane and Wells 2004b). Conceptual flaws in ICDPs also became obvious. Local people were more likely to incorporate new sources of income as complements to existing activities, rather than as substitutes for them (Ferraro and Kiss 2002). Convincing examples where ICDPs have effectively helped reconcile local people's development needs with protected area management remain difficult to find (McShane and Wells 2004b). Despite the lack of initial success of ICDPs, McShane and Wells (2004:7) state that

> "*no other approach has been more effective. Linking protected area management with the interests of local stakeholders remains one of the few widely applicable approaches to site-based biodiversity conservation that offers a realistic prospect for success…learning more lessons is less important than applying the ones that are already available*".

A summary of the primary constraints to a successful ICDP and potential solutions are listed in Table 10.1.

10.1.2. Project Evaluation

No matter what strategies for conservation management are implemented, evaluation will always be an essential component of management. Unfortunately, evaluation is too often neglected. For example, although a scheme of the Indian Wildlife Department existed to compensate villagers who lost livestock to snow leopards, an evaluation revealed that the scheme was ineffective, as a result of bureaucratic apathy, the time and costs involved in securing compensations, and low compensation rates (estimated to offset only 3% of the total loss) (Mishra 1997).

Table 10.1. A summary of the potential constraints to development and implementation of Integrated Conservation Development Projects (ICDPs), with a corresponding list of potential solutions to these constraints.

ICDP Constraints	ICDP Potential Solutions
• IDCPs are intrinsically limited in space, time and numbers of beneficiaries, while the main cause of biodiversity decline is the loss, fragmentation and degradation of habitat over large areas due to many kinds of different human activities (Sayer and Wells 2004).	• Cooperate and build relations with other agencies able to effectively address larger-scale threats. • Work on broad fronts that link site-specific activities with complementary activities designed to strengthen policies, institutions and governance (Sayer and Wells 2004).
• Over-optimistic goals and weak assumptions result in unrealistic expectations of project activities (Wells *et al*. 2004). • Lack of specified targets for conservation and development (Wells *et al*. 2004).	• Set general goals and targets and recognise that adaptability and learning will be required to reach them (*i.e.*, adaptive management) (Sayer and Wells 2004). • Ensure a mix of stakeholders are involved in the decision-making process.
• Less than optimal project design and execution (McShane and Wells 2004).	• Use qualified and experienced technical assistance and implementing personnel (McShane and Wells 2004). • Provide relevant training for local staff.
• Loss of linkage with development activities and conservation (McShane and Wells 2004).	• Refer to conservation goals during all development activities (McShane and Wells 2004).
• People incorporate new sources of income as complements to existing activities (McShane and Wells 2004).	• Develop legislation to restrict undesirable activities (McShane and Wells 2004). • Continue enforcement and monitoring of regulations and legislations (McShane and Wells 2004).
• Project staff unable to work in rural environments and are disrespectful of poor rural communities (McShane and Wells 2004).	• Encourage project staff to show humility and respect in their dealings with local interest groups and a fundamental commitment to an equitable relationship (Sayer and Wells 2004).
• Projects are not sustainable in the long-term and without donor support (McShane and Wells 2004).	• Commit to the process for the long-term (Sayer and Wells 2004), with a constant view towards eventual sustainability by communities. • Generate sustainable economic benefits without compromising the biodiversity conservation objectives should be a priority (McShane and Wells 2004). • Move at the pace of the slowest (Sayer and Wells 2004), with community training and capacity building being a major focus of project activities.
• Communities lose interest in the project and donors withdraw funding (McShane and Wells 2004)	• Involve communities in the initial project stages, preferably at their request. Provide good information about the project, and species of interest • Ensure everyone's expectations are realistic (Sayer and Wells 2004). • Ensure funding follows process and is adaptive (Sayer and Wells 2004).
• Ineffective conservation of biodiversity and non-achievement of project goals (McShane and Wells 2004).	• Analyse and act on threats to protected areas and endangered species at a variety of spatial scales. Function on a large enough scale to address local threats while also addressing the major threats to biodiversity (Wells *et al*. 2004). • Take an adaptive management approach incorporating research into conservation action. Integrate design, management and monitoring to systematically test assumptions in order to adapt and learn (Wells *et al*. 2004).

Table adapted from Sayer and Wells (2004), Wells *et al*. (2004) and McShane and Wells 2004).

10.1.3. Freshwater Conservation Strategies

As discussed in Chapter 3, freshwater species and habitats are undoubtedly among the most threatened in the world (Abell 2002). Protected areas are one strategy that may be used to protect mega-fauna and associated flora and fauna of freshwater habitats from immediate threats (Saunders *et al.* 2002). However, as mentioned in the introduction to this chapter, the simple creation of a protected area does not guarantee the long-term survival of vital ecosystems. Communities living adjacent to freshwater protected areas often do not suffer the same costs as communities living adjacent to terrestrial wildlife, such as large carnivores or herbivores (Saunders *et al*. 2002). Nonetheless, local livelihoods are still heavily reliant on freshwater resources. Freshwater protected areas will be affected at some level by activities occurring outside the area, or within the buffer boundaries (Saunders *et al.* 2002). As with terrestrial and coastal conservation, communities must be involved in developing and implementing freshwater conservation strategies, especially when local livelihoods may be lost through the establishment of a protected area (Baird and Flaherty 2005). Futhermore, there are significantly fewer freshwater protected areas than terrestrial or marine protected areas (Abell 2002). Even fewer examples exist of incentives to encourage community cooperation with freshwater dolphins and/or mega-vertebrate conservation and management.

In this chapter, I present details of an ICDP, named Dolphins for Development, that was trialled to increase co-operation of local communities towards conservation of Irrawaddy dolphins in the Mekong River using indirect conservation incentives (an ICDP and promotion of community benefit from dolphin-watching tourism)[19]. I discuss the potential effectiveness of these project components and introduce 'Community Conscious Conservation' as a concept to guide species and habitat conservation in Cambodia, and perhaps other developing countries. This project is the first to trial direct conservation incentives to conserve a freshwater dolphin species.

[19] Although there were various options for incentive programmes to be trialled, direct payments for conservation were not considered appropriate at this stage of the study, as a result of the uncertain and inequitable land-tenure, limited ability to enforce legal contracts, and limited local opportunity for nonagricultural investment or employment Ferraro, P. J. and A. Kiss (2002). "Direct payments to conserve biodiversity." Science **298**: 1718-1719.. These factors were accentuated by the objective of conserving an endangered freshwater species, which was mobile and affected by threatening processes both up- and downstream.

10.2. 'DOLPHINS FOR DEVELOPMENT': A CONSERVATION INITIATIVE IN CAMBODIA

10.2.1. Project Background

Chapter 3 provides a background to the Mekong River and introduces the Kratie to Khone Falls river stretch (190 km) as one of the most biologically important and diverse sections of the Mekong River.

As I have detailed in earlier chapters, my ecological studies indicate that the total population of Irrawaddy dolphins in the Mekong River is very small, numbering between 127 and 161 individuals (Chapters 5 and 6). Dolphins face numerous threats to their survival - primarily accidental entanglement in gillnet fisheries (Beasley *et al.* 2003) (Chapter 9). Dolphin groups exhibit high site fidelity, often being found year after year in the same small deep pool areas (often no larger than 2 km^2) (Chapter 7). A dedicated carcass recovery program established that mortality rates are unsustainable (*i.e.*, an apparent population decline of 4.8%/year) and without effective conservation initiatives the population could become extinct in the next 10-15 years (Beasley *et al.* 2003, Chapter 9). As a result of my research, the Irrawaddy dolphin sub-population in the Mekong River was recently classified as *Critically Endangered* by the IUCN, based on its small population size and range decline (Smith and Beasley 2004b).

As I outlined in chapter 3, the socio-economic conditions in Cambodia suggest that an integrated conservation development project might be successful at reducing fishing effort in critical dolphin habitats and encouraging community cooperation with freshwater conservation activities. The traditional social framework for making and implementing decisions is based on a village council system, with the head of village possessing the power to make decisions for the community. Fishing areas are generally public access, with few restrictions other than the prohibition of illegal fishing gears and practices (*e.g.*, electric and dynamite fishing, of use of gears less than 1.5 cm or greater than 15 cm). These restrictions are irregularly enforced, with continuing problems of corruption amongst all sectors. Communities adjacent to critical dolphin areas are poor, subsistence rural communities, with little to no access to toilets, freshwater or other livelihood options. Villagers were therefore eager to explore options for economic development and improvements in livelihoods. Additionally, I conducted extensive interviews throughout the lower Mekong River which determined that local perceptions of dolphins and conservation practices were positive (Chapter 4). Most local communities were eager for conservation to be undertaken (Chapter 4). The majority of people along the river do not intentionally harm dolphins.

10.2.2. Project Location

As I outlined in Chapter 7, Kampi Village is situated adjacent to Kampi Pool, which is the most southerly pool on the Mekong River regularly inhabited by dolphins. Kampi Village is located in Kratie Province, approximately 15 km north from Kratie Township. A total of 135 families live in Kampi Village (as of 2004), in small, wooden houses with no toilets or access to clean freshwater. Most villagers earn their living from a combination of fishing and farming, with some individuals collecting forest products many kilometres from their homes. Kampi Pool (adjacent to Kampi Village), is the most important dolphin habitat remaining in the river. Approximately 25-35 dolphins inhabit this area during the dry season (Chapters 6 and 7). Fishers use this pool to catch fish for their daily food requirements (primarily using cast nets, gillnets, hooks and traps). However, the pool was declared a protected area for dolphin conservation and tourism, by Provincial Decree (decreed by the Governor of Kratie Province) in 2001. This decision was made without consultation with the local community. Although prohibitions on fishing were in place, regulations were irregularly enforced by the relevant government departments.

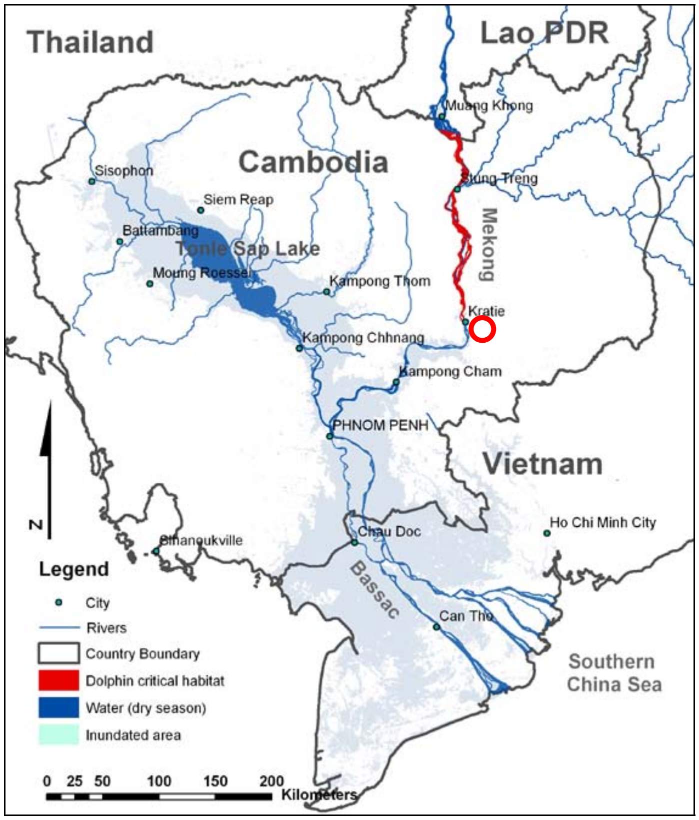


Figure 10.1. Location map of Kampi Village where the Dolphins for Development ICDP was implemented (indicated by the red circle).

10.2.3. Dolphin-watching Tourism

In the Mekong River, dolphin-watching tourism is facilitated by the reliable occurrence of dolphins in small deep water pools during the dry and wet seasons (Chapter 7). As discussed in Chapter 2, there are two locations where tourists can view Irrawaddy dolphins in the Mekong River: Chiteal Pool on the Laos/Cambodian border, and Kampi Pool in Kratie Province. Tourism was initiated at Kampi Pool in 1997 by an international NGO, Community Aid Abroad, with a local committee of seven villagers from Kampi Village. These seven villagers (and their families) were voluntarily moved from the area overlooking Kampi Pool, so the area could be informally designated as a 'tourist-viewing site'. From 1997-2000, viewing of dolphins was conducted sporadically from land, with no formal management. International tourists were also able to view dolphins by small row-boat, opportunistically, for a small fee (US$1), if a committee member was available. Normally, a guide was hired by the tourist in Kratie Township to facilitate communication between both parties. In 2001, the seven villagers changed the small row-boats to larger 'stand-up' paddle-boats with motors and sunshades over the boats for the tourists. These arrangements ensured tourist comfort and enabled dolphin viewing all year round (previously, when the current was strong during the wet season, the small row-boat was unsafe).

In 2002, the Kratie Tourism Department became formally responsible for dolphin-watching tourism at Kampi Pool and cooperated with the seven families. No other village families were allowed to participate in the venture and the financial benefits (50% of revenue) were distributed only to the seven families, with Kratie Tourism Department receiving the remaining 50% of revenue. Most villagers were therefore not able to participate in the tourism but had lost their rights to fish in the pool as a result of the prohibition by Provincial Decree. Conflict was rife and the seven families became segregated from all other villagers. Villagers who could not participate in the tourism were very hostile towards the villagers involved in the tourism and also became threatening towards the dolphins for loss of their fishing rights (villagers often implied during interviews that it would be better if no dolphins were in the area and it would be easy to get rid of them). No management plan existed for development of tourism and the boats were unregulated. Local people were unaware that the sound from the boat motors and the boats' activities had the potential to interfere with the dolphins' daily activities. Additionally, villagers were unable to communicate with foreign tourists and no information (verbal or printed) was provided to tourists regarding the dolphins, or their conservation status in the river. Thus, I perceived the situation at the time to be unmanaged, unregulated, and in a state of chaos, contributing little, if anything, to dolphin conservation or management.

As a result of benefits accrued through guesthouses, restaurants, and motor bike drivers taking tourists to the Kampi viewing site, Kratie Township slowly began to benefit financially from the tourism. However, this township is located 15 km downstream of Kampi Pool and most individuals and businesses are not directly involved in contributing to threats the dolphins were facing, or directly involved in dolphin conservation activities. Strategies therefore needed to be developed urgently to address both the threats to the dolphins in Kampi Pool and the unmanaged dolphin-watching industry.

10.2.4. Project Initiation and Methods

In January 2004, my colleagues and I conducted a series of initial workshops in four villages in Kratie Province: Kampi, Chroy Banteay, Sombok and Kbal Kampi Villages. The aim of these workshops was to update villagers on the research findings from 2001-2003, discuss each community's perceptions of threats to dolphins and the river system, and discuss each community's perceptions of dolphin-watching tourism in Kampi Pool. These workshops confirmed that the village most directly involved in the dolphin conservation was Kampi Village, situated directly adjacent to Kampi Pool. The three other villages are located either upstream, or downstream of Kampi Pool and therefore are not directly involved in fishing activities inside the pool, nor with the dolphin-watching tourism.

The conclusions of each of these four workshops were presented at a large stakeholder workshop (5th workshop), entitled '*Conservation and Management of Irrawaddy Dolphins at Kampi Pool, Kratie Province*'. The participants who attended were the Provincial Governor and Deputy Governors, all Kratie government departments, NGOs, and an Under Secretary of State (Council of Ministers) from Phnom Penh. Activities to conserve dolphins in the area and to manage the dolphin-watching tourism were discussed and potential management strategies formulated (Beasley 2005b).

These strategies were then presented back to Kampi Village in February 2004 (6th workshop), with the meeting attended by the British Ambassador to Cambodia (facilitated by the British Embassy, Phnom Penh, primarily funding the project) and the Provincial Governor. The workshop was facilitated by an individual from a government agency named SEILA (meaning '*foundation stone*' in Khmer Sanskrit), a Cambodian government agency dedicated to achieving a decentralised approach to rural development and poverty reduction. The involvement of these three high ranking individuals significantly raised the profile and credibility of the meeting. The aims of the meeting were to present strategies for management of the Kampi area developed at the stakeholder meeting in January 2004, discuss threats to dolphins and fisheries at Kampi Pool, formulate potential solutions to these threats, and discuss the current dolphin-watching tourism situation and how it could be improved.

The major conclusions from this 6th workshop were that:

1. the community was very unhappy at being prevented from fishing in Kampi Pool without adequate consultation;
2. the fishing restrictions forced local people from the village to conduct illegal fishing, an arrangement with which most villagers were uncomfortable
3. outsiders would often come to fish in the area, however, enforcement would nearly always arrive after the outsiders had already departed;
4. as a result of decreasing fish stocks, the community wanted to support the fishing regulations, however the villagers required assistance to develop alternative livelihoods if the prohibition on fishing was to continue; and
4. the community was extremely unhappy with the current tourism situation and requested some involvement in the industry.

10.2.5. Dolphins for Development Project

Based on the above factors, I developed and trialled an ICDP named Dolphins for Development, to facilitate conservation of dolphins and fisheries in Kampi Pool, while promoting diversification of local livelihoods and equitable distribution of revenue generated from the dolphin-watching industry. This ICDP was conducted simultaneously with my biological and social studies for this thesis (Chapters 4-9).

The Dolphins for Development ICDP consisted of four project components, which included rural development and diversification of livelihoods, promoting community benefit from dolphin-watching tourism; awareness-raising and education activities conducted through MDCP (see Chapter 4); and relationship building with government stakeholders (e.g., Department of Fisheries), to ensure their cooperation with the necessary project components.

10.2.5.1. Rural Development and Livelihood Diversification

As reported by Alpert (1995), most conservation NGOs are inexperienced with development activities: collaboration between conservation and development NGOs is suggested as a possible solution. In mid 2004, I enlisted the assistance of a local rural development organisation, the Cambodian Rural Development Team (CRDT), to begin the Dolphins for Development ICDP. CRDT comprised a group of four enthusiastic Cambodians from rural backgrounds, who had recently graduated from a local rural development university. CRDT also enlisted the assistance of up to five Cambodian volunteers from the university, to assist with project implementation. CRDT was coordinated and advised by an Australian volunteer, who had extensive experience in rural development and project management and who had previously taught the team members at the university. CRDT began project activities in 2001. CRDT had successfully completed three projects to assist inland rural Cambodian communities between 2001 and 2003. However, no biodiversity conservation element had been included in these initial projects. All team members were eager to assist poor, rural communities and showed great respect for rural Cambodians.

The development component of Dolphins for Development aimed to:

1. ensure dolphin conservation was beneficial to the local community through improved hygiene and access to freshwater;
2. offset the costs to local people of conservation programs already implemented prior to this projects inception (*i.e.* fishing restrictions in the protected area) through diversification of livelihoods;

3. reduce local fishing activity in and adjacent to, this important dolphin area; and
4. ensure project sustainability through training in all elements of project implementation.

My long-term relationship with the villagers was fundamental to this project. My research assistants and I had conducted dolphin research and awareness-raising activities in this village since 2001. Therefore, I had already established excellent relations with the community. It was also important that adequate funding had been secured before the project began, and the village chief approved CRDT activities to be conducted in the village. On the first day of the project, I organised a large village workshop to announce CRDT activities, with all CRDT and MDCP team members present. Throughout the workshop, I emphasised that we were assisting the village with development and livelihood diversification activities with the major goal of conserving both dolphins and fisheries (therefore emphasising the link between the two projects). The villagers were also aware that they had requested assistance for livelihood diversification through the series of workshops held in January and February 2004. Villagers therefore welcomed this assistance, rather than feeling as though it was being forced upon them.

A major emphasis of the development component was training of the villagers to undertake livelihood diversification activities and providing materials for infrastructure if required. In taking this approach, individuals often felt a greater sense of ownership with the project, rather than being simply provided with infrastructure and assistance. The main outcomes are listed in Table 10.2 and a selection of relevant images is provided in Figure 10.1.

Table 10.2. Summary of the objectives and outputs for the rural development and livelihood diversification component of the Dolphins for Development' project at Kampi Village, Kratie Province.

Objective	Output
(1) Ensure dolphin conservation was beneficial to the local community through improved hygiene and access to freshwater.	• 60 **toilets** constructed. • 8 concrete-ring lined **wells** constructed (by the beneficiaries). • 15 **rainwater collectors** constructed. • 5 **biodigestors**[20] constructed and installed.
(2) Offset the costs to local people of restrictions already implemented prior to this project's inception (*i.e.* fishing restrictions) through diversification of livelihoods.	• 2 **pigs** provided to 41 families. • 15 **ducks** provided to 75 families. • 5 **chickens** provided to 29 families. • **Vegetable seed distribution** for all 135 families. • 5 demonstration plots of **system rice intensification.** • **Mushroom production** training and implementation for 12 families.
(3) Reduce local fishing activity in and adjacent to this important dolphin area.	• 25 **fish ponds** constructed. • Fish ponds stocked with **fingerlings.**
(4) Ensure project sustainability through training in all elements of project implementation.	• 96 hours of **varied agricultural training** provided for all 135 villagers (and often neighbouring villagers), including **separate courses** on: - pig, chicken and duck raising - fish raising and pond maintenance - vegetable production - mushroom production - system of rice intensification - water and sanitation - biodigestor technology • Training the Village Development Committee (VDC) on their roles, responsibility, simple management tools and accounting skills • A study tour for 15 people including the VDC and 'model farmers' (farmers targeted for specific diversification activities).

Figure 10.2. Rural development and diversification of livelihood project activities: (left) crops being grown in the village, (middle) fingerlings being distributed to villagers for the land-based fish ponds, (right) a well constructed in the village to provide freshwater.

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[20] A **biodigestor** is a closed system that collects a gas that is generated by bacteria in the absence of air. When organic matter such as livestock faeces are used in the system, the gas is able to be collected and used in rural areas for cooking, thus conserving forest products that would otherwise be used.

10.2.5.2. Community-based Tourism

After the six community and stakeholder workshops in January/February 2004, I began the 'Kampi Community-based Tourism Project' in March 2004, as part of the Dolphins for Development project. The aims of the community-based tourism project were to:

1. promote community benefit from the dolphin-watching tourism, which had been implemented prior to this project's inception;
2. encourage effective management of this industry to minimise threats to the dolphin group inhabiting this area; and
3. promote visitor satisfaction and awareness raising of dolphin conservation and status.

Throughout all these activities, my colleagues and I worked closely with the Provincial Government, Kratie Department of Tourism, Kratie Commune Chief and Chief of Kampi Village. The objectives and outputs for this component are listed in Table 10.3 and selected images in Figure 10.2.

All activities were completed by the end of 2004. In December 2004, a written agreement was finalised and signed to ensure that a newly developed entrance fee (US$2/international tourist, US$0.15/national tourist) would be shared between the community (40%: for development activities), Department of Tourism (30%: to ensure maintenance of the tourism site) and Department of Fisheries (30%: for dolphin conservation activities). Critical to the success of this agreement was that the community had the capacity to manage the funds adequately and that all activities were accountable and transparent to avoid the potential for corruption at all stakeholder levels. CRDT played an essential role in this process through the establishment and development of a Village Development Committee (VDC) that was able to initiate an effective process for management.

Table 10.3. Summary of the objectives and outputs for the community-based tourism project component of the Dolphins for Development project, initiated at Kampi Village, Kratie Province.

Objective	Output
(1) Promoting community benefit from dolphin-watching tourism implemented prior to this project's inception.	• **Selling** children's colouring books and T-shirts at a restaurant in Kratie Township, where all the profits were directed to community development activities. • Development and training of a **Village Development Committee (VDC),** that was elected democratically in Kampi Village and is responsible for facilitating the ICDP and management of funds obtained from tourism activities. • Meetings with stakeholders involved, to secure an **agreement for the community to benefit financially** from the tourism through an entrance booth at the viewing site.
(2) Encourage effective management of this industry to ensure it does not threaten the dolphin group inhabiting this area.	• Various meetings with boat owners and other stakeholders to **develop and finalise boat operating guidelines.** • Construction of signboards at the Kampi viewing site clearly explaining **regulations** for boat use and tourist behaviour. • Initiation of a **visitor recoding system** at Kampi viewing site through **provision of a computer** to the Kratie Department of Tourism.
(3) Promoting visitor satisfaction and awareness-raising of dolphin conservation and status.	• Development of **educational materials** to raise national and international awareness of the dolphins and their habitat. • A two day **guide training course** to provide training for local guides from Kratie Township (including four individuals from Kampi village) • Providing **English lessons** to two young individuals from Kampi Villages to facilitate communications with tourists (these two also attended the two day guide training course). • **Infrastructure development** at the Kampi viewing site (e.g. toilets, car park, souvenir stalls, food stalls), to ensure its attractiveness for international and national visitors.

Figure 10.3. Examples of the community-based tourism project activities at Kampi viewing site: a sign constructed to inform tourists not to swim in the dolphin pool (left), development of regulations to minimise boat disturbance to the dolphins, such as operators paddling when dolphins are near the boat (middle), a toilet block constructed by CRDT (right), which tourists can use by paying a small fee for its maintenance.

10.2.5.3. Awareness Raising and Education

Although long-term conservation impacts are often slow to materialise (particularly those tackling habitat loss), and social and economic issues constantly need to be addressed, environmental education programs can have important short term outcomes and establish the foundation for future conservation efforts (Trewhella *et al.* 2005). Community awareness raising and education were integral components of the Dolphins for Development project and undertaken primarily by MDCP. Efforts focused on increasing local awareness of the importance of conserving dolphins, fisheries and their habitat in the Kratie to Khone Falls river section, increasing national and international awareness on the status of the dolphins in the lower Mekong River; and increasing national and international awareness related to dolphin-watching tourism in the Mekong River. The outcomes of these three objectives are listed in Table 10.4 and a selection of images provided in Figure 10.4.

Table 10.4. Summary of the objectives and outputs for the awareness raising and education component of the Dolphins for Development project, initiated at Kampi Village, Kratie Province.

Objective	Outputs
(1) Increasing local awareness of dolphin and fishery conservation in the Kratie to Khone Falls river section.	• A **poster** on the dolphin folklore to enhance local beliefs regarding the dolphins' close human origins. A **poster** illustrating the cetaceans found in coastal waters, with a feature on the Mekong dolphins. • A **children's colouring story-book**. The story of a Mekong dolphin 'family', to personalise the dolphins and their behaviour. • Dolphin and fisheries **conservation signs** located at three important deep water pools in Kratie Province (including Kampi Pool) (see Fig 10.5). • Employment of 19 local families along the river to record **dolphin distribution** on calendars provided (a black sticker on days they saw dolphins from the village/fishing and a red sticker if they did not see dolphins (Fig. 10.5). • Production of **dolphin conservation T-shirts** distributed to villagers that assisted with carcass collection (see Chapter 9) and other MDCP activities).
(2) Increasing national and international awareness of dolphin and fishery conservation in the lower Mekong River.	• A two hour **radio discussion** on dolphins and their conservation at a local radio station in Phnom Penh (in Khmer). • Production of an **article** that was published in a popular magazine in Cambodia (in Khmer). • Designation of the Irrawaddy dolphin population in the Mekong River as ***Critically Endangered*** by the IUCN (Smith and Beasley 2004a) • Four **popular articles** and two **peer reviewed** publications about the dolphins' status in the Mekong River. • Production of a **coloured leaflet** regarding MDCP and CRDT activities. • Creation of a **web-site** describing the MDCP and project activities (www.mekongdolphin.org).
(3) Increasing national and international awareness related to dolphin-watching tourism in the Mekong River	• **Educational signboards** at the Kampi viewing site and in Kratie Township (English and Khmer). • **Information posters** at restaurants and guesthouses in Kratie Township (English and Khmer). • Production of **dolphin postcards**. • Production of a **coloured leaflet** for distribution to tourists regarding dolphin biology and conservation status (English and Khmer).

Figure 10.4. Education and awareness-raising project activities: (left) construction of dolphin and fisheries conservation signs; (middle) a young boy holding a calendar his family was given to record dolphin distribution; (right) one of two educational signboards erected at the Kampi viewing site.

10.2.5.4. Strengthening Stakeholder Relationships

An important component of the project from its initiation in 2001 was my attempt to build and strengthen relationships with government departments and other stakeholders in Cambodia. All aspects of this study (biological, social and conservation) were conducted in co-operation with the Cambodian Department of Fisheries (a Department under the Ministry of Agriculture, Forestry and Fisheries), the agency which has the primary government mandate for dolphin conservation in Cambodia. At the time of my project, the activities of the Department of Fisheries were often constrained by un-trained personnel who had limited resources (e.g. boats, boat engines, fuel) to achieve their mandate of protection of riverine resources. The objectives of my collaboration with government departments were to strengthen the capacity of officials from the Department of Fisheries to conduct dolphin research and conservation activities; improve government awareness of the dolphin's status and potential conservation strategies; and enable regular enforcement of existing regulations regarding illegal fishing. The objectives and outcomes are listed in Table 10.5 and a selection of relevant images is provided in Figure 10.5.

Table 10.5. Summary of the objectives and outputs for the stakeholder relationship strengthening component of the Dolphins for Development project, initiated at Kampi Village, Kratie Province.

Objective	Output
(1) Strengthen capacity of Department of Fisheries' officials to conduct dolphin research and conservation activities.	• One **full-time Phnom Penh based** Department of Fisheries counterpart, hired by my project to assist project activities (2001-2004). • Two **full-time Fisheries Officers** from Kratie and Stung Treng Townships hired by my project to assist project activities (2003-2004). • Four **Part-time Fisheries Officers** from Kratie Township hired by my project to assist project activities (2002-2004). • A **two day workshop** conducted each year (2001-2005) to train local counterparts on survey methods. • **Continuous training** on survey methodology, use of global positioning system, and survey equipment throughout all surveys (2001-2005).
(2) Improve government awareness of the dolphins' status and potential conservation strategies.	• **Monthly reports** on project activities and results submitted to the Department of Fisheries, Phnom Penh and Fisheries offices in Kratie and Stung Treng Townships (2001-2004). • Detailed **stranding reports** submitted to the Department of Fisheries, Phnom Penh and Fisheries offices in Kratie and Stung Treng Townships within 3-5 days of a stranding event. • Production of a detailed **'Mekong Dolphin Conservation and Management Strategy'** that has since been adopted as national policy.
(3) Enable regular enforcement and patrolling of existing regulations on illegal fishing.	• Provision of **one boat and engine** to Kratie Fisheries Office. • Provision of **adequate funding for fuel and oil**, for the Kratie Fisheries Office to conduct 6 patrols in Kratie Province each month.

Figure 10.5. Stakeholder relationship building project activities: a boat and engine being donated to the Kratie Fisheries Office, with funding obtained from the British Embassy, Phnom Penh (left); a local counterpart being trained to use the camera for photo-identification of individual dolphins (middle: Chapter 6); increased patrols to ensure compliance with fishing regulations, such as the use of cast-nets which is a permitted fishing method (right).

10.2.6. Project Evaluation

An important component of the Dolphins for Development project that could not be completed was the project evaluation. Upon conclusion of the first stage of the project in December 2004, observable measures of success were:

1. increased infrastructure in the village;
2. the potential for diversification of livelihoods through provision of livestock and seeds;
3. increased capacity of villagers for infrastructure construction and livestock care;
4. community benefit from the dolphin-watching tourism through a community development fund;
5. creation of a functioning Village Development Committee (VDC), to democratically manage and distribute the community development fund;
6. apparent (but unquantified) reduction of fishing activity in Kampi Pool; and
7. increased frequency of enforcement and patrolling by the Department of Fisheries.

However, there is currently no quantifiable measure of success available. Interviews relating to the community's knowledge of dolphins, perceptions of dolphins and conservation and socio-economic status were conducted prior to implementation of the Dolphins for Development project. The next stage of the project will be to repeat the questionnaire, to assess the success/failure of various project components (to be completed in 2008).

10.3. DISCUSSION

The Dolphins for Development project was the first ICDP to be trialled in Cambodia and the first known to contribute towards the conservation of a freshwater dolphin species. Results from the project indicate that a multidisciplinary approach to conservation is essential, as is liaison with all stakeholders. It was important to continually reiterate to Kampi community the link between Dolphins for Development project and efforts to conserve the dolphins. Similarly, government involvement and support was important to ensure adequate enforcement of existing regulations, particularly the prohibition on illegal fishing gears and prohibiting outsiders from fishing in Kampi Pool. Initial results are encouraging, with very positive community feedback. This project provided a baseline of experiences from which future management strategies in Cambodia and abroad can be built.

10.3.1. The Potential for Conservation Success Using Integrated Conservation Development Projects

No previous studies are known that have trialled ICDPs to conserve freshwater dolphin or mega-vertebrate populations. ICDPs have been trialled extensively in terrestrial management, although many situations have met with limited success and a significant amount of criticism (McShane and Wells 2004b). As a result of the poverty in rural Cambodia and lack of government infrastructure to enforce regulations, ICDPs may be one of the few approaches that have any chance of contributing towards successful conservation of the Irrawaddy dolphin population and other flora and fauna in Cambodia. Ferraro (2001) has argued that paying individuals or communities directly for conservation may be simpler and more effective than the ICDP approach. This type of ‘conservation contracting’ can often simplify the achievement of conservation goals and strengthen the links between individual actions and habitat conservation, thus creating a local stake in ecosystem protection (Wells *et al.* 2004a). However, in Cambodia, as in other developing nations, the obstacles to implementing a direct payment system approach include uncertain or inequitable land tenure; limited experience with, and enforcement of, legal contracts; limited opportunities for non-agricultural/aqua-cultural investment or employment; potential displacement of biodiversity loss to other areas; and potential social conflict through direct payments to only a portion of the community (Ferraro and Kiss 2002). Additionally, conservation payments to individuals, such as for releasing a dolphin trapped in fishing gear may have a negative effect: people may begin to deliberately catch dolphins in anticipation of a monetary reward. Further obstacles exist with ICDPs in areas surrounding aquatic-protected areas, in that the species of conservation interest are often migratory and highly mobile, therefore, communities outside the ICDP focus area also become involved.

Wells *et al*. (2004: 416-417) set-out characteristics of ICDPs that have shown some success. These are compared with activities included in the Dolphins for Development project (Table 10.6). Factors that assisted with the implementation of this project included:

1. immediate threats to the dolphins were localised (e.g. accidental gillnet entanglement) and outside factors (e.g. habitat degradation) were not a major consideration in the preferred dolphin habitat;
2. as a result of the remoteness of the study area, communities were generally small and isolated;
3. community training throughout all aspects of CRDT project activities (e.g. fish culture, livestock raising, agriculture) and relationship building were a major focus to ensure project sustainability; and
4. all project activities were linked with the primary aim of assisting to conserve fish stocks, which local communities rely upon for subsistence fisheries.

Although apparently initially successful in many aspects, the project showed some potential constraints to effective implementation, which included:

1. a lack of confirmed long-term funding for adequate development activities;
2. insufficient linkages established between development and conservation activities;
3. inadequate enforcement and patrolling of regulations by the Department of Fisheries;
4. increasing usage of the area by outsiders who were moving into the village, or fishing in the protected area; and
5. wet season flooding in the villages, which hindered various development activities (e.g., agriculture, livestock and wells)[21].

A comprehensive evaluation of the Dolphins for Development project has not yet been undertaken. Nevertheless, the integration of all project components (e.g. rural development, diversification of livelihoods, community-based tourism, awareness raising and education, and strengthening stakeholder relations) appear to significantly benefit the community from Kampi Village and to raise local and national awareness of the importance of dolphin and fishery conservation. Despite the limitations outlined, this trial project has provided a comprehensive basis from which further conservation actions can be developed along the upper Cambodian Mekong River.

[21] Through personal experiences, I believe the long-term success of project activities was constrained by: (1) local and international agencies and organisations becoming involved in dolphin conservation primarily because of the potential for donor-funding and/or improving government relations - with little, to no genuine commitment to effective conservation, and importantly, (2) high level government politics interfering with conservation activities, with a focus on dolphin-watching tourism potential rather than conservation (see Chapter 11).

Table 10.6. Characteristics of successful ICDPs and comparison with the Cambodian Dolphins for Development ICDP.

Characteristics of Successful ICDP Projects (Wells *et al*. 2004)	**'*Dolphins for Development*' ICDP**
(1) Clearly articulated **objectives** of the Protected Area (PA) and the external intervention.	• The primary objective of the project was conveyed to all stakeholders.
(2) Building **alliances** with and among **local communities** to help establish trust.	• The Mekong Dolphin Conservation Project (MDCP) had been building relations with local communities since 2001. • The Cambodian Rural Development Team (CRDT) team consisted of local enthusiastic Cambodian nationals and an Australian project coordinator. Team members were from rural backgrounds and respectful of local communities, understood the importance of building good relations and had a long-term commitment to poverty alleviation.
(3) Building coalitions for conservation by engaging with stakeholders who can help address **broader development-related issues** and constraints beyond the scope of site-specific projects.	• A long-term Mekong dolphin conservation project had been initiated in Cambodia, supported by major non-government organizations (NGO) (e.g. World Wildlife Fund (WWF) and the World Conservation Union (IUCN)), that provided funding for development projects, supported enforcement and patrolling of regulations, and attempted to address wider scale issues affecting dolphin conservation.
(4) Supporting **capacity building** for independent local planning and action among emerging community-based organisations whose activities are linked to adjacent protected areas.	• An international NGO (WWF) was assisting with capacity building of CRDT to assist with future project implementation. In addition, CRDT established a Village Development Committee at Kampi Village, to address development issues.
(5) Increasing the **capacities** of the PA and resource management agency staff and facilitating **better relations** between these staff and local communities: helping reorient PA guards to be more sympathetic to local needs.	• All project activities were undertaken in close partnership with Cambodian Department of Fisheries' officials. Support was provided by MDCP for enforcement and monitoring, with community interests and relations emphasised.
(6) Opening lines of **communication** with local sectoral government agencies that are in a position to deliver key services to PA residents and neighbours.	• The Cambodian government (primarily through the Department of Fisheries), was creating dolphin/fisheries protected areas, to provide some legal backing to restrict fishing activities. Additional linkages were developed with other government agencies (e.g. Ministries of Tourism and Environment)
(7) Supporting basic **environmental education** to broaden and deepen the constituency of support for biodiversity conservation.	• Mekong dolphin research, conservation and awareness raising activities were undertaken by MDCP which cooperated with all CRDT project activities (workshops, meetings and trainings) to increase awareness about dolphin and riverine conservation, thus creating a direct link between development and conservation.
(8) Raising **local awareness** of the extraordinary values of local biodiversity and the importance of conservation.	• MDCP had been working to raise local awareness of the importance of riverine conservation since 2003 through workshops, and publications such popular magazines, posters and children's books.
(9) Supporting carefully selected, tentative, small-scale **pilot income generating activities** with genuine local support, real prospects of sustainability and clear benefits for biodiversity conservation.	• Small-scale agricultural revenue generating activities (e.g. mushrooms and small livestock production) were initiated by CRDT. MDCP worked to secure community benefit from existing dolphin-watching tourism.

10.3.2. Community-based Tourism Initiatives

Ecotourism world-wide is experiencing a growth rate of 10-15% per year and is one of the largest industries in the world (Scheyvens 1999). While some emphasise the potential for ecotourism to promote the well-being of both local peoples and the environment (Hvenegaard 1994), others caution that ecotourism is often merely used as a marketing tool (Thomlinson and Getz 1996), with revenue and/or benefits rarely reaching local communities (Bookbinder *et al.* 1998). This situation existed at Kampi Village, prior to 2003. Many international tourists made comments to me about how tourism must be significantly benefiting both the dolphins and the community. In reality, tourism served to alienate, rather than benefit, the local community.

Throughout the Dolphins for Development project, the integration of development and dolphin-watching tourism not only provided financial benefit to the community, but also contributed to resolve community conflict and tensions. Many of the problems that were encountered with the tourism situation, such as community conflicts, inappropriate boat usage around the dolphins, and inadequate information to tourists, would have be avoided if a system of appropriate management had been put in place by the agencies that first established the dolphin-watching tourism. The situation is still inadequate with only a small proportion of the village being allowed to take tourists out to view the dolphins and obtain direct profits for their household. Nevertheless, equity has improved.

A community-based approach to ecotourism recognises the need to promote both the quality of people's lives and the conservation of resources (Scheyvens 1999). This concept was a major focus of my project. Villagers in Kampi and surrounding communities were able to observe and experience the direct financial benefit from conserving dolphins in the area. The education and awareness programs that MDCP developed also emphasised to communities that if there are no dolphins, the opportunity for tourism will be lost for future generations. The integration of these awareness-raising programs with tourism has been essential to elicit community support for my project. In addition to the financial benefits accrued by the dolphin-watching tourism industry through the community fund, villagers have also benefited significantly through feeling empowered about their ability to manage and control their dolphin-watching industry. Prior to this project, the Kratie Tourism Department dictated regulations and did not involve the community (apart from the seven families that owned the boats) in decision-making processes. However, with the development of the VDC (which was democratically elected), villagers can now voice their concerns and participate in, and manage, their dolphin-watching industry.

Akama (1996) suggested that ecotourism initiatives that empower local people, while contributing to natural resource conservation are needed. Scheyvens (1999) devised an empowerment framework to evaluate the of ecotourism initiatives. The Kampi project is compared with this framework in Table 10.7.

Table 10.7. Summary of the dolphin-watching tourism at Kampi Pool and my perceived levels of community empowerment resulting from the Mekong River Dolphins for Development project.

	Situation '**before**' the community ecotourism project (classic signs of disempowerment: from Scheyvens 1999)	Situation '**after**' the community ecotourism project (classic signs of empowerment: from Scheyvens 1999)	Dolphins for Development project **evaluation** and potential for empowerment
Economic empowerment	• Ecotourism results in small, spasmodic cash benefits mainly to local elites and outside operators/government. • Many locals have no access to ecotourism benefits because lack capital and skills.	• Ecotourism brings lasting gains to the community. Cash earned is shared between households. • Visible signs of improvements from ecotourism income (e.g. revenue deposited into a community fund).	• **Minimal economic empowerment**: direct ecotourism beneficiaries remain the seven families and government offices. • Most villagers still do not receive direct monetary benefit.
Psychological empowerment	• Many people excluded from the benefits of ecotourism, yet facing hardships because of reduced access to the resources. • Villagers confused, frustrated, disinterested and/or disillusioned with the initiative (e.g. inability to fish because of the protected area).	• Self-esteem of community members enhanced from outside recognition of the uniqueness and value of their natural resources. • Community members more confident to seek out further education and training opportunities. • Employment and cash increases status for traditionally low-status sectors of society, e.g. women and youths.	• **Positive psychological empowerment**: increased awareness of the uniqueness of their area through workshops and awareness raising. • Villagers organised local NGO to provide English teaching for young children to have future jobs as guides. • Youths have increased importance in society.
Social empowerment	• Disharmony and social decay. Resentment and jealousy are commonplace.	• Ecotourism enhances the community's equilibrium. • Community cohesion is improved, villagers work together to build a successful ecotourism venture.	• **Positive social empowerment**: less disharmony and social decay. • Apparent increased positive perceptions towards dolphins. • One building was constructed from community funds, where villagers are able to sell handicrafts.

Political empowerment	• Agencies implementing the ecotourism venture treat communities as passive beneficiaries, failing to involve them in decision-making. • Villagers feel they have minimal say over ecotourism initiatives.	• Community's political structure provides a forum where people can raise questions about the ecotourism venture and deal with their concerns. • Agencies implementing the ecotourism venture seek out the opinions of community groups and provide opportunities for them to be represented on decision-making bodies.	• **Positive political empowerment**: through creation of the Village Development Committee (VDC), the community now has significantly more power over decisions related to ecotourism. • A member from the VDC is now present at all relevant meetings and included in the decision-making process.

This table is based primarily on the theory developed by Scheyvens (1999), with my project evaluation summary of the Mekong Dolphins for Development project.

My evaluation of the MDCP based on the empowerment framework developed by Scheyvens (1999), suggests that benefits from the project are evident but the situation is still far from ideal and limitations are still apparent (Table 10.8).

Table 10.8. Summary of the limitations encountered in the community-based tourism project at Kampi Village and the potential solutions that could be implemented.

Limitations	Potential Solutions
(1) Little 'direct' financial benefit to individual families from the dolphin-watching tourism. Revenue only goes to a community fund.	• All families in the village should be organised in groups (e.g. 10 groups of 13 families) and each group follow a rotation schedule for boat hire. This arrangement would allow each group a specified period of time to operate the boats, with the revenue being distributed equally among the families.
(2) Inadequate compliance of boat operator regulations, particularly motor use.	• Buoys should demarcate the important dolphin area. • All boats operating around dolphins should be provided with a boat licence, after a day of training on rules and regulations of boat use around the dolphins. • If a boat operator uses a motor inside the buoys, a warning should be given. Upon a second warning, the licence should be revoked for a pre-determined period .
(3) Inadequate enforcement of boat operator regulations, particularly motor use.	• The tourism police[22] stationed at the site daily should be provided with some financial benefit for their work, contingent on the requirement that they adequately enforce the regulations (currently the police do not receive an extra wage for patrolling the site).
(4) Dolphins are harassed daily by tourism boats.	• A study needs to be conducted immediately on the potential effects of dolphin-watching tourism boats on the dolphins' behaviour. Expansion of dolphin-watching tourism to other pools along the lower Mekong River should be prohibited until this study has been conducted.

[22] The tourism police are an official branch of the Cambodian Police Force, that are directly responsible for the safety and well-being of foreign tourists to Cambodia.

Positive steps have been made to provide benefits to the local community and to reduce pressure on the dolphin population caused by constant boat harassment. The local community is now beginning to gain some financial benefit from the dolphin-watching tourism and is also gaining an interest in dolphin conservation for intrinsic reasons, as a result of the education and awareness programme. However, economic and political pressures will continue to increase from national and international agencies, which have a short-term financial benefit as a major focus, and little concern for conservation of the dolphin population in the Mekong River.

10.3.3. Community Conscious Conservation

Most current conservation issues are symptoms of large, more complex problems that are beyond the scope of any one discipline (Kessler *et al.* 1998). Successfully addressing these issues requires a diverse range of skills and activities (e.g. environmental education, ecological research, management, legislation and enforcement) coupled with effective partnerships between organisations with these skills (Jacobson 1995, Kessler *et al.* 1998) and regular program evaluation (Ehrenfeld 2000, Kleiman *et al.* 2000). Effective conservation projects, especially in developing countries, therefore also require:

1. an integration of conservation and development;
2. enforcement from mandated agencies (particularly to assist with prevention of illegal fishing from outsiders);
3. liaisons with relevant government departments and stakeholders;
4. continued research on the target species and/or habitats; and
5. innovative conservation strategies.

These components may be beyond the scope of simply assisting with development and livelihoods in communities. For any management plan developed to implement these strategies, important factors to consider are:

1. clearly stated objectives;
2. explicit and testable assumptions;
3. tangible conservation targets;
4. stakeholder involvement;
5. effective and relevant evaluation;
6. flexible, adaptive implementation; and
7. effective long-term commitment of resources and technical assistance (Wells *et al.* 2004a).

It is essential that the managers involved fully understand all aspects of the situation at hand, have a good knowledge of projects trialled in other regions to conserve other species, and are able to develop appropriate management plans and adapt strategies accordingly.

Wells *et al*. (2004:409) note that "*the notion that biodiversity can be conserved without considering local peoples' needs and aspirations' is simply not viable*". Conservation of endangered species in developing countries is a multifaceted and complex process, where social, economic and political factors often have significant influence on the conservation process. Based on the trial Dolphins for Development project in Cambodia, it is clear that conservation strategies need to be multidisciplinary and forge excellent relationships with all stakeholders involved (from local community members to national and regional government agencies). Additionally, project evaluation and adaptation are essential components of any management strategy developed. Although community involvement in conservation is fundamental to the success of a management strategy, focusing activities at only one level (either local or national) will often be insufficient to ensure effective species conservation.

I therefore propose '*community conscious conservation*' as an appropriate term encompassing the fundamental requirement of community involvement with conservation of endangered species and habitats (particularly in developing countries), while addressing other factors of importance. Community conscious conservation emphasises community involvement and consideration of community issues as fundamental to project success, however, also recognises that other stakeholder levels must be integrated into the conservation process.

To conserve endangered species adequately, specific threats (both direct and indirect) must be identified, and then appropriate programs developed to mitigate these threats. As an example, a main cause of biodiversity decline is most often reduction, or change in habitat and isolation of wildlife populations (Pletscher and Schwartz 2000). In much of the world, these problems can ultimately be attributed to increases in human population and per capita consumption. The world's human population is currently approximately 6 billion and is growing at a rate of 3 people per second, or approximately 250,000 people each day (United Nations 1999). Despite continued human population growth, taking away the freedom of humans to reproduce is not morally acceptable, socially feasible, or politically possible in many countries (Pletscher and Schwartz 2000). However, it is possible to raise local awareness that birth control methods are available and initiate programs to provide birth control and relevant information, when requested.

Community conscious conservation, encompassing locally based, on-the-ground initiatives would ideally be combined with a '*comprehensive conservation cooperative programme*' that targets regional, national, and international factors relevant to conservation. These factors are necessary to ensure that high-level policy-making, management agencies are appropriately involved. Additionally, learning by experience through adaptive management, where successes and failures are explicitly stated, is a fundamental part of a projects' implementation (Mace and Hudson 1999). Based on the trial of the Dolphins for Development project in Cambodia, my suggestions regarding the various project components necessary for future conservation efforts are summarised in Table 10.9.

Table 10.9. Local and national conservation programs required and the necessary components of each programme.

Conservation Programme	Necessary Components
Community Conscious Conservation	(1) Local livelihood diversification through ICDPs (2) Community-based tourism (3) Local education and awareness raising (2) Health and midwifery programs (4) Co-ordination with local stakeholders (5) Continued research and monitoring (6) Project evaluation, adaptation and reporting
Comprehensive Conservation Cooperative Programme	(1) Developing appropriate national legislation (2) Managing trans-boundary conservation issues, rationalising ecologically and culturally relevant scales

Whatever management approach is used (depending on resources available), successful conservation of endangered species and habitats in developing countries (such as the Irrawaddy dolphin population in the Mekong River), will require provision of some incentive for conservation to local communities, while also addressing the biological, economic and political factors relevant to each unique situation. Importantly, evaluation is a critical component of any conservation project, where both successes and failures must be presented to various stakeholders, including the scientific community, if valuable lessons are to be learnt for future projects.

10.4. CONCLUSIONS

The work described in Chapter 10 aimed to investigate social considerations influencing conservation strategies and trial an ICDP conservation initiative (thesis objective 5: see Chapter 1). A summary of the major conclusions from Chapter 10, are listed below.

- Strategies necessary to conserve endangered species and habitats are complex and vary according to the biological, social, economic and political considerations of each situation.
- Conservation projects have previously trialled a combination of direct and indirect approaches. Education and awareness-raising are also important elements.
- Few previous projects are known that have trialled a combination of conservation strategies, which include conservation incentives, to local communities.
- An integrated conservation and development project named Dolphins for Development was trialled in Cambodia to assist with conservation efforts towards Irrawaddy dolphins that inhabit the Mekong River. Project components included rural development and diversification of livelihoods, community-based ecotourism, education and awareness raising, and strengthening stakeholder relationships.
- As a result of time limitations, no formal project evaluation was possible. However, several observable measures of success were evident, and are discussed in '*10.2.6. Project Evaluation*'
- Limitations to the development and livelihood diversification component of my project were evident. These constraints are discussed in '*10.3.1. The Potential for Conservation Success Using Integrated Conservation Development Projects*'
- Limitations to the community-based tourism component of my project were evident. These constraints are discussed in '*10.3.2. Community-based Tourism Initiatives*'
- To conserve endangered species in developing countries, some incentive must be provided to local communities.
- 'Community conscious conservation' is a term that I developed to describe multidisciplinary on-the-ground conservation programs that work towards integrating communities with conservation of endangered species and habitats.
- A 'comprehensive conservation cooperative program' is required to integrate local conservation efforts with regional and national conservation priorities and decision-making.
- Chapter 11: Table 11.8 summarises the main research and conservation implications from Chapter 10.

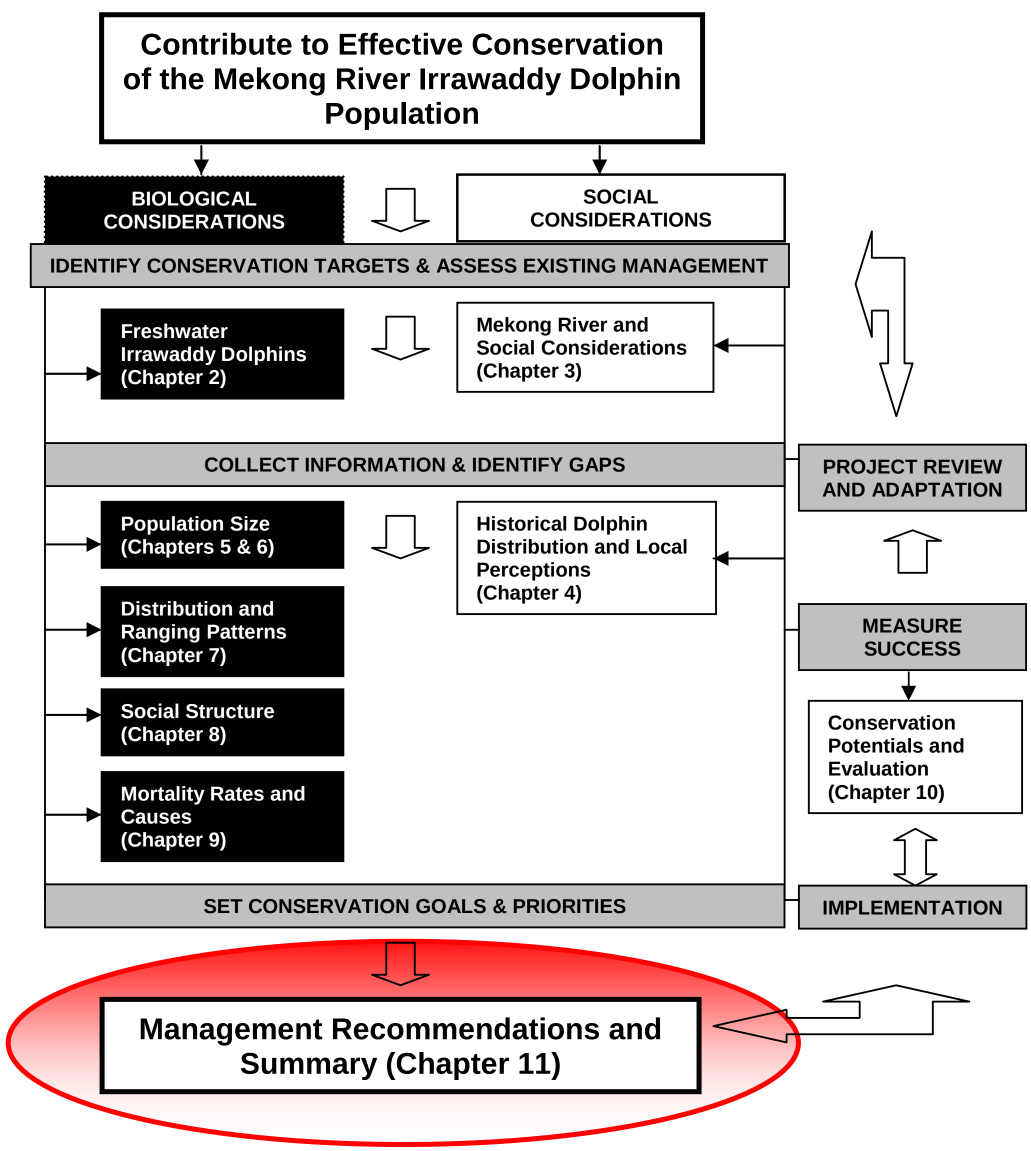
11. CONSERVATION AND MANAGEMENT OF THE IRRAWADDY DOLPHIN POPULATION THAT INHABITS THE MEKONG RIVER

The goal of my PhD research was to *contribute to the effective conservation of the Irrawaddy dolphin population that inhabits the Mekong River*. The aims of my study were to contribute towards a comprehensive understanding of the population biology of Irrawaddy dolphins that inhabit the river, and to investigate the social considerations directly relevant to the long-term conservation of this population. In this chapter, I outline the major results of my study and describe how these results achieved my six main study objectives. I then present my recommendations for future biological research, socio-economic studies and management.

An adult Irrawaddy dolphin from Kampi Pool, Kratie Province, Mekong River. Photo: Laura Morse

11. CONSERVATION AND MANAGEMENT OF THE IRRAWADDY DOLPHIN POPULATION THAT INHABITS THE MEKONG RIVER

Chapter 11 combines the biological and social considerations from my thesis in the context of the '*setting conservation goals and priorities*' section of my conceptual framework. The aim of Chapter 11 is to development management recommendations that will contribute to effective conservation of the Irrawaddy dolphin population inhabiting the Mekong River (thesis objective 6: see Chapter 1).



11.1. INTRODUCTION

The conservation of endangered species is a significant challenge, particularly in developing countries. Challenges result from: (1) the competition between species and humans for limited resources; (2) the poverty of subsistence communities, that lack basic education, health, sanitation, food security and clean drinking water; (3) communities perceiving endangered species as direct threats or menaces and therefore not participating in conservation actions; (4) individual people actively hunting and/or collecting flora and fauna for food, or to sell for revenue; and (5) local governments typically being under-staffed, inadequately resourced and facing the challenges of corruption, lack of adequate governance, and politically driven conservation decision-making. As a result of these factors, national priorities often focus on increasing basic human living standards, without major consideration of environmental concerns. Neither traditional conservation management strategies, nor those used by developed nations, can operate effectively in such situations.

Effective conservation requires consideration of biological and social factors, combined into an adaptive long-term management strategy. As outlined in Chapter 2, freshwater dolphins are among the most threatened of cetaceans. Freshwater dolphins directly compete with humans for freshwater resources, resulting in significant and increasing threats to their survival. Despite the precarious status of Asian freshwater dolphin populations, very little rigorous scientific study has been conducted on them and few on-the-ground long-term conservation efforts have been implemented. The importance of habitat preservation to species conservation is discussed in Chapter 3. Habitat preservation is a major consideration for effective management, as endangered species have little chance of survival if their habitats do not remain intact. Although dolphins primarily occur in the 190 km river section from Kratie to Khone Falls, if dolphins are to be sustained in the long-term, conservation and management of downstream areas important for migrating fish (such as Tonle Sap Great Lake) should be promted whenever possible.

The goal of my study was to *contribute to the effective conservation of the Irrawaddy dolphin population that inhabits the Mekong River*. To meet this goal (recognising that conservation planning needs to be effective within a scientific, social and political framework), I developed a conceptual basis to my study by considering the five principles for effective aquatic mammal conservation (Meffe *et al*. 2000), integrating these five principles into a seven step conservation process (Margoluis and Salafsky 1998), and adapting the seven steps of effective planning for biodiversity conservation (Groves 2003) (as discussed in Chapter 1). The results obtained from my study have resulted in significant new knowledge of the taxonomic status of the genus *Orcaella*, and the ecology and conservation of the Irrawaddy dolphin population inhabiting the

Mekong River. The preliminary result of my research in 2004, was developing the 'Mekong Dolphin Conservation and Management Plan'. This plan outlined comprehensive recommendations for future research and conservation actions (Appendix IV). My strategy was presented to the Cambodian Department of Fisheries (DOF) in September 2004 and adopted as national policy by the Ministry of Agriculture, Forestry and Fisheries (MAFF) in January 2005 (Appendix V: although see '*11.2.9. Objective 9*', below, for further discussion on the final DOF strategy).

11.2. MAJOR RESULTS OF THE STUDY

My study has two main aims:

1. to contribute towards a comprehensive understanding of the population biology of Irrawaddy dolphins that inhabit the Mekong River; and
2. to investigate social considerations that are directly relevant to the long-term conservation of the population.

To achieve these aims, I developed six primary objectives based on my conceptual framework. The major results of my study are described below.

11.2.1. Objective 1. Determine the current status and biodiversity importance of freshwater Irrawaddy dolphin populations (Chapter 2).

To determine the current status and importance of freshwater Irrawaddy dolphin populations, I reviewed all available published and unpublished literature on Irrawaddy dolphins from throughout their range (both coastal and freshwater habitats). At the start of my candidature, I conducted fieldwork in two of the five freshwater Irrawaddy dolphin sites in Asia (Chilka and Songkhla Lakes: Beasley *et al*. 2002) and coastal marine sites in East Malaysia (Beasley and Jefferson 1997) and Malampaya Sound, Philippines (Smith *et al*. 2003). I focused on fieldwork in the Mekong River of southern Laos, Cambodia and Vietnam from 2001-2005. I also incorporated data obtained as part of this thesis, which describes a new species of dolphin from Australian waters, the Australian snubfin dolphin (Beasley *et al*. 2005: Appendix I, Beasley *et al*. 2002: Appendix II). Table 11.1 summarises the main research and conservation implications of Chapter 2[23]. The primary research findings from Objective 1 are:

1. all freshwater Irrawaddy dolphin populations are small and declining;

[23] All tables are placed at the end of this Chapter, so as to not disrupt the flow of the text.

2. threats to the survival of freshwater Irrawaddy dolphin populations continue to intensify;
3. there has been a notable lack of on-the-ground conservation measures to halt population declines; and
4. Irrawaddy dolphins should be considered an effective flagship species for freshwater biodiversity conservation.

11.2.2. Objective 2. Provide information on the study area and justification for why habitat conservation should be a major priority (Chapter 3).

My study area was the lower Mekong River of southern Laos, Cambodia and Vietnam. To provide a background to the study area and illustrate issues affecting successful conservation, I reviewed and discussed the published literature. Table 11.2 summarises the main research and conservation implications of Chapter 3. The primary research findings from Objective 2 are:

1. all lower Mekong countries are developing quickly and experiencing significant human population growth, which exerts additional stresses on natural resources;
2. conservation lessons need to be learnt from other countries;
3. community involvement in conservation is imperative; and
4. preservation of a functioning ecosystem is essential to endangered species conservation, as well as for the survival of subsistence rural human communities and associated fauna and flora.

11.2.3. Objective 3. Investigate the historical status of the population and reasons for any population change using local knowledge (Chapter 4).

The historical status of Irrawaddy dolphins in the Mekong River and local knowledge and perceptions towards dolphins and conservation were investigated using a structured questionnaire. This study represents one of the first attempts to quantify historical distribution of a riverine dolphin species by using interviews with local communities. Table 11.3 summarises the main research and conservation implications of Chapter 4. The primary findings from Objective 3 are:

1. reports indicate a significant decline in dolphin occurrence and abundance throughout the lower Mekong River;

2. most local communities revere dolphins in the river and have positive perceptions towards conservation of dolphins and fisheries. As a result, local communities should be involved in conservation strategies, whenever possible; and
3. interviews with local communities can provide important information regarding species and their habitats which would take researchers years, if not decades, to obtain.

11.2.4. Objective 4a. Obtain estimates of total population size (Chapters 5 and 6).

I estimated absolute abundance of Irrawaddy dolphins in the Mekong River using capture-recapture analysis of photo-identified individuals (Chapter 5), line-transect, and direct count methodologies (Chapter 6). I compared these three survey methodologies to investigate the most appropriate survey technique for accurate and precise long-term monitoring. My abundance surveys represent the first trial of line-transect methodology for an Asian river dolphin population and the second capture-recapture population estimate of an Irrawaddy dolphin population. Photo-identification studies were conducted in the Kratie to Khone Falls river section. No dolphins were sighted south of Kratie Township (Chapter 5).

Boat surveys were undertaken throughout the lower Mekong River to provide estimates of abundance with which to compare capture-recapture estimates (Chapter 6). A combination of line-transect and direct count boat surveys were undertaken in the Kratie to Khone Falls river section. Line-transect surveys were undertaken from Kratie Township and south to the Vietnamese Mekong Delta. Land-based observations were undertaken in the Kratie to Khone Falls river stretch to investigate the feasibility of boat surveys to estimate abundance reliably. The main research and conservation implications of Chapters 5 and 6 are summarised in Tables 11.4 and 11.5 respectively. The primary research findings from Objective 4a are:

1. direct count estimates of abundance are inaccurate and imprecise. Direct count methodology is not recommended for future monitoring;
2. a combination of capture-recapture and line-transect methodologies resulted in an estimate of 127–161 (range: 89–289) individual dolphins inhabiting the Mekong River (as of April 2005);
3. photo-identification is the preferred methodology for long-term monitoring;
4. the population is worryingly small, and vulnerable to local extinction.

11.2.5. Objective 4b. Obtain baseline data on ranging patterns and habitat use (Chapter 7).

Individual Irrawaddy dolphins exhibit extremely high site fidelity. Analysis of ranging patterns for the 15 most frequently sighted photo-identified individuals yielded a mean area range per dolphin of only 16.0 km^2 in the dry season (range = 0.7–73.0 km^2) and 42.0 km^2 in the wet-season (range 0.9–99.0 km^2). Table 11.6 summarises the main research and conservation implications of Chapter 8. The primary research findings from Objective 4b are:

1. Irrawaddy dolphins inhabiting the Mekong River regularly occur in 9 deep water (>10 m in depth) habitats, along the Kratie to Khone Falls river section during the dry season;
2. During the wet season, most dolphins from Koh Pidau and Kampi are associating at Phum Kreing primary area;
3. individual dolphins exhibit extremely high site fidelity; and
4. Chiteal and Stung Treng communities are isolated from each other, and both are isolated from Koh Pidau and Kampi communities.

11.2.6. Objective 4c. Obtain data on school dynamics and social structure (Chapter 8).

School dynamics and social structure of photo-identified Irrawaddy dolphins in the Mekong River were investigated during boat surveys in the Kratie to Khone Falls river stretch. No dolphins were sighted south of Kratie Township. Temporal variation was assessed and mathematical models were applied to determine the association that best described their social structure. Table 11.7 summarises the main research and conservation implications of Chapter 8. The primary research findings from Objective 4c are:

1. the Irrawaddy dolphin population inhabiting the Mekong River is highly structured, with the majority of individuals having preferred, long-term associates;
2. the population is now separated into four communities. Two of these communities (Chiteal and Stung Treng), are seemingly isolated from each other, as well as from Koh Pidau and Kampi communities.

11.2.7. Objective 4d. Obtain data on mortality rates and causes (Chapter 9).

To obtain data on Irrawaddy dolphin mortality rates and causes in the Mekong River, I initiated a dedicated carcass recovery program in 2001. This program consisted of a necropsy program to collect samples and measurements from all recovered dolphin carcasses, as well as awareness-raising activities with local communities on the importance of reporting dolphin carcasses. Information obtained from this program contributed to: (1) the IUCN Red Listing of the Mekong population as *Critically Endangered* (Smith and Beasley 2004a); (2) the designation of a new dolphin species, the Australian snubfin dolphin (Beasley *et al*. 2002: Appendix II, Beasley *et al*. 2005: Appendix I); and (3) an internal publication on the status of Irrawaddy dolphin mortality rates and causes in the Mekong River (Appendix VII). Table 11.7 summarises the main research and conservation implications of Chapter 9. The primary research findings from Objective 4d are:

1. the mean adult mortality and early calf survival are estimated to be 5.5% and 0.7%/year, respectively. The population is therefore estimated to be experiencing a yearly decline of 4.8%;
2. a large number of carcasses recovered are newborns, with no explanation as to the cause of death. This high newborn mortality is unsustainable;
3. as a result of the small population size, the allowable human-caused mortality is less than one dolphin a year. Management must aim to reduce anthropogenic mortality to zero;
4. entanglement in gillnets and direct deaths through destructive fishing practices (e.g. dynamite fishing) are known causes of anthropogenic mortality; and
5. other potential indirect causes of dolphin mortality are contaminants, disease, boat harassment and noise, boat collision, reduced fish stocks, and inbreeding depression. The carcass recovery program is essential to establish causes of mortality.

11.2.8. Objective 5. Investigate social considerations influencing conservation strategies and trial a Dolphins for Development conservation initiative (Chapter 10).

One of the major accomplishments of my PhD research was a trial of the Dolphins for Development integrated conservation development project. I believe this project was the first of its kind to assist with conservation efforts of a riverine population of mega-fauna. To implement this project, I partnered with a local NGO, the Cambodian Rural Development Team (CRDT), to ensure the project was delivered effectively and efficiently and with the necessary expertise relevant to rural development and livelihood diversification. This project component has resulted in publication of numerous popular articles (Beasley 2005a, Beasley 2005b). This project component is now continued by CRDT, and has been expanded to include seven other villages adjacent to critical dolphin habitats along the Kratie to Khone Falls river stretch. Table 11.8 summarises the main research and conservation implications of Chapter 10. The primary research findings from Objective 5 are:

1. strategies necessary to conserve endangered species and habitats are complex and vary according to biological, social, economic and political considerations;
2. to conserve endangered species in developing countries, some positive incentive must be provided to local communities;
3. community conscious conservation is a term that can be applied to multidisciplinary, on-the-ground conservation programs, which work towards integrating communities with conservation of endangered species and habitats;
4. a well-planned evaluation of conservation programs is vital for determining project successes and/or failures.

11.2.9. Objective 6. Provide recommendations for the effective conservation of Irrawaddy dolphins and their riverine habitat in Cambodia (Chapter 11).

Based on preliminary results obtained for my thesis (*i.e*., before comprehensive analyses of most data), I developed a conservation and management strategy (MDCP Strategy: Appendix IV), and submitted it to the Ministry of Agriculture, Forestry and Fisheries, in September 2004. This strategy followed the ‘project cycle’ as described in Chapter 1 (see ‘*1.7.2. Conservation Process*’), which included ‘setting priorities’ and ‘developing strategies’ (see ‘*1.7.2.1 Setting Priorities*’ and ‘*1.7.2.2. Developing Strategies*’).

The objective of this initial MDCP strategy was to *ensure the long-term survival of the Irrawaddy dolphin population inhabiting the Mekong River*. The five management goals were to: (1) reduce threats and mortality rates; (2) increase local education and awareness; (3) effectively manage dolphin-watching tourism; (4) continue research and monitoring; and (5) clarify regional and national management responsibilities. My initial strategy comprehensively outlined the population’s conservation status, perceived threats to the population’s survival, gaps in knowledge, and recommendations for research and conservation activities based on priority.

My initial management strategy was edited by government officials and an international conservation NGO (neither agency was involved with previous activities or was up-to-date with the complex dolphin conservation situation). This edited document was formally adopted as Cambodian policy in January 2005 (DOF Strategy: Appendix V). A published document was distributed to all relevant agencies and stakeholders (in both English and Khmer). The Cambodian government is to be congratulated for their efforts to consider and support the conservation and management recommendations in this document. However, unfortunately, when the original MDCP strategy was edited, the resulting DOF strategy did not state any objectives or goals, and the list of priority activities was omitted. All that remained in the DOF strategy was a replicated list of required activities, with no specification of the urgent management requirements. Based on new information obtained from my study on abundance, ranging patterns and local perceptions towards dolphins and conservation, I recommend that the resulting prioritised recommendations are considered by the relevant agencies now responsible for dolphin conservation in Cambodia, and that the current DOF strategy (Appendix V), is modified accordingly.

The remainder of this chapter uses data obtained from the major results above (see *'11.2. Major Results of this Study*'), to build upon recommendations developed in the original MDCP strategy (Appendix IV). These recommendations acknowledge that the Irrawaddy dolphin population inhabiting the Mekong River is very small (based on survey information and anecdotal reports), declining (based on results from the carcass recovery program), and in urgent need of effective management. The following recommendations, therefore, identify the priority activities that are most urgently required to contribute towards the dolphins' immediate and long-term conservation.

11.3. SETTING CONSERVATION GOALS AND PRIORITIES

As a result of the comprehensive analyses of my data, serious conservation concerns affecting the potential survival of the Irrawaddy dolphin population in the Mekong River have become evident. The main concerns are:

- Based on interview surveys (Chapter 4), I established that prior to the early 1970s, the Irrawaddy dolphin population occurred south of Khone Falls throughout the lower Mekong River (including Tonle Sap Lake). Information from my boat surveys has confirmed that the population has declined in range and is now primarily restricted to the Kratie to Khone Falls river stretch (190km), although during the wet season some individuals occasionally move downstream and into large tributaries (e.g. the Sekong River). This reduction represents a decline in extent of occurrence of 90-99% (dry and wet season declines respectively).

- Based on a combination of capture-recapture and line-transect estimates (Chapters 5 and 6), the best estimate of current total population size is between 127-161 individuals (95% CI: 89-289). Although there are no historical estimates of population size, based on dedicated interviews my team members and I conducted, the anecdotal information from local people indicate that the Irrawaddy dolphin population inhabiting the Mekong

River has experienced a significant decline in population size, since at least the early 1970s (Chapter 4).

- The mortality records indicate that the Irrawaddy dolphin population inhabiting the Mekong River appears to be declining at a rate of at least 4.8%/year (Chapter 9). The most conservative allowable Potential Biological Removal (PBR) from anthropogenic mortality is less than one individual/year. If this dolphin population has any chance of survival in the river anthropogenic mortality must be reduced to zero, as a primary management goal.

- The confirmed major threats to the population's survival are accidental entanglement in gillnets, direct catch in seine nets, and direct deaths through illegal fishing. The potential threats that have not yet been confirmed are boat collision and harassment, environmental contaminants, dam or waterway construction, direct catch for traditional use of dolphin body parts for medicine, habitat loss (including reduction in prey), and waste discharge (village, agricultural and industrial). These potential threats continue unregulated in the lower Mekong River. The reason(s) for the high rate of newborn mortalities remain(s) unknown. It is critical that causes of mortalities are confirmed and mitigated (Chapter 9).

My research has confirmed the critical conservation status of the Irrawaddy dolphin population in the Mekong River, and identified the confirmed and potential causes of mortality (Chapter 9). The overall objectives and goals of the original MDCP strategy are therefore valid. However, based on new information obtained from my thesis, some of the original priority recommendations and activities should be adapted accordingly to facilitate effective conservation.

Much of the following is based primarily on my 10 years of field experience in Asia and particularly on my four years of research and conservation experience in Cambodia. The following section outlines various recommendations for activities that I believe would contribute to the long-term conservation of the remaining Irrawaddy dolphin population in the Mekong River. Many of these recommendations could also be applied to other freshwater dolphin populations. Clearly, these priorities are based on my perceptions and are certainly not intended to be a definitive list. As with the development of all management strategies, my recommendations are designed to be a basis of ideas, which can be improved over time through review and adaptation. Individuals and organisations will usually have different viewpoints on activities and priorities; however, at the very least, a start must be made to initiate a comprehensive conservation process. I therefore hope that the following recommendations and discussions can provide a solid basis to initiate more effective management of the remaining Irrawaddy dolphin population.

11.3.1. Recommendations for Future Research

11.3.1.1. Future Biological Studies

Many dedicated biological studies have been conducted on cetaceans worldwide. These studies provide examples of considerations that may be important to future studies on Irrawaddy dolphins in the Mekong River. Importantly, the design of long-term biological studies is an important consideration for management. Scott *et al*. (1990) stated that "*conclusions based on short-term data tend to be simplistic and transitory. Collecting data for only 2-3 years is unlikely to give a complete picture of a complex society of long-lived animals*".

As explained above, the original MDCP strategy was developed before my comprehensive analysis of data was undertaken (Appendix IV: Table 3). New findings, resulting from my analyses of data, have led to changes in required studies and methodology, particularly for population monitoring. Appendix VIII: Table VIII.1 presents an updated table of research recommendations for future biological studies of Irrawaddy dolphins in the Mekong River. Under ideal circumstances and with an unlimited budget, all recommended requirements would be addressed. However, with ever-present financial and personnel limitations, prioritisation of research efforts is required. I consider that the high priority research activities necessary to contribute towards immediate management needs are:

1. continue and expand the **carcass recovery program**, to collect all reported carcasses, analyse samples collected, identify threats, and increase local awareness about the importance of reporting carcasses immediately;
2. investigate the potential effect of **dolphin-watching tourism** boats on dolphin behaviour and habitat use; and
3. continue **photo-identification studies** throughout the Kratie to Khone Falls river stretch. At a bare minimum, these studies should be conducted every year during April (at least two sampling periods).

Figure 11.1. Brendan Boucher (CRDT Project Manager) and I conduct photo-identification studies at Kampi Pool, Kratie Province.

11.3.1.2. Future Socio-Economic Studies

As described in Chapter 1, and illustrated with conservation efforts towards the mountain gorilla (see '*1.6. Mountain Gorilla Conservation – An On-the-ground Example*'), social considerations are an important component of any management plan to conserve endangered species. Recent successes with mountain gorilla conservation have reportedly occurred as a result of integrating local communities with conservation activities (Harcourt 1986, Nowak 1995, Hart *et al.* 1997). Many river dolphin populations are small and declining, with the majority of threats related to human activities. Nevertheless, very few projects have conducted dedicated socio-economic evaluations.

The original MDCP strategy recommended that future socio-economic studies are conducted as a secondary priority under research (Appendix IV). These activities consisted of secondary informant and household interviews, and government agency and relevant NGO interviews. Social considerations were also a priority through education and awareness, and rural development and livelihood diversification activities. The results of my thesis (particularly Chapters 4 and 10), indicate that higher priority should be given to socio-economic investigations, especially if the surveys suggested above can be quantified and contribute towards project evaluation. Appendix VIII: Table VIII.2 presents the updated table of additional socio-economic research recommendations related to dolphin conservation in the

Mekong River. Additionally, Table VIII.3 presents the recommended socio-economic studies required to investigate levels of threats to dolphins in the Mekong River. I consider that the high priority research activities necessary to contribute towards immediate management needs are to:

1. conduct an independent **evaluation** (using an expert consultant) of the **long-term economic and social effects** of banning non-selective, unsustainable fishing methods;
2. investigate **local perceptions** towards the recently implemented Dolphins for Development ICDP. Importantly this assessment should **evaluate the project's effectiveness** at eliciting support for dolphin conservation and reducing fishing pressure in the river; and
3. clarify the **roles and responsibilities** of each stakeholder group in the lower Mekong region (southern Laos, Cambodia and Vietnam) involved in dolphin conservation efforts.

Figure 11.2. Example of a small-scale workshop held a Kampi Village to inform the village about the results of the MDCP interviews.

11.3.2. Recommendations for Future Management

Few effective management strategies have been developed for any river dolphin population. Perhaps the most comprehensive strategies and development of conservation activities has been for the baiji, although these efforts have been largely unsuccessful (see Braulik *et al*. 2005 for a comprehensive summary of research and management activities and further discussion below '*1.4. Measuring Success and Adaptation*'). Some management activities are being undertaken on various other river dolphin populations in Asia, however, often without integration into a comprehensive strategy. Significant conservation and management efforts have been made in the Mahakam River by Kreb (2005) and local colleagues, which is a positive step forward for freshwater Irrawaddy dolphin conservation in Asia.

Management strategies are also absent for most cetacean populations throughout Asia (although a detailed strategy has been developed for the Indo-Pacific humpback dolphin population inhabiting Taiwanese waters: Wang *et al*. 2004). The activities discussed in the humpback dolphin management plan assisted with the development of the original MDCP strategy (Appendix IV).

In addition to biological and social research priorities, the three main management goals for the MDCP management strategy are to reduce threats and mortality rates; increase local education and awareness; and clarify regional and national management responsibilities. A major consideration for current management of the Irrawaddy dolphin population inhabiting the Mekong River is to establish the cause of unsutainable newborn mortalities, and subsequently manage the threat. Although reducing gillnet entanglement should be a high priority, no matter what other management activities are conducted, the Mekong dolphin population will not survive in the long-term if newborn survival does not improve. Similarly, any major dam construction along the mainstream Mekong River from Khone Falls south to the Vietnamese/Cambodian border (including Tonle Sap Great Lake), will almost certainly lead to the dolphin populations' extirpation. Any proposed constructions should be prohibited wherever possible, not only for the sake of the dolphins, but also for other flora and fauna along the river, and local communities that rely on the river system for daily survival.

Appendix IX: Table IX.1 summarises the threats to dolphins in the river, potential management options and the potential impact of these management options on local communities. Table IX.2 summarises specific methods to reduce threats and mortality rates, Table IX.3 outlines the priority recommendations for education and awareness, and Table IX.4 outlines the priority recommendations for clarifying national and regional management priorities. I consider that the high priority management activities (separated into local, national and international priorities), are to:

Local Priorities

1. develop **community-based conservation areas** in critical dolphin habitats along the Kratie to Khone Falls river stretch, where no gillnet use is allowed;
2. strictly **manage dolphin-watching tourism** to ensure minimal impact on the dolphin population (importantly research must be conducted on the effect of tourism on the dolphins' behaviour: see *'11.3.1.1. Future Biological Studies'*);
3. investigate **gear modifications/compensation programs** in cooperation with local fishers to reduce gillnet use in the river;
4. investigate **potential sources of contaminants** along the river, and mitigate use wherever possible; and
5. continue the **Dolphins for Development ICDP** *only* after an independent evaluation has been conducted of project activities and local perceptions towards the project (see *'11.3.1.2. Future Socio-economic Studies'*);

National Priorities

6. develop an **updated national management plan** for dolphin conservation that all stakeholders contribute to, and support;
7. encourage management and conservation of the lower Mekong River wherever possible, ideally opposing any large dam construction plans;

International Priorities

8. re-establish **cooperation with southern Laos stakeholders** to urgently manage the transboundary Chiteal area and the remaining dolphin group inhabiting the area.

11.3.3. ON-THE-GROUND IMPLEMENTATION OF RECOMMENDATIONS

The development of recommendations and/or a management strategy is merely the initial step in the conservation process for endangered species or habitats. Effective on-the-ground *implementation* of management strategy components is critical, yet surprisingly it is often overlooked or neglected (see '*1.7.2.3. Taking Action*'). Numerous recommendations for future research and/or conservation activities exist in many publications following initial studies of river dolphin populations; however, evidence suggests that few recommendations, if any, are ever implemented (Bearzi 2007).

One relevant example of an uncompleted recommendation is evident from recent activities concerning Irrawaddy dolphin conservation in the Mekong River. A high priority activity in the DoF strategy (Appendix VI) was to hold a *Stung Treng (Cambodia) and Champasak (Lao) provincial meeting to discuss conservation priorities for Chiteal Pool*, with an aim of contributing to conservation of the small group of dolphins inhabiting Chiteal Pool on the Laos/Cambodian border. This meeting was convened in December 2004 by the Mekong Biodiversity and Sustainable Use Project (MWBP)[24]. Although fulfilling one of the priority activities in the overall strategy, none of the resulting recommendations from this important meeting has been implemented (see Chapter 1: '*1.7.2.3. Taking Action*'). A long time-lapse between 'developing' recommendations at workshops and 'implementing' recommendations, is a significant impediment to any momentum and enthusiasm gained at such events; which are also often very expensive and time-consuming to organise, also leading to locals being disillusioned by the conservation process. Numerous other examples are undoubtedly evident in many conservation programs worldwide. Some reasons (such as lack of resources or political constraints) for inactivity may be valid. However, other reasons for inactivity may be less acceptable, and include: (1) organisational apathy and un-interest; (2) ineffective project management; (3) the necessity for a 'tick in the box' in terms of outputs and a subsequent lack of preparation to implement recommendations; (4) an organisation's lack of dedication to project goals, or a change in regional program priorities; and (5) managers, and/or local team members moving on to other projects or areas.

A long-term commitment by various stakeholders to project goals is critical for effective project implementation. Initial attempts at new activities will often not be successful immediately, and periods of review and adaptation will be required (sometimes multiple times). Based on my experience in Cambodia, I conclude that there are two main 'levels' of a project that are relevant to successful implementation of a management strategy, particularly in situations where the conservation target is politically, or economically important [25]:

1. **High-level implementation**: led by a project director who is responsible for regional and national aspects of the project, such as coordination of management authorities and political negotiations and public consultations.

2. **On-the-ground level implementation**: led by a project manager (either a foreigner or national depending on relevant qualifications and experience) with an effective local team.

[24] A large project focusing on the sustainable use of the Mekong River, implemented by the United Nations Development Fund, the World Conservation Union and the Mekong River Commission.
[25] The 'high-level implementation' may be unnecessary in situations where there is little economic or political interest in the conservation target or area.

Of fundamental importance to on-the-ground implementation are an effective project team (consisting of a manager and local team members), and adequate funding. Effective implementation of management strategies is the major responsibility of the on-the-ground team.

A manager is important for establishing long-term consistency and ensuring project staff have access to data and resources, as well as appropriate technical expertise, experience and enthusiasm for project goals and activities (Bunce *et al*. 2000). The manager is responsible for developing recommendations (if none exist), designing and coordinating recommended project components, analysing and presenting the data (both nationally and internationally), obtaining adequate funding, and communicating effectively with the project director. The local project team assists with data collection (particularly the interviews), analysis, report writing and presentations. Bunce *et al*. (2000) stated that it is important that the combination of local team members have good interpersonal skills, are motivated and analytical, and are interested in the project. Based on my experience in Cambodia, I would also add that local team members need to be respectful of the rural communities, be able to work independently and be able to work in rural environments (if necessary). Finally, it would be helpful if at least one team member is able to read and write English (or the language of the project manager) proficiently.

Under ideal circumstances, each major component of a management strategy (e.g. research, education and awareness, rural development and diversification of livelihoods), would be undertaken by cooperating teams, each comprised of a manager and local staff, with expertise in their respective component. As an example, to implement the Dolphins for Development ICDP, MDCP was responsible for education and awareness activities and CRDT was responsible for the rural development and livelihood diversification. This division of project components greatly facilitated the effectiveness and efficiency of the activities undertaken.

During implementation, the project team's relations with local communities will always be important. If bad relations exist between local communities and team members, the opportunities for successful conservation will be greatly reduced. Team members should be required to always be respectful of individuals in local communities (particularly leaders), and to express interest in, and acknowledge locals who assist with project activities (particularly if individuals do so voluntarily). A relevant example of this approach is shown by the carcass recovery program that I initiated and implemented (Chapter 9). Villager reports of dolphin carcasses were sporadic in the first few years of the project, as villagers believed that if they reported a carcass no-one would be interested. However, villagers eagerly assisted our project very promptly once they:

1. understood that our project would recover every carcass as soon as practical;

2. received information as to why the dolphin carcasses were important;
3. were always reimbursed for out-of-pocket expenses (such as telephone, gasoline);
4. received thanks and a gift of a T-shirt for their assistance; and
5. received feedback on the results of the carcass program during village workshops.

In order to improve community relations, an important aspect of the implementation process is to communicate the project results back to local communities. This involves discussing the findings during workshops and/or meetings, seeking feedback and validation, and investigating appropriate decisions and actions to make use of the results (Bunce *et al.* 2000).

Major considerations for effective project implementation are to ensure that:

1. a structured project plan is formulated (with activities and timelines) for a specified duration (ideally less than a one year period);
2. each activity is well-designed (with the potential for evaluation, where possible);
3. adequate resources and staff capacity are available to effectively undertake each activity; and
4. all stages of the implementation process for each activity are appropriately documented by local team members.

If these four requirements are not being met, then a reassessment of resources and the project team is required. In my opinion, effective implementation of a few priority activities is much more preferable than ineffective implementation of many activities.

11.4. MEASURING SUCCESS, REVIEW AND ADAPTATION

As discussed in Chapter 1, a well-designed project evaluation component is of critical importance to effective management of endangered species is (see '*1.7.2.4. Measuring Success – Project Evaluation*'). Evaluation procedures should be designed before the onset of any project activities and aim to measure the success of activities in achieving the stated goals and objectives of a management strategy quantifiably. Importantly, the objectives of a project should be regularly reviewed and adapted, if required. Although evaluation has often been a neglected component of many conservation programs, an increasing number of projects are now conducting evaluations (Alpert 1996, Margoluis and Salafsky 1998).

There are no known dedicated evaluations of project success for a river dolphin population – however, this is not surprising considering that few river dolphin studies have gone far beyond initial research of abundance and distribution (Chapter 2). Numerous conservation initiatives have been developed for the *Critically Endangered* baiji population, since dedicated efforts began in the mid 1980s (Chapter 3: see Braulik (2005) for a comprehensive review of baiji conservation efforts). Although no formal project evaluation has been conducted to assess the success of project activities, the lack of baiji remaining in captivity or in semi-natural reserves and a lack of sightings during recent dedicated boat surveys indicates that these conservation efforts have been ineffective (Dudgeon 2005, Reeves and Gales 2006).

A preliminary project in the Ganges River investigated the use of oil scraps as an alternative to Ganges River dolphin oil as a fish attractant (Sinha 2000). Results of comparisons between fishing with dolphin and fish oil indicated no statistically significant difference in fish caught between the two attractants. However, no studies were undertaken to investigate fishers' continued use of the oil scraps after the project was completed. Thus, the feasibility of this new fishing method to reduce dolphin mortality (the aim of the investigation) remains unknown.

No single evaluation approach is applicable to all conservation programs, although some basic principles apply. To assist with developing evaluation programs, published reviews of evaluation and monitoring techniques are now becoming available (Salafsky 1999, Kleiman 2000, Stem 2005). The success of a management strategy will always be judged against its associated management goals. These goals must therefore always be kept in mind during the design, management, and evaluation of a strategy.

11.5. CONCLUSIONS

I believe that I have successfully achieved the main aims of my thesis, which were firstly, to contribute towards a comprehensive understanding on the population biology of Irrawaddy dolphins inhabiting the Mekong River, and secondly, to investigate social considerations directly relevant to the long-term conservation of the population. Some of the major achievements of my study include:

- Designation of a new dolphin species, the Australian snubfin dolphin (*Orcaella heinsohni*) (Beasley *et al*. 2005).
- Designation of the Mekong dolphin sub-population as *Critically Endangered* by the World Conservation Union (IUCN), in 2004 (Smith and Beasley 2004).

- Development of a conservation and management strategy (Appendix IV) that was formally adopted as national policy by the Cambodian Ministry of Agriculture, Forestry and Fisheries (Appendix V), in January 2005.
- Development of a small conservation organisation, the Mekong Dolphin Conservation Project, which consisted of myself and a local team of five Cambodian nationals who I trained in dolphin research and conservation methodologies.
- Development of a successful carcass recovery program. This program is currently being continued and expanded in Cambodia by the WWF Cambodia Mekong Dolphin Conservation Project (CMDCP).
- Initiation of the first integrated conservation development project contributing towards conservation of a freshwater mega-vertebrate population. This program is currently being continued and expanded by CRDT.
- Management of community-based tourism at Kampi Village, Kratie Province, where the community is now responsible for co-managing this industry and the entire community receives some benefit through a community fund. This program is currently being overseen by CRDT.

Although I achieved the two aims of my study, it remains unknown whether I achieved my goal of *contributing to the effective conservation of the Irrawaddy dolphin population that inhabits the Mekong River*. Many project components were implemented throughout my study, such as research, education and awareness, rural development and diversification, and development of community-based, dolphin-watching tourism. Unfortunately, a formal evaluation of project activities was not possible as a result of time constraints. Although initial results indicate that the activities that I implemented have contributed towards dolphin conservation in the Mekong River, the ultimate indications of success will be a reduction in dolphin mortalities[26], increased calf survival, and/or a subsequent increase in total dolphin population size[27]. Long-term monitoring is crucial to determine these factors. In the absence of any such indications, project evaluation will be very important to ensure that conservation activities are contributing to, rather than hindering, management efforts.

[26] Importantly, a reduction in dolphin mortalities may occur because the dolphin population has become so small that comparatively fewer carcasses are recovered. Long-term monitoring of population size is therefore also an important component of project activities to assess mortality rates.

[27] A recent Reuters news article reported that the Mekong dolphin population had increased from 90 to 160 individuals in just one year. This report was without any scientific basis or evaluation and is biologically impossible:
http://today.reuters.com/news/articlenews.aspx?type=scienceNews&storyid=2007-03-

One of the most significant lessons that I have learned from my study is the powerful influence that politics, economics and inter-organisational relations exert on the potential success of endangered species' conservation programs. I believe that when dealing with governments and/or various organizations, the following are of major importance for progress with conservation and management strategies:

1. positive government support from all levels (local, provincial and national);
2. a single management plan, with clear goals and strategies that all involved organisations contribute to, and work towards, without duplication; and
3. clear avenues for communication and discussion.

Unfortunately, unpleasant personal relations are likely to hinder positive conservation efforts. It is important to ensure at all times that clear communication between all parties, particularly at the onset of potential conflicts, is a priority.

The Irrawaddy dolphin population inhabiting the Mekong River is worryingly small and apparently declining (Chapters 2, 5, 6 and 9). Effective conservation of the remaining dolphin population will require the full cooperation of all conservation organisations and relevant stakeholders throughout the region. This approach is particularly relevant in Cambodia, where the majority of the dolphin population now occurs. Long-term funding for implementation and evaluation of conservation measures is required to implement conservation and management activities. I believe that although the situation facing Irrawaddy dolphins in the Mekong River is precarious, it is not yet as dire as for the baiji, and we are not yet at a point were species triage should be considered (Reeves and Gales 2006, Wang *et al.* 2006, Yang *et al.* 2006). Very important lessons can, however, be learnt from attempts to conserve the baiji. It is imperative that factors preventing successful conservation of the baiji (*i.e.*, a lack of government, donor and international support, continued habitat degradation) are not repeated.

As mentioned in the discussion of this Chapter, a major consideration for current management of the Irrawaddy dolphin population inhabiting the Mekong River is to establish the cause of unsutainable newborn mortalities, and subsequently manage the threat. Although reducing gillnet entanglement should be a high priority, no matter what other management activities are conducted, the Mekong dolphin population will not survive in the long-term if newborn survival does not improve. Similarly, any major dam construction along the mainstream Mekong River from Khone Falls south to the Vietnamese/Cambodian border (including Tonle Sap Great Lake), will almost certainly lead to the dolphin populations' extirpation. Any proposed constructions should be prohibited wherever possible, not only for the sake of the dolphins, but also for other flora and fauna along the river, and local communities that rely on the river system for daily survival.

Although the situation facing the Irrawaddy dolphin population inhabiting the Mekong River is very precarious, there are many positive factors evident in the region that contribute to conservation efforts (*i.e*., strong community support, dedicated local staff, restricted areas where dolphins occur, numerous calves still being born, strong stakeholder support, significant financial support from donors). As a result of these factors, if it is not possible to conserve the population of Irrawaddy dolphins inhabiting the Mekong River, then I hold little hope for the future of other endangered species along the river, or indeed for other freshwater dolphin populations in Asia.

Figure 11.3. Irrawaddy dolphin from the Mekong River. Photograph by Yim Saksang

11.6. RECOMMENDATIONS FOR FRESHWATER DOLPHIN CONSERVATION

Although I could make numerous recommendations regarding the conservation of freshwater Irrawaddy dolphin populations, based on my thesis results, I consider that the most relevant in terms of conservation and management include the following factors.

- Partnerships and good relations with communities are essential for conservation efforts to be successful. As mentioned by Baird and Mounsouphom (1997), more attention needs to be given to adequately considering socio-economic factors and the belief systems of local people whose lives are intertwined with those of the dolphins and other living aquatic resources.
- There has been a near total absence of effort in assessing the socio-economic characteristics and perceptions of local people living adjacent to freshwater dolphin habitats. Increasing socio-economic studies must be a future priority if conservation initiatives are to be successful.
- Local perceptions are generally favourable towards freshwater Irrawaddy dolphins, with many communities revering dolphin populations. This local reverence should be built into conservation programs.
- As stressed by Baird and Mounsouphom (1997), conservation programs should not only publicise the threats to dolphins but also the threat to fisheries, livelihoods and human health.
- Habitat protection and multi-species conservation programs must be a high priority. Dolphins will not survive in freshwater systems without high water quality and conservation of associated flora and fauna assemblages.
- Politically and/or economically driven conservation agendas can significantly influence the potential success of a conservation program. Depending on the situation relevant to the country of activities, it would often be beneficial to constantly inform the relevant government agencies of project activities and ensure good relations at all times through close cooperation.
- There has been a notable absence of on-the-ground conservation efforts directed at freshwater populations of Irrawaddy dolphins. These populations are known to be small and declining, and most threats are already known. Therefore, implementation of conservation and management activities needs to be a high priority.
- Carcass recovery programs are integral to any conservation program. These programs provide essential data on mortality rates and causes and life-history data.
- More effort and resources are required to establish the life history parameters of freshwater Irrawaddy dolphin populations. This approach will assist with

understanding their population dynamics and natural susceptibility to anthropogenic impacts, thus creating concrete justification for conservation efforts.

- While little is known about freshwater Irrawaddy dolphin populations, it is important to note that there is generally even less known about coastal Irrawaddy dolphin populations and the Australian snubfin dolphin. In many coastal areas (e.g., Bangladesh, East Malaysia, northern Australia), the status of populations may not yet be as precarious as freshwater populations. Research and conservation initiatives therefore should be focused in such areas, before populations become so small that conservation efforts are essentially futile.

Objective 1. Determine the current status and biodiversity importance of freshwater Irrawaddy dolphin populations (Chapter 2).

Table 11.1. Summary of the main research and conservation implications of Chapter 1: Objective 1 - to determine the current status and importance of freshwater Irrawaddy dolphin populations.

Research Findings	Research Implications	Conservation Implications
(1) All freshwater Irrawaddy dolphin populations have been researched to varying degrees; however accurate abundance estimates are lacking for most populations.	• Improved, standardised methods of population assessment are required (HIGH).	
(2) All freshwater populations of Irrawaddy dolphin are small (e.g. less than 200 individuals) and declining.		• Effective long-term management strategies are urgently required for all populations (HIGH).
(3) Very little is known of Irrawaddy dolphin life history (Appendix VI).	• Life history should be investigated, using relevant tissue samples collected from carcasses (MEDIUM).	
(4) Threats to freshwater dolphins are numerous and continue to intensify (Chapter 9).	• Threats need to be identified and addressed (HIGH). • Threat mitigation measures need to be investigated and scientifically trialled (HIGH).	
(5) Few on-the-ground conservation measures exist to conserve and manage freshwater dolphin populations (Chapter 10).		• Well designed, on-the-ground conservation measures urgently need to be developed and implemented (HIGH). • Socio-economic considerations are an essential component of management (HIGH).
(6) Irrawaddy dolphins should be considered an effective flagship species for freshwater biodiversity conservation.		• Conservation efforts will also benefit other flora and fauna and subsistence human communities (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 2. Provide information on the study area and justification for why habitat conservation should be a major priority (Chapter 3).

Table 11.2. Summary of the main research and conservation implications of Chapter 3: Objective 2 – to provide information on the study area and justify why habitat conservation should be a major priority.

Research Findings	Research Implications	Conservation Implications
(1All lower Mekong countries are now developing quickly and experiencing significant human population growth.		• It is imperative to initiate conservation strategies early, rather than waiting for a crisis situation to occur (HIGH).
(2) Major threats to habitats are often linked with poverty and human overpopulation. It is essential that threats are mitigated and future large-scale destructive projects prohibited.		• Well-designed on-the-ground conservation measures urgently need to be implemented (HIGH). • Socio-economic considerations are vital to assist with effective conservation (HIGH).
(3) Conservation lessons need to be learnt from experiences in other countries.	• Investigation into the success/failures of other projects worldwide should be a high priority (HIGH)	
(4) Based on lessons learnt elsewhere, positive community involvement in conservation is imperative.		• Community fisheries management systems should be investigated and implemented, where possible (HIGH).
(5) Preservation of habitat is essential to subsistence rural human communities and other flora and fauna that rely on the river system.		• The link to environmental conservation and health of human communities living along the river should be emphasised (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 3. Investigate the historical status of the population and reasons for any population change using local knowledge (Chapter 4).

Table 11.3. Summary of the main research and conservation implications of Chapter 4: Objective 3 – to investigate the historical status of the Irrawaddy dolphin population in the Mekong River and reasons for any population change using local knowledge.

Research Findings	Research Implications	Conservation Implications
(1) Dolphin occurrence has declined significantly throughout the lower Mekong River.	• Further interview surveys should be conducted in the Sekong River and its tributaries in southern Laos (LOW).	• Resulting from the small and declining population size, effective management needs to be undertaken urgently (HIGH).
(2) Dolphin abundance has reportedly declined significantly south of Kratie Township.	• Research should be conducted to assess dolphin movements south of Kratie Township (LOW).	• The dolphin's distribution in the river has declined significantly in recent years, providing further evident for a population decline (HIGH).
(3) The Kratie to Khone Falls river segment is the most important dolphin habitat remaining in the river.		• The Kratie to Khone Falls stretch is the most important focal area for conservation (HIGH).
(4). Dolphins are occasionally sighted south of Kratie Township, but are now considered locally extinct in the Vietnamese Mekong River.		• Awareness raising activities should continue south of Kratie Township, to ensure any dolphins sighted in this area are reported to the relevant agencies (MEDIUM).
(5) No dolphins have been recently sighted in the Sekong, Srepok and Sesan Rivers (limited interviews were conducted).	• Further interview surveys should be undertaken along these rivers (LOW).	• Resulting from the small and declining population size, effective management needs to be undertaken urgently (HIGH).
(6) Most interviewees consider it important to conserve dolphins in the river.		• Local communities should be fully involved in the design and management of any conservation areas (HIGH).
(7) Local communities revere dolphins in the Mekong River, primarily as a result of local folklores		• Awareness raising activities should reiterate local folklore about dolphins (MEDIUM).
(8) Local knowledge and perceptions provide useful information regarding endangered species' status and conservation.		• Interviews with local communities should be a high priority for endangered species research (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 4a. Obtain estimates of total population size (Chapters 5 and 6).

Table 11.4. Summary of the main research and conservation implications of Chapters 5: Objective 4a – to obtain estimates of total population size of Irrawaddy dolphins in the Mekong River, using capture-recapture of photo-identified individuals.

Research Findings	Research Implications	Conservation Implications
(1) Higher quality photographic equipment greatly increased the number of photo-identified individuals obtained.	• A digital camera with 300 mm (2.8) lens and extender (2x) is required for future photo-identification studies (HIGH).	
(2) Photo-identification studies require intensive photographic effort.	• Future photo-id should be conducted independently of any distance-sampling boat surveys (HIGH).	
(3) A plateau in identifications had not been reached (90 individuals identified).	• Photo-identification surveys should be continued (HIGH).	
(4) Eighty-three percent of dolphins were identifiable during the study period.	• Photo-id is a feasible method to obtain population size estimates.	
(5) Based on photo-id, a minimum of 127 dolphins (95% CI: 108-146) inhabited the Mekong River, as of April 2005.	• Photo-identification is the preferred survey methodology to assist with long-term monitoring (HIGH).	• Long-term monitoring is required for integration into management programs (HIGH).
(6) Reduced photographic effort in the Stung Treng area probably resulted in a downward bias of the abundance estimates.	• Increased photographic effort is required in the Stung Treng area (HIGH).	• Effective management requires a well-designed study to obtain accurate and precise estimates of abundance (HIGH).
(7) It is likely that no more than 180 individuals inhabit the river, as of April 2005.	• Future photo-id needs to incorporate lessons learnt on study design and sampling requirements (particularly from the Stung Treng area), to obtain more accurate estimates of abundance (HIGH).	• The total population size is worryingly small. Effective management is urgently required (HIGH).
(8) It would take 6 years to detect a 5% per annum decline but only 2 years to detect a 20% per annum decline.	• It will be difficult to obtain any trends in abundance as a result of the small population size.	• Managers must act on the precautionary principle, and implement management immediately (HIGH).
(9) The Irrawaddy dolphin population in the Mekong River is worryingly small and declining.		• The population is particularly vulnerable to extinction. Effective management is urgently required (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 4a continued. Obtain estimates of total population size (Chapters 5 and 6).

Table 11.5. Summary of the main research and conservation implications of Chapter 6: Objective 4a – to obtain estimates of total population size of Irrawaddy dolphins in the Mekong River, using direct count and line-transect methodologies.

Research Findings	Research Implications	Conservation Implications
(1) Abundance estimates resulting from direct counts were both inaccurate and imprecise	• Direct count survey methodology is not recommended for long-term monitoring purposes (HIGH).	
(2) The highest estimates of dolphin abundance were obtained during the lowest low water.	• Boat surveys should be carried out during lowest low water to maximise sightings (HIGH).	
(3) Dolphins only regularly inhabit 11%, of the available habitat in the Kratie to Khone Falls river stretch.	• Line-transect surveys should be undertaken at least once a year during lowest low water to monitor habitat use (MEDIUM).	• An increase in habitat use may represent an increasing population. Long-term monitoring is imperative (HIGH).
(5) Line-transect analyses resulted in an estimated 161 dolphins (95% CI: 89-289).	• Line-transect methodology is a feasible methodology to estimate abundance; however, sample size restrictions are problematic.	• Line-transect provides reliable estimates, but is resource intensive and should only be conducted if resources are abundant (LOW).
(6) During line-transect boat surveys, no dolphins were sighted south of Kratie Township.	• Research should now focus in the Kratie to Khone Falls river stretch (HIGH)	• The Kratie to Khone Falls river section is the most important dolphin habitat and should be the focus for management (HIGH).
(7) Using line-transect, it would take 17 years to detect a 5% per annum decline and 6 years to detect a 20% per annum decline.	• It will be difficult to obtain any trends in abundance as a result of the small population size.	• Managers must act on the precautionary principle, and implement effective management immediately (HIGH).
(8) Based on a combination of photo-identification and line-transect, the total population size is estimated to be between 127 -161 (95% CI: 89-289) individuals.	• Dedicated photo-identification surveys should be continued high priority, to monitor population size (HIGH).	• The population is particularly vulnerable to local extinction. Effective management is urgently required (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 4b. Obtain baseline data on ranging patterns and habitat use (Chapter 7).

Table 11.7. Summary of the main research and conservation implications of Chapter 7: Objective 4b – investigate Irrawaddy dolphin ranging patterns in the Mekong River.

Research Findings	Research Implications	Conservation Implications
(1) Individual dolphins exhibit extremely high site fidelity	• Continued photo-identification studies are essential for long-term monitoring (HIGH)	• Conservation of critical areas is urgently required (HIGH).
(2) Dolphins are commonly found in deep pool areas	• Investigation of deep pool characteristics may explain why some deep pools are used by dolphins, and not others (LOW).	• Conservation efforts must ensure the integrity of deep pool areas remains intact (MEDIUM).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 4c. Obtain data on school dynamics and social structure (Chapter 8).

Table 11.6. Summary of the main research and conservation implications of Chapter 8: Objective 4c – investigate Irrawaddy dolphin school dynamics and social structure in the Mekong River.

Research Findings	Research Implications	Conservation Implications
(1) Average group sizes during the dry and wet seasons were 6.8 and 5.7 dolphins respectively.	• Group sizes remain relatively large during both seasons.	• Social structure does not appear to exhibit seasonal fluctuations.
(2) Individuals were seen with a particular companion more often than would be expected by chance.	• Association patterns show a highly structured population. Continued photo-identification will provide further long-term information on social structure (HIGH)	• Conservation efforts may be more challenging with a highly structured population, than if the population was more fluid.
(3) Analyses indicate four largely discrete sub-populations. Chiteal and Stung Treng sub-populations appear isolated.	• Future photo-identification research should encompass all four communities (HIGH).	• Conservation efforts should be focused on the four communities and their associated critical areas (HIGH).
(4) During the wet season, Chiteal and Stung Treng communities appear to remain isolated.	• Further photographic studies are recommended during the wet season, to investigate seasonal association patterns (LOW).	• The conservation status of the four communities is critical. Urgent management needs to be implemented immediately (HIGH).
(5) Analyses indicate that the population is highly structured, with the majority of individuals having preferred, long-term associates.	• Future studies on behaviour (such as feeding), acoustics and genetics would contribute further information to investigate hypotheses to explain reasons for the highly structured population (LOW).	• It is critical that conservation efforts are implemented urgently to prevent further reduction in population size – particularly in very small communities such as Chiteal (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 4d. Obtain data on mortality rates and causes (Chapter 9).

Table 11.7. Summary of the main research and conservation implications of Chapter 8: Objective 4d - investigate mortality rates and causes affecting survival of Irrawaddy dolphins in the Mekong River.

Research Findings	Research Implications	Conservation Implications
(1) Fifty-four dolphin carcasses were confirmed from 2001 to April 2005, with no obvious gender bias.	• Carcasses must be recovered as soon as possible, to enable gender determination for a higher proportion of carcasses (HIGH).	• Threats to Irrawaddy dolphins in the Mekong River do not appear to be gender specific (MEDIUM).
(2) Forty-three percent of all carcasses recovered were newborns. Only two newborns are known to have survived longer than 6 months, since 2001.	• Continued monitoring of the newborn occurrence will assist with calculation of early survival rates (HIGH).	• The current newborn survival rate is extremely low. The cause(s) for newborn mortality need(s) to be identified urgently for the population to increase (HIGH).
(3) All but three dolphin carcasses were recovered from the Kratie to Khone Falls river stretch.	• Continued carcass recovery throughout the entire lower Mekong River system is essential (HIGH).	• There are still occasional movements outside this river stretch during the wet season.
(4) Fifty-two percent of adult deaths were confirmed to result from entanglement in large mesh fishing gear. The cause of the high number of newborn deaths could not be confirmed.	• The causes of many dolphin deaths are unknown – particularly newborns. Continuation and expansion of the carcass recovery program, with a qualified veterinary surgeon involved, is vital (HIGH).	• Mitigation methods to minimise gillnet mortality need to be investigated, trialled and implemented immediately (HIGH).
(5) Mercury levels were low in all but one adult female (although 58% of samples were from newborn dolphins).	• Further studies of contaminant levels and sources are critical (HIGH).	• Prohibition of environmental pollutants, if evident, will benefit the entire ecosystem (HIGH).
(6) The allowable Potential Biological Removal (PBR) from anthropogenic mortality is less than one dolphin a year	• Continuation of the carcass recovery program is vital to monitor mortality rates and causes, and provide tissues samples for life-history analysis (HIGH).	• A major management aim should be to reduce anthropogenic mortality to zero (HIGH).
(7) Irrawaddy dolphin mortality rates in the Mekong River are high and apparently unsustainable.	• Continuation of the carcass recovery programme is an immediate priority for monitoring mortality rates (HIGH).	• A major management aim should be to reduce anthropogenic mortality to zero. (HIGH).
(8) New data were obtained on Irrawaddy dolphin life-history from samples collected through my carcass recovery program (Appendix VII).	• Collection of samples for life-history analyses should be a high priority (HIGH).	• Increased life-history knowledge will assist developing effective management strategies (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.

Objective 5. Investigate social considerations influencing conservation strategies and trial a Dolphins for Development conservation initiative (Chapter 10).

Table 11.8. Summary of the main research and conservation implications of Chapter 10: Objective 5 – to investigate social considerations influencing conservation strategies and trial a Dolphins for Development conservation initiative.

Research Findings	Research Implications	Conservation Implications
(1) Strategies necessary to conserve endangered species and habitats are complex and vary according to the biological, social, economic and political considerations.	• Conservation strategies must acknowledge and encompass all factors influencing the potential success of conservation strategies. • Evaluation processes must also be established to investigate these variables.	• An effective management strategy needs to encompass and acknowledge biological, social, economic and political considerations (HIGH).
(2) Various factors contributed to the successful initiation of the Dolphins for Development ICDP (see '*10.2.4.1. Rural Development and Livelihood Diversification*').	• Future Integrated Conservation Development Projects (ICDPs) should consider factors that assisted project initiation in Kampi Village (HIGH).	• Effective ICDP project initiation is assisted by: (a) existing good relations with communities in the target area, (b) a team advisor with a sound understanding of ICDP issues, (c) team members respectful of rural communities, (d) the communities initially requesting assistance with rural development activities, and (e) confirmed long-term funding (HIGH).
(3). Various limitations were evident with the development and livelihood diversification component (see '*10.3.1. The Potential for Conservation Success Using ICDPs*').	• Future ICDP activities must build on previous knowledge of project limitations and adapt project activities accordingly to become more effective (HIGH).	• Management models must be adaptable with lessons learnt from previous activities being integrated into future projects (HIGH).
(4) Various project limitations were evident with the community-based tourism component of the project (see '*10.3.2. Community-based Tourism Initiatives'*).	• Future community-based tourism activities must build on previous knowledge of project limitations and adapt project activities accordingly to become more effective (HIGH).	• Management models must be adaptable with lessons learnt from previous activities being integrated into future projects (HIGH).
(5) To conserve endangered species in developing countries, some positive incentive must be provided to local communities.	• Community conscious conservation (CCC) projects must be well designed from the onset and include an evaluation component to ensure that local communities are satisfied with incentives (HIGH).	• Local subsistence communities require some form of benefit if they are to fully support and participate in conservation activities (HIGH).
(6) '*Community conscious conservation'* (CCC), is a term I developed that can be applied to	• CCC project components included: (1) rural development and diversification of livelihoods, (2) community-	• CCC projects have significant potential to contribute to endangered species conservation. An

multidisciplinary on-the-ground conservation programmes, which work towards integrating communities with conservation of endangered species and habitats.	based ecotourism, (3) education and awareness raising, and (4) strengthening stakeholder relationships. Other important components to add to future projects may become evident through project evaluation (HIGH).	integration of all project components is an important management consideration (HIGH).
(7) A '*comprehensive conservation cooperative programme*' is also required to integrate local conservation efforts with regional and national conservation priorities and decision-making.	• Good communication and relations between all national and regional policy/decision makers should be encouraged at all times. Research needs to be disseminated where appropriate and coordination of activities is an important priority (HIGH).	• Economic and political considerations are a critical consideration to effective conservation. It is imperative that governments are supportive of management strategies if initiatives are to be successful (HIGH).
(8) As a result of time limitations, no formal project evaluation was possible. However, observable measures of success were evident (see '10.2.5. Project Evaluation').	• Project evaluation is an essential component of any future research program (HIGH).	• ICDPs appear to assist with conservation of Irrawaddy dolphins in the Mekong River; however, a formal, quantitative evaluation needs to be conducted (HIGH).

The priority of each activity (e.g. HIGH, MEDIUM, LOW) is summarised in brackets.