NESTING ECOLOGY, HARVEST AND CONSERVATION OF THE PIG-NOSED TURTLE (*Carettochelys insculpta*) IN THE KIKORI REGION, PAPUA NEW GUINEA

by

CARLA CAMILO EISEMBERG DE ALVARENGA

B.Sc. (Federal University of Minas Gerais – UFMG) (2004)
M.Sc. (National Institute for Amazon Research) (2006)

Institute for Applied Ecology
University of Canberra
Australia

A thesis submitted in fulfilment of the requirements of the Degree of Doctor of Philosophy at the University of Canberra.

October 2010

Certificate of Authorship of Thesis

Except where clearly acknowledged in footnotes, quotations and the bibliography, I certify that I am the sole author of the thesis submitted today, entitled

Nesting ecology, harvest and conservation of the Pig-nosed turtle (*Carettochelys insculpta*) in the Kikori region, Papua New Guinea

I further certify that to the best of my knowledge the thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis. The material in the thesis has not been the basis of an award of any other degree or diploma.The thesis complies with University requirements for a thesis as set out in *Gold Book Part 7: Examination of Higher Degree by Research Theses Policy, Schedule Two (S2).*

……………………………………………

Signature of Candidate

Arthur Georges.

....

Signature of chair of the supervisory panel

………15-Mar-11……………………..

Date

Copyright

Acknowledgments

It has been an interesting journey, from the Amazon to Australia and further to Papua New Guinea and what I learned in the last four years both academically and personally was priceless. Many people have contributed to my PhD experience and are deserving of my acknowledgements. I would firstly like to thank my family (Júlio, Maria Helena, Tiago and Igor), for their unconditional support on my adventures in the other side of the planet and my grandparents for passing from one generation to the other their belief that the richest inheritance you can leave to your children is education. You couldn’t be more right. Many thanks to Fernando Perini, who always believed, supported and encouraged me to pursue my dreams and also made the beautiful drawings that illustrate this thesis.

Equally deserving of thanks is my primary supervisor Arthur Georges, who provided me with the opportunity to travel to these wonderful countries to work with such an interesting subject. His support and guidance also enabled me to pursue and develop the ideas that are presented in this thesis. Ben Yaru also provided supervision and I am grateful for his perspectives and insights about Papua New Guinea wildlife conservation. An especial thanks to Mark Rose, whose data about the pig-nosed turtle in the Kikori from the early 80’s transformed my three years work into a long-term comparison. His generosity will be an example to follow.

I would like to thank everyone in the Institute for Applied Ecology (IAE). Thanks to Anna MacDonald, David Wong, Kerrie Aust, Deborah Bower and Kate Hodges, who provided valuable insights for my chapters and fought bravely against my grammar monstrosities. Thanks to the staff and PhD students at the IAE for friendship and support, including Niccy Aitken, Alex Quinn, Nadav Pezaro, Anett Richter, Michael Jensen, Marion Hoehn, Wendy Diamond, Rachel Walsh, Christina Castellano, Stephen Sarre, Nancy Fitzsimons, Will Osborne, Larissa Schneider, Stewart Pittard, Matthew Young, Maria Boyle, Claudia Yoshida, Anelise Hahn, Sarah Vargas, Erika Alacs, Lisa Schwanz, Xiuwen Zhang, Max Powell, Sam Walker, Jaqui Richardson, Veronika Vysna, Tara Goodsell and Vicky Smith. I would like also to thank Jennie Robens and Anita Clarke. Local and remote support and friendship was indispensable during this journey. Thank you to all my friends especially Fabi, Mari, Maki, Marilda, André, Bruno, Flávia, Paulinha, Leo, Mela, Des, Suzana, Prabha and Epere.

Funding was generously provided by Oilsearch, the University of Canberra and the Australian Endeavour International Postgraduate Research Scholarship. I would like to acknowledge the indispensible logistical support of WWF, CDI (Community Development Initiative), NRI (Papua New Guinea National Research Institute) and Oilsearch. Thanks to Jack Kaiwari, Mathew Wa'abiya, Michael Boru, Bagi Oni, Steven Dekene, Andrew Nema, Arnold Moi, Rober Kiapranis, Morgan Veao, Sarah Ekali, Ken Webb, Lidia Kaia, Dennis Badi, Felix Kinginapi, Paul Fearman, Cathy Alex, Veronika Kenisi and many others. My sincere gratitude also to James Robins (NRI), Augustine Mudkaji and Lance Hill (UPNG). Thank you to all Kopi camp workers and Kikori people who did their best to make my time in Papua New Guinea a pleasant experience. My field work involved visiting many local communities. We were always greeted warmly, granted access to sites and offered assistance. Thank you to all the traditional land owners that granted us permission to visit your lands.

Thank you to my Watemu Warriors, Les Bauer, Ricardo França Silva and Steve Reynolds who were my volunteer field assistants. I couldn’t have done the field work that culminated in this thesis without you. Local volunteers collected indispensable data presented in this thesis. Thanks to Ruth Boru, Celine Oni, Albert Waime, Alex (Veraibari), Atai Menemea, Aubai Aubomia, Baiara Eraro, Brandy Iavi, Brian Jimmy, Cain Keiwake, Eddie Samai, Emake Karea, Frank John, Gigove Joe, Imei Beiau, Jacob Simon, Jimmy John, Justin Jimmy, Kaibiri Euu, Kairi Arono, Kaki Kupere, Kiti Sumila, Marian Motawa, Maroua Kava, Monike Mapai, Moris Koveri, Moses Kemuru, Okei (Dopima), Patrick Ito, Petrick Kemuru, Rex Kiti, Rex Paimiri, Robim Kemuru, Roddie Bauno, Rodim Amua, Roni Warem, Sandra Thomas, Sara Masena, Sigaro Bauno, Sox Michael, Staley Morris, Taibu Nadai. Many thanks to the Kikori, Ogomabu and Kopi teachers, who helped with the development of the environment educational activities and the students from the Piku-project Boro Kaumi, Jerry Kera, Delilah Peter, Elma John, Susan Kokou, Jonah Kupere, Hebbie Jeffery and Olivia Peter.

Finally, I would like to thank everybody who contributed to the successful realisation of this thesis, as well as expressing my apology that I could not mention personally each of you one by one. Thank you, tak, danke, obrigada, tenkyu tru, tanikiu bada herea. This thesis is dedicated to the Kikori children. Ene kamau eke pilo tamute (my bye under your pillow).

Table of contents

List of Figures

List of Tables

Abstract

The pig-nosed turtle (*Carettochelys insculpta*) is a species of great conservation concern because it is the sole survivor of a once widespread family of turtles (Carettochelyidae); it has a very restricted distribution in a global sense. Moreover, *C. insculpta* is unusual among turtles in many facets of its morphology, ecology and behaviour. However, it is subjected to intensely high harvest pressure though much of its range. Highly prised as food, it is the most exploited turtle in New Guinea. Both turtle and eggs are collected for trade or consumption by villagers. In this thesis, I investigate aspects of the interactions of *C. insculpta* with its environment and with humans. I examine the relationship between *C. insculpta* nesting ecology and its environment within and among different populations. I also demonstrate population decline in the last thirty years and how this decline relates to the patterns and trends of adult and egg harvest in the Kikori population in Papua New Guinea.

The specific aims of my thesis were (a) to compare nesting areas and nesting phenology in populations of *C. insculpta* and to interpret differences in life history in an evolutionary and ecological context; (b) examine potential reasons for the evolution and maintenance of the coastal-riverine nesting dichotomy in the Kikori region of Papua New Guinea; (c) evaluate the ecological traits of coastal and riverine areas by comparing nests and sandbanks attributes and water inundation patterns; (d) report the results of a matched market and village survey of the pig-nosed turtle over almost 30 years in the Kikori Delta; (e) assess the effects of new fishing technologies and compare the proportion of turtle capture methods utilised recently with those common thirty years ago; and (f) evaluate the effect of change from a subsistence economy to a cash economy in different tribes.

Throughout its range, *C. insculpta* nests during the drier months when suitable sandbanks are exposed. Rainfall in the drier seasons and residual flows from the wet season dilutes salinities in the estuaries of the larger rivers in PNG, where *C. insculpta* nests in upstream, estuarine and coastal areas. In the wet-dry tropics of Australia, high flows are restricted to the wet season and high salinities prevail in estuarine regions during the nesting season. Substantial marine incursion occurs at this time in the estuaries and estuarine salinities are high. Nesting is only recorded from the upstream reaches of the rivers inhabited by *C. insculpta* in Australia. Pig-nosed turtles nesting on the coast are significantly larger than those nesting in riverine areas of the Kikori and both are significantly larger than riverine populations in Australia. The same pattern is observed in the superfamily Trionychoidea generally. Trends

towards larger body sizes between species and within and between populations, suggest that the coastal environment and its challenges have an important influence on the size of species.

In the Kikori region riverine areas, flooding is highly unpredictable, often remodelling the distribution of sandbanks after the eggs are laid. In any one year, riverine inundation can last for several days, increasing the risk of egg mortality from hypoxia; or, depending on rainfall, may not happen at all. Riverine inundation is often a result of rain in the upper catchment remote from the nesting area and so there is a spatial mosaic in the impact of flooding across sub-catchments. In contrast, on the coast, inundation is caused by tides and is spatially universal and more frequent, but is predictable and of short duration. In addition, coastal sandbanks are usually located on islands where monitor lizards (*Varanus indicus)*, the major nest predator at riverine sites, are absent. Females nesting on the coast avoid the extremely high nesting predation rates that occur from non-human predators in riverine areas.

I propose that the differing climatic regimes between the wet-dry tropics of northern Australia and the wet tropics rivers of southern New Guinea explain the differences in nesting patterns and contribute to the difference in body size and attendant life history attributes between these two landmasses. Coastal nesting exhibited by *C. insculpta* is probably a response to highly stochastic environments, such as the Kikori region. Coastal nesting is complementary to riverine nesting, increasing the nesting season period and providing predator-free nesting areas. Adaptation to marine environments in Papua New Guinea populations may explain the traits in Australia that otherwise defy explanation such as two clutches every second year and delayed egg emergence. It may be a case of traits evolving in one ecological context (coastal beaches) and being maintained because of different advantage from those that drove their evolution in other parts of its range (wet-dry tropics of Australia). Of course the reverse could be true, but my study provides an example of the caution required when placing evolutionary interpretations on life history traits whose manifestation is studied only within a restricted portion of a species range.

I provide, for the first time, concrete evidence of a substantive decline in populations of the pig-nosed turtle. My study combines matched village and market surveys separated by 30 years, trends in nesting female size and assessment of levels of harvest, all of which are essential to making a definitive assessment of population trends. Turtle harvest extended from the headwaters to the coast, but no small juveniles (< 15 cm maximum carapace length) were found outside the delta. On the basis of these data, my best estimate of the level of decline is

57.2% since 1981. Hand capture of female turtles during nesting was the most common hunting method in the coastal and riverine areas, whereas in the delta, owing to the lack of nesting sandbanks, the most common method of capturing turtles was by fishing line. Hunting methods in the delta and river in 2007-09 were significantly different from those employed in 1980-82. The proportion of captures using fishing line was greater in 2007-09 (10.3%) and use of nets, nonexistent in 1980-82, was responsible for 8.9% of the captures in 2007-09.

The proportion of *C. insculpta* meat sold at market differed between the two periods of study among language-groups. The impact of the introduction of outboard motors was greatly moderated by the scarcity and cost of fuel. It seems that hunting in distant areas is still greatly moderated by the scarcity and cost of fuel and the lack of fundamental infrastructure to facilitate travel and transport of goods. This lack of availability of fuel and access to transport networks and infrastructure represents a latent threat to *C. insculpta* in the Kikori. In a sense, the impact of changes to Kikori communities through introduction of modern technologies is dampened by the limitations the community faces in putting those technologies to effective use.

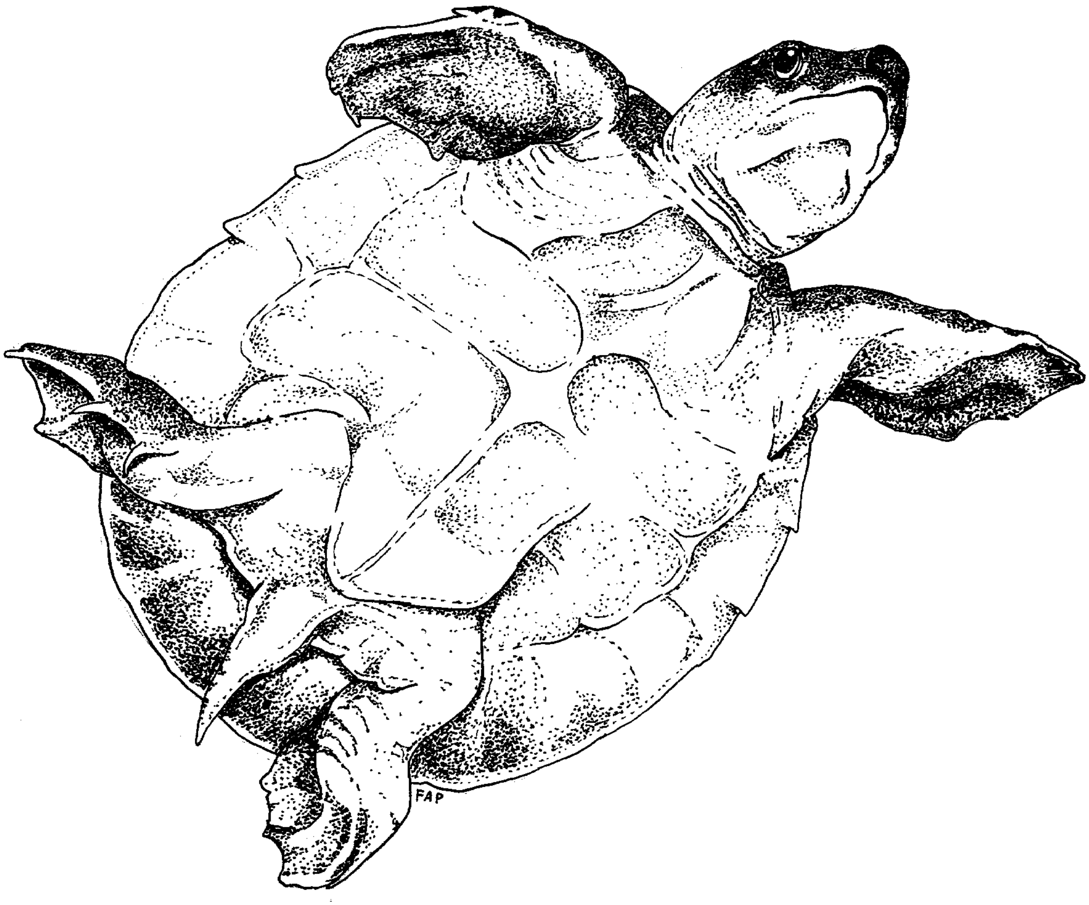
Carettochelys insculpta was suspected of dramatic declines over most of its range. My results give substance to those concerns and should result in a re-evaluation of the status of the species in New Guinea and globally. However, the global and local perspectives of the pig-nosed turtle are dramatically different. From one side, local villages consider it a fishery to be managed sustainably. From the other side, the global community will see the pig-nosed turtle as an important relict species to be preserved. Both perspectives are similar in their common desire to see populations of the species persist into perpetuity. However, they differ in their response to declines in abundance and in the perception of what level of population decline is acceptable. This diversity in perspective is an important consideration while creating conservation plans for the pig-nosed turtle in PNG.

Without community-led action informed by applied research and environmental education and supported by wildlife protection; the current declines will continue to yield unsatisfactory outcomes for both fisheries and conservation. I propose to establish a protected nesting beach zone in the Kikori riverine and coastal areas and non-take zones in delta areas. This project would draw upon community members and committed land owners to alleviate pressure on the pig-nosed turtle population, especially nesting females and their nests in critical breeding areas. In so doing, it will provide new employment opportunities for local people and build capacity for the local community to take control over the sustainability of their natural resources. This will yield a sustained program to redress the decline in the species. It will also instigate a long-term monitoring program of eggs and meat through the Kikori markets and villages. Monitoring would be an opportunity to engage the community and local schools in a long term program to monitor egg consumption in the villages and markets surveyed also in 1980-81 and 2008-09.

Constant environmental education activities should be maintained through the local radio station and schools. These activities will inform the communities about conservation issues related to the area and the progress of the project activities. *Carettochelys insculpta* population dynamics are still poorly understood in the Kikori. Genetic and satellite/radio tracking studies have more chances to succeed and can improve the understanding of the population dynamics and nesting patterns in the Kikori region. Genetic studies can also confirm if *C. insculpta* in this region is in fact a single population, which is essential for an effective management plan. Ethnobiological, socioeconomic and political studies are also needed to better understand pig-nosed turtle exploitation and its role in the traditional communities of the Kikori region. A rapid increase in the Kikori pig-nosed turtle population is not realistic. Long-term conservation projects are absent in the Kikori region. The use of the pig-nosed turtle as a “flagship” and “umbrella” species may hopefully act as a trigger for many other wildlife conservation and management projects in this area and other regions of PNG.

CHAPTER 1

General Introduction



The study species – The pig-nosed turtle (*Carettochelys insculpta*)

Illustration by Fernando Perini

"The little turtle in the river
Sticks her nose and gives a shiver
It is far too cold to dig a nest
So she goes back in for a rest"
Anonymous, 1981
Verses found in a fieldwork datasheet

CHAPTER 1

General Introduction

One of the biggest drivers of environmental change in today's world is humankind. This is true even outside the domain of western industrialization and applies wherever humankind builds and changes environments to meet its needs. Environmental disturbances caused by humans may be particularly extreme and global in extent (Hughes et al. 1997; Pimm et al. 1995; Vitousek et al. 1997). The capacity of natural populations of plants and animals to persist through human-induced environmental change is determined by their capacity for phenotypic plasticity (Hendry et al., 2008) and genetic change (Burger & Lynch 1995; Grether 2005; Kinnison & Hairston 2007; Pigliucci & Murren 2003; Stockwell et al. 2003). Phenotypic plasticity and genetic adaptation have limits (Hendry et al. 2008). Decline and even extinction are likely when populations are pushed beyond their limits. Human influence in the recent decline and extinction of many species is undeniable. For example, since 1900, 123 freshwater animal species in North America have become extinct (Ricciardi & Rasmussen 1999) and Australia has the worst record for mammal extinctions in the industrial age (Burbidge & McKenzie 1989; Lunney et al. 1996; Short 1998).

According to the International Union for Conservation of Nature (IUCN) Red List, the number of threatened species increases every year. At least 38% of the 44,837 assessed species are considered threatened and 804 are already extinct (Vié et al. 2009). This recent loss of biodiversity is happening in a relatively short period and some consider the planet to be facing extinction rates similar to the five great mass extinctions of the geological past (Eldredge 2001; Erwin 2001; Wake & Vredenburg 2008). Nearly every aspect of this sixth wave of extinction is linked directly or indirectly to human activities (Wake & Vredenburg 2008). Dramatic human population growth has imposed massive demands on the environment. Humans have severely modified and destroyed habitats (Myers 1983) and introduced exotic organisms (Roemer et al. 2002) and new pathogens (Daszak et al. 2004). Anthropogenic impacts on global climate can also potentially influence the environment and its biological communities (Jackson 2008; Thomas et al. 2004).

The outcome of these activities is often the decline and extinction of wildlife populations. Preventing or ameliorating the impact of human population growth, economic development and associated pressures on the natural environment and its biota through active intervention requires knowledge of how the natural environment functions to maintain biodiversity and how it will respond to human-induced change. One threat to global biodiversity in particular and of direct relevance to the topic of this thesis is wildlife overexploitation, which is closely linked to the increase of human population (Dudgeon et al. 2006; Rosser & Mainka 2002). Development of modern harvest technologies and market economies, together with the loss of traditional controls and greater access to resources through road building and forest fragmentation, are among the main reasons for overexploitation (Bennett & Robinson 2000).

Effects of exploitation on long-lived, K-selected species are particularly insidious. Most long-lived species can sustain only a limited adult mortality and may not recover strongly or rapidly enough from reductions in population densities to ensure their persistence (Musick 1999; Sminkey & Musick 1996). These species generally exhibit slow growth and late maturity. Reproduction is usually characterized by low fecundity (e.g. large cetaceans) or variable and infrequent recruitment (e.g. sea turtles) (Musick 1999). These characteristics make long-lived species particularly vulnerable to excessive mortality. Additionally, overexploitation and stock collapse may be masked, since the absence of recruitment is often masked due to the presence of long-lived senescing adults. A long time may pass before decline is detected and overcome (Bodie 2001; Browne & Hecnar 2007; Musick 1999). Turtles are a good example of long-lived animals with low capacity to recover from severe population reductions (Crouse et al. 1987; Frazer 1992).

Eventually, wildlife declines due to overexploitation affect the livelihoods of those who are exploiting the resource. Poor people in rural communities are the most affected, since the decline in harvest reduces the available animal protein and removes one of their few trade commodities (Milner-Gulland & Bennett 2003; Robinson & Bennett 2002). To promote the conservation and management of wildlife in these communities, holistic approaches are recommended which integrate biological, socioeconomic and political disciplines (Campbell 2002; Frazer 1992; Ludwig 1993; Milner-Gulland & Bennett 2003). A way to promote biological conservation activities and set management priorities is to define organisms that require special conservation attention. These species are often used by institutions during the design of environmental regulations and establishment of protected areas (Frazier 2005; Simberloff 1998).

Two common terms used in conservation are “umbrella” and “flagship” species. “Umbrella” species have territories and life history requirements that are so vast that a conservation plan focusing on them will consequently protect most species in the same area (e.g. carnivorous mammals) (Wilcox 1984). The concept of a “flagship” species is more related with social context and usually represents organisms that attract special attention from the general public (e.g. primates and elephants) (Myers 1983; Western 1987). Although the use of both “umbrella” and “flagship” species have been heavily criticized (Andelman & Fagan 2000; Roberge & Angelstam 2004), in many cases the concern raised for these species has resulted in a global network of conservation projects with profound implications for community empowerment, international relations and governance (Frazier 2005). However, lack of ecological information is a block to effective action. Conservation and management of flagship and umbrella species needs to focus on applied and conservation research. Otherwise conservation programs will fail to deliver successful outcomes.

Case studies on flagship and umbrella species are important for a number of reasons. Detailed ecological studies of endangered species identify key population traits essential in successful conservation programs. They also are vital to determine the reasons for population decline (Caro & Laurenson 1994; Pimm 1991). However, evidence of population decline of overexploited wildlife is extremely difficult to obtain in remote communities (Milner-Gulland & Bennett 2003). In this thesis I provide indirect and direct evidence of the decline of the pig-nosed turtle (*Carettochelys insculpta*) in the Kikori region, Gulf Province, Papua New Guinea. I also explore the aspects and trends of pig-nosed turtle harvest by local communities, which is the main driver of its decline and I provide fundamental information on the biology of this species that will be important in charting a course for its successful management as a resource for indigenous communities and its conservation as a flagship species.

At the same time, I will address some more fundamental questions associated with its biology. A central tenet of biology is that taxa are adapted to their environment. Many studies assume that species comprise homogeneous, non-evolving populations and thus mistakenly overlook their genetic variation and potential for rapid evolutionary change (Johnson & Stinchcombe 2007). The life history elements of a species have been defined as the set of most suitable traits to enable it to persist in a particular environment (Ballinger 1979; Stearns 1976). The implication is that, at any point in time, a species is optimally adapted to its environment, that equilibrium is rapidly achieved and that natural selection allows organisms to closely track environmental change. Certainly, phenotypic change can happen in the short space of only a few generations (Hairston et al. 2005; Hendry & Kinnison 1999; Kinnison & Hendry 2001;

Palumbi 2002; Reznick & Ghalambor 2001; Stockwell et al. 2003). The existence of phenotypic plasticity, itself an evolved attribute, is testimony to the inability of evolution *per se* to keep pace with environmental change (Grether 2005).

When the environment changes or a species range expands into new environments, there is a possibility that biological traits will lag behind. In this case organisms may be currently in the process of tracking those changes through adaptation (Hairston et al. 2005). This places limitations on interpretations, when inferring selective advantage, by matching current traits with current environmental conditions, or when interpreting adaptive advantage from studies that focus only on a small fraction of the distribution of a species and the range of environments that it experiences. This has two consequences that are relevant to this thesis.

The first is that we can anticipate variation in morphology, physiology and behaviour in organisms across their range both because of differing phenotypic responses to the differing environmental conditions they encounter and because of local adaptation to the more persistent elements of those varying conditions (Shine 1987; Vitt & Congdon 1978; Young et al. 1989). Local adaptation entails a lag, attenuated by gene flow, which can allow retention of traits evolved to meet past conditions that do not necessarily apply to the local contemporary environment (Blomberg & Garland 2002). Autecological studies at a single restricted part of a species range run the risk of interpreting traits in too narrow an ecological context. In this thesis, I provide examples where insights on the evolutionary significance of life history traits arise from comparative studies of a single species across disparate parts of its range. Phenotypic variation can mask the full repertoire of life history responses to environmental conditions; so again, greater insights into species ecological responses to differing environments can be gained by study across the range of species.

In my study of the pig-nosed turtle in Papua New Guinea and in comparisons with earlier extensive work in Australia, I do not attempt to disentangle phenotypic responses from local adaptation. Rather, I revisit some of the major interpretations placed on key and unique traits of this iconic species. The second consequence of plasticity in a species response to environmental conditions is that it provides scope for accommodation of novel environmental change in the future, even though this plasticity has presumably arisen through historical experience. Both genetic variability that provides fodder for natural selection and local adaptation and the capacity for phenotypic plasticity provide scope for a species to respond to change.

The study species – *Carettochelys insculpta*

The pig-nosed turtle (*Carettochelys insculpta*) is both an “umbrella” and a “flagship” species. It is of great significance to conservation because of its status as the sole survivor of a once widespread family of turtles (Carettochelyidae) and its restricted global distribution (Georges et al. 2008b). It is also subjected to intense harvest pressure throughout much of its range (Georges et al. 2008b; Groombridge & Wright 1982). Highly prized as food, it is the most exploited turtle in New Guinea (van Dijk 2009). Both turtle and eggs are collected for trade or consumption by local villagers (Georges et al. 2008a; Georges et al. 2008b). The pressure on pig-nosed turtle populations has increased in recent years, especially in Western Papua and Papua New Guinea, due mainly to the growth in human populations, a greater propensity for villages to establish on riverbanks following the cessation of tribal warfare and the introduction of new technologies. For example, traditional methods of capture have been substituted by modern fishing technologies (Cann 1972; Georges 1987; Georges et al. 2006).

In the Kikori region, Gulf Province, Papua New Guinea, the introduction of outboard motors and modern fishing equipment is related to increased capture rates of *C. insculpta* (Georges et al. 2006; Georges et al. 2008a; Georges et al. 2008b; Rose et al. 1982). Local villagers harvest the pig-nosed turtle eggs with efficiency close to 90% (Pauza 2003). This has led to the widespread view that *C. insculpta* has suffered severe population declines (Georges et al. 2008b; Groombridge & Wright 1982; Pauza 2003). There is, however, remarkably little direct evidence of these declines. The IUCN lists *C. insculpta* as Vulnerable (IUCN 2009), which rests largely on a precautionary approach. Studies of *C. insculpta* population trends and harvest patterns in New Guinea are critical to assess the accurate status of the species.

Moreover, *C. insculpta* is unique and unusual among turtles in many facets of its morphology, ecology and behaviour (Georges et al. 2008b). The pig-nosed turtle has temperature-dependent sex determination (TSD) as its sex is determined by substrate temperature during the incubation period (Georges 1992; Webb et al. 1986). Substrate temperature is closely related to the thermal environment (Doody et al. 2004); therefore *C. insculpta* requires specific habitats to produce both males and females (Wibbels et al. 1998). Optimum habitats can potentially vary spatially and temporally in different environments with specific thermal patterns. In the Daly River in tropical northern Australia, multiple evolutionary processes such as natural selection, physical constraints and phenotypic plasticity influence nest site choice and timing of *C. insculpta* nesting (Doody et al. 2004). In this population, flood waters and predation by monitor lizards (*Varanus panoptes* and *Varanus mertensi*) are the major source of embryonic mortality and they play an important role in nest site selection and nesting time (Doody et al. 2003b; Doody et al. 2003c; Doody et al. 2004).

Phenotypic plasticity probably influences the onset of the nesting season in the Daly River. The start of the nesting season is related to the energy accumulated by gravid females during the wet season; nesting starts earlier after more productive wet seasons (Doody et al. 2001; Doody et al. 2004). On the other hand, natural selection has an important role in delimiting the end of the nesting season. Embryos that are not sufficiently developed are drowned by early wet season rains that cause flooding of nests. Consequently, females that nest in the late dry season risk losing their reproductive effort for that year (Doody et al. 2001; Doody et al. 2004). Nest site choice is most likely a trade-off between flood mortality in lower sites on the sandbank and non-cohesive sand in the higher bank sites. Females usually choose median elevation sites to nest, avoiding both scenarios (Doody et al. 2004). The variability of the nesting environment in the Daly River, where beaches are ephemeral and few last for successive years, probably also shaped female behaviour, since beach homing behaviour is probably absent (Doody et al. 2003b; Doody et al. 2003c).

Pig-nosed turtles are considered a freshwater species. Australian populations are restricted to the upper reaches of rivers (Doody et al. 2003b; Doody et al. 2003c; Georges et al. 1989; Georges et al. 2008b). However, females nest in large numbers in both riverine sandbanks and coastal beaches in the Gulf of Papua (Georges et al. 2008a; Georges et al. 2008b; Rhodin & Rhodin 1977). This difference between Australian and Papua New Guinean populations extends to maximum female size, reproductive parameters and nesting seasons (Georges et al. 2008a; Georges et al. 2008b; this thesis). These different phenotypes are probably evolutionary responses to the different environments in Australia and New Guinea. However, to better understand the ecological and evolutionary processes behind nest site and nest time selection in different populations of *C. inscuplta*, especially in relation to coastal nesting site choice, a detailed study needs to be done in New Guinean pig-nosed turtle populations that nest in both coastal and riverine areas.

Thesis aims and structure

In this thesis, I investigate some aspects of the interactions of the pig-nosed turtle (*Carettochelys insculpta*) with its environment and with humans. I examine the relationship between *C. insculpta* nesting ecology and its environment within and among different populations. I also investigate the pig-nosed turtle decline in the last thirty years and how this decline relates to the patterns and trends of adult and egg harvest in the Kikori population in Papua New Guinea. My results are presented in a series of four chapters, each written as a stand-alone manuscript to be prepared for publication. As a consequence, there is some repetition, especially in the material and methods, which was unavoidable. The literature cited is presented in a single reference list at the end of the thesis. A set of specific objectives are introduced in the following outline of thesis structure.

In Chapter 2, I compare nesting areas and nesting phenology in populations of *C. insculpta* to interpret differences in life history in the context of differences in rainfall patterns. I relate body size and other characteristics of coastal nesting in *C. insculpta* of the Kikori region and compare them with those of Australian populations. At a broader taxonomic scale, I also compare the difference in body size of obligate riverine species and riverine species with estuarine or marine components of their life history within the super-family Trionychoidea. I use these comparisons to argue that the differing climatic regimes between the wet-dry tropics of northern Australia and the wet tropics rivers of southern New Guinea can explain, at least in part, the differences in nesting patterns and contribute to the difference in body size and attendant life history attributes between Australian and New Guinea populations of *C. insculpta*. This paper is destined to be submitted to Zoological Journal of the Linnaean Society.

In Chapter 3, I examine the key ecological mechanisms behind the evolution and maintenance of the pig-nosed turtle coastal-riverine nesting dichotomy in the Kikori region of Papua New Guinea. I evaluate the ecological traits of coastal and riverine areas by comparing nests and sandbanks attributes and water inundation patterns. I test a possible female behavioural response to areas with different inundation patterns by examining the relationship between the number of hours a sandbank spent submerged and how close to the maximum elevation of the sandbank the female chose to nest. I also chose different areas in relation to predation and persistence of sandbanks and nests. Finally, I compare the homogeneity of nest distributions within sandbanks among different nesting areas and identify configurations of sandbank use. This paper is destined to be submitted to Ecology.

In Chapter 4, I report the results of a matched market and village survey of the pig-nosed turtle over almost 30 years in the Kikori Delta. This provides the first evidence of population declines. I compare nesting female size between two periods to evaluate the effect of selective harvesting towards females nesting on the sandbanks. I monitor nest survivorship in natural sandbanks to ascertain the level of poaching pressure. Finally, I identify opportunities for an effective community level response to the decline I have identified with a view to establishing sustainable harvest practices for this important food resource. This paper is destined to be submitted to Conservation Biology.

In Chapter 5, I identify *C. insculpta* hunting areas for each language group in the Kikori delta and measure their relative number of harvested animals. I investigate the correlations among the hunting methods and harvest turtle size and sex ratio with different hunting areas and language group aggregations. I assess the effects of new fishing technologies and compare the proportion of turtle capture methods utilised recently with those common thirty years ago. I evaluate the effect of change from a subsistence economy to a cash economy in different tribes and compare the percentage of *C. insculpta* sold at market recently to those sold thirty years ago. Finally, I identify how cultural diversity needs to be recognised during the implementation of an effective community level response to a wild meat decline with a view to establishing more sustainable harvest practices for this important food species. This paper is destined to be submitted to Biological Conservation.

Chapter 6 is a final synopsis that summarises the findings of each of the previous chapters. I explore the outcomes in a local and global context and highlight their contributions to advances in science and conservation. I discuss the challenges for conservation and environmental education in countries that have high biodiversity, but are considered logistically and culturally complex in a western point of view and offer options for future research and conservation and environmental education plans.

CHAPTER 2

Coastal Nesting and Life History Attributes

“Does anybody want to go to the mountains with me?”
Cartoon from Fernando Gonzales, Níquel Náusea, Brazil

“This story is based on the true story: Long, long time ago there lived a Piku or Turtle. Its name was Matua. She was a Young Piku Girl. (...) Anyway, this young female Piku (Matua) lived there all alone by herself. She had everything she wanted but she had no friends to talk to and play with. The Piku (Matua) sometimes swim to the mouth of Kahuki Creek and watch the big fast flowing Kikori River and wished one day she would go out there and explore the big river. One day she decided to swim to the mouth of Kahiki Creek and to the big river and headed downstream. (...) Matua the Piku was scared but she kept moving down with the water. Matua kept on going down until she came to a strange place that she had never seen in her life. She stopped and was looking at the very open area very deep and wide. (...) She was standing there wondering what she was looking at, when she heard a men voice behind her. Matua turn back and saw a nice handsome Piku man standing, the Piku man said who are you? You look like you are new around here. I am Mr Kerewo said the Piku Man and this is my land. Matua said my name is Matua and am from the mountains of Kikori River. What is this place anywhere I have never see place like this before. Oh, this place! said, Mr. Kerewo. It is called Davara. It does not have an end and its very deep down there. You don’t want to go out there, because there so many dangerous sea animals live out there, some of them are bigger them you and me. So if I were you I would turn back from here. Said the Piku man Mr. Kerewo. The Piku man said it is going to be dark soon so why don’t you stay with me tonight. So Matua stayed overnight with Kerewo the Piku Man. In the night the Piku Man slept with Matua. Matua stayed for a month and found that she was pregnant, so one night she left for her home up stream without telling Mr. Kerewo the Piku Man. On the way she laid her eggs in every sand until she reached her home. She the Piku girl never went out of her home again. So if you travel by boat or canoe from Goaribari Island to Kaiam you will collect a lot of eggs. But you won’t see any eggs beyond Kaiam Village. Matua didn’t go there.”

(Joe Kokou; Kopi Village; Recorder: Susan Joe)

CHAPTER 2

Coastal Nesting and Life History Attributes

Abstract

Freshwater species that also inhabit estuaries face a challenging and variable environment, one that is especially problematic for osmoregulation. Few species of freshwater turtle regularly enter the sea or estuaries, or nest on coastal beaches. The pig-nosed turtle (*Carettochelys insculpta*) does so in Papua New Guinea (PNG). In this chapter, I argue that this has been an influential factor in the evolution of its life history attributes, including body size and vagility. Throughout its range, *C. insculpta* nests during the drier months when suitable sandbanks are exposed. Rainfall in the drier seasons and residual flows from the wet season dilute salinities in the estuaries of the larger rivers in PNG, where *C. insculpta* nests in upstream, estuarine and coastal areas. In the wet-dry tropics of Australia, high flows are restricted to the wet season and high salinities prevail during the nesting season. Substantial marine incursion occurs at this time in the estuaries and estuarine salinities are high. Nesting is only recorded from the upstream reaches of the rivers inhabited by *C. insculpta* in Australia. Pig-nosed turtles nesting on the coast are significantly larger than those nesting in riverine areas of the Kikori and both are significantly larger than riverine populations in Australia. The same pattern is observed in the superfamily Trionychoidea. Trends towards larger body sizes between species and within and between populations, suggest that the coastal environment and its challenges have an important influence on the size of species. I propose that the differing climatic regimes between the wet-dry tropics of northern Australia and the wet tropics rivers of southern New Guinea explain the differences in nesting patterns and contribute to the difference in body size and attendant life history attributes between these two landmasses. Adaptation to marine environments in Papua New Guinea populations may explain the traits in Australia that otherwise defy explanation such as two clutches every second year and delayed egg emergence. Different populations may vary in terms of habitat and time of origin (i.e. time of colonisation of a new area). When only part of a species range is studied, variability in life history traits must be taken into account and conclusions are limited.

Key words: Osmoregulation, softshell turtles, Trionychoidea, Carettochelyidae, distribution, habitat selection, estuaries, natural selection, body size, exaptation.

Introduction

Population attributes, such as morphology, physiology, life history, demography and behaviour vary across different environments within a species range through local adaptation, phenotypic plasticity, or both (Ballinger 1979; Shine 1987). This relationship between population attributes and the environment can be used to better understand life history evolution (Ballinger 1979). Of particular interest in this regard are species whose ranges span well-recognised ecotones (Dunson & Mazzotti 1989), such as terrestrial-aquatic (Roe & Georges 2007) or marine-freshwater (Bilton et al. 2002; Georges et al. 2008b). When individuals of a species move between these ecotonal regions, they face many challenges. In estuarine systems, these challenges can be physical (e.g. nesting site availability and water flow) and biotic (e.g. competition, predation, parasitism and eating habits) (Kinneary 1993; Kinneary 1996). However, osmoregulation probably poses the most significant challenge (Winemiller & Leslie 1992). Water salinity is arguably the dominant factor limiting the distribution of freshwater reptiles in estuarine habitats (Dunson 1986; Dunson & Mazzotti 1989; Laurén 1985).

Extant estuarine reptiles show a variety of adaptations to marine life, which could reflect transitional stages in a gradual evolution from freshwater to the sea (Dunson & Seidel 1986). The first of these transitional states is related to a behavioural osmoregulation phase. Intermediate stages would involve a reduction in net salt uptake and water loss through a specialised integument and feeding behaviour. The last stages are related to the development and enlargement of salt glands and morphological changes for pelagic life (Dunson & Mazzotti 1989). Large body size may also be an important advantage for reptiles in marine environments, especially considering osmoregulation, thermoregulation and energetic challenges (Dunson 1986; Hendrickson 1980; Kinneary 1996; Paladino et al. 1990).

A few species of freshwater turtle are sporadically found swimming in the sea and estuaries or nesting on coastal beaches (Bonin et al. 2006; Dunson & Moll 1980; Moll 1994; Portal et al. 2005; Pritchard & Trebbau 1984). Those that routinely occupy estuaries and marine habitats have relatively large body sizes. This phenomenon has been particularly well documented for nesting females (Dunson & Mazzotti 1989; Kinneary 1996). Large females are in part interpreted as an explicit adaptation to the challenges presented by their marine phase (Moll 1994). The cost of dealing with physiological challenges of a saline habitat and the potential predation of adults, hatchlings and eggs is presumably counterbalanced by greater availability of suitable nesting habitat (Dunson 1986; Kinneary 1996; Moll 1994; Pritchard 2001). The physical and biological constraints of the ocean environment, such as remoteness of nesting beaches, the need to migrate, and higher risk of predation, could drive the selection of relatively large, highly vagile and fecund turtles (Hendrickson 1980).

Primarily a freshwater group, many species of softshell turtle (Trionychidae) nest and occupy estuarine or even marine habitats (Carr & Carr 1985; Rhodin & Rhodin 1977). Sister family to the Trionychidae is the Carettochelyidae and its single species, the pig-nosed turtle *Carettochelys insculpta*. This species also occurs and nests in coastal areas of southern New Guinea (Georges et al. 2008b; Rhodin & Rhodin 1977). Females nest in large numbers on coastal beaches and isolated sandbanks of the Gulf of Papua, at the mouth of the Fly, Kikori, Omati and Purari Rivers (Georges et al. 2006; Georges et al. 2008a; Georges et al. 2008b; Pernetta & Burgin 1980). Coastal nesting does not occur in Northern Australia, where populations are restricted to the upper parts of the Daly and South Alligator Rivers (Doody et al. 2003a; Doody et al. 2003c; Georges et al. 1989; Georges et al. 2008b). Australian and Papua New Guinean populations also differ in terms of size, reproductive parameters and nesting phenology (Georges et al. 2008a; Georges et al. 2008b). These differences between populations may be related to their differing habitats and associated environments. Rainfall patterns are dramatically different between these two landmasses and this in turn affects patterns of seasonal river flow and estuarine salinities. Knowledge of local and temporal water saline variations is required to understand the process of adaptation to salt-freshwater ecotones (Kinneary 1996). Tidal fluctuations and vertical salinity gradients are important variables physiologically (Kinneary 1992, Kinneary 1993; Kinneary 1996). River flow and penetration of freshwater into estuarine and coastal marine systems, periodically diluting salinity in these coastal environments, may be an important element in the progression of evolution from obligate freshwater habits to facultative marine or estuarine habits (Dunson & Moll 1980).

The aim of this study was to compare nesting areas and nesting phenology in populations of *C. insculpta* and to interpret differences in life history in the context of differences in rainfall patterns. I studied body size and other characteristics of coastal nesting in *C. insculpta* of the Kikori delta and compared them with those of Australian populations. At a broader taxonomic scale, I also compared the difference in body size of obligate riverine species and riverine species with estuarine or marine components of their life history within the super-family

Trionychoidea. I use these comparisons to argue that the differing climatic regimes between the wet-dry tropics of northern Australia and the wet tropics rivers of southern New Guinea can explain, at least in part, the differences in nesting patterns and contribute to the difference in body size and attendant life history attributes between Australian and New Guinea populations of *C. insculpta*. I also discuss how the adaptation to marine environments in Papua New Guinea populations may explain the traits in Australia that otherwise defy explanation such as two clutches every second year and delayed egg emergence.

Material and Methods

Study site

The Kikori River drainage of Papua New Guinea (PNG) extends from the alpine grasslands of Doma Peaks of the Southern Highlands Province to the extensive mangrove wetlands of the Gulf Province. The western boundary of my study site extended from Kaiam Village (7° 5'40.96"S; 143°59'37.00"E) upstream on the Kikori River to Dopima Island (7°48'12.02"S; 144°13'20.32"E) on the coast and the eastern boundary extended from Kuru-Sire Junction (7° 9'4.45"S; 144°23'6.84"E) on the Sirebi River and Veraibari Village (7°40'49.69"S; 144°31'2.86"E) on the coast. Thus my study site essentially encompassed the coastal, delta and riverine areas of the Kikori lowlands (Figure 2.1).

The studied riverine area occupies the central part of the Kikori basin at ca 40 – 100 m elevation and is highly confined within its limestone bed. Meanders and oxbows are absent. It includes numerous small tidal creeks and swamps, small creeks emerging from small limestone caverns, numerous waterfilled circular depressions between 20 and 100 m in diameter and the main river channel. High tidal influence is observed in the lower parts of the river system (Enesar 2005). Sandbanks suitable for turtle nesting are common mostly in the main channel and its larger tributaries (Georges et al. 2008a). The delta is a large alluvial plain below 40 m elevation. It is dissected by a tributary system of river channels and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain (Enesar 2005). The few sandbanks in the delta are located in the boundaries with coastal and riverine areas (Georges et al. 2008a).

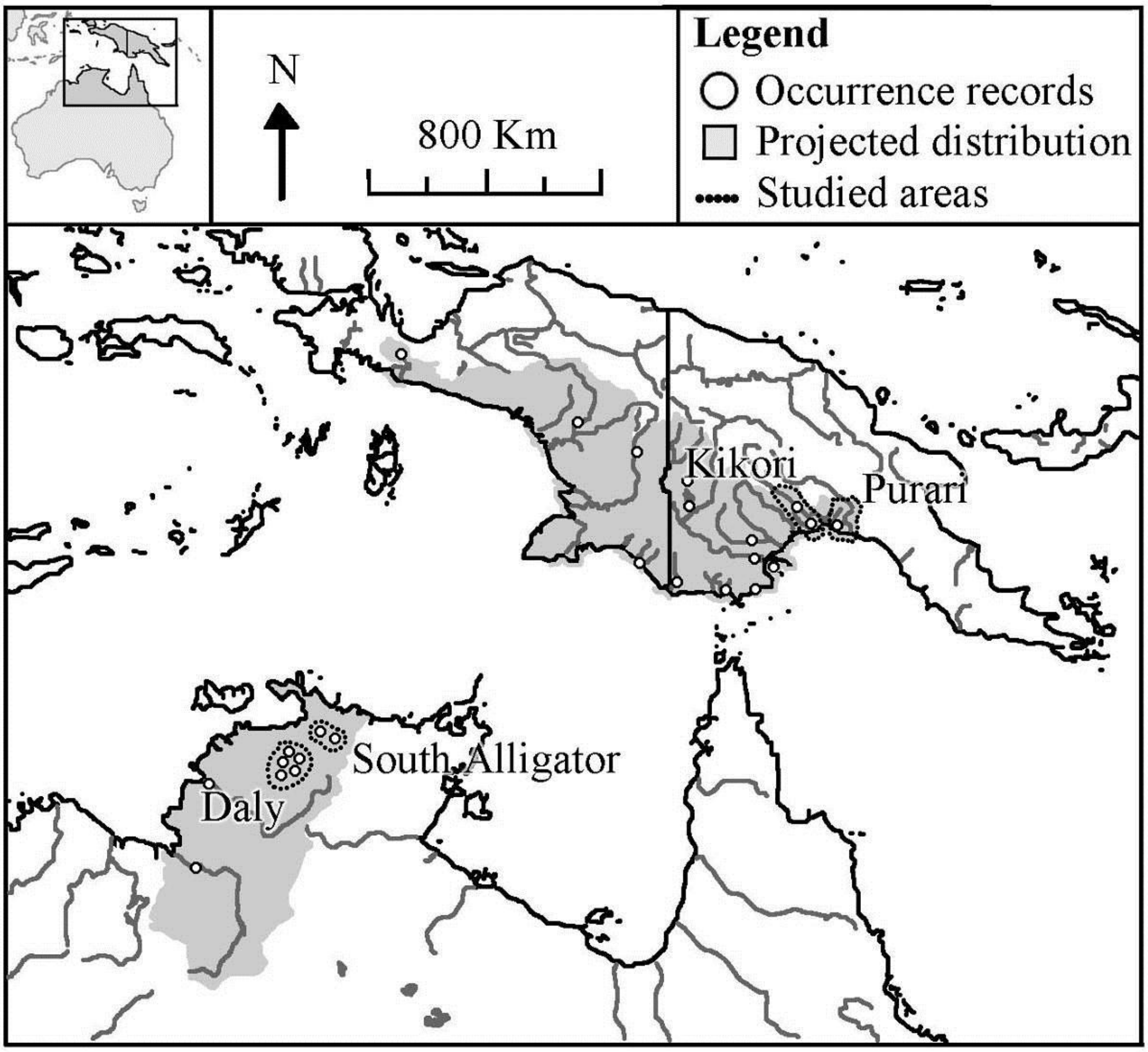


Figure 2.1 Distribution of *Carettochelys insculpta* in Papua New Guinea and North Australia with the projected distribution. White circles represent recorded observations; grey shading is the projected distribution; populations that have been the subject of study are delineated by dotted lines (Daly, South Alligator, Kikori and Purari). Adapted from Georges et al. 2008a.

The coast comprises the delta islands exposed to the Gulf of Papua. It is a very dynamic system, where coastal beaches, sand bars and sand islands are created by wind and wave action (Enesar 2005). New nesting areas can emerge in some places, while existing areas can erode with a consequential loss of nesting habitat. Turuvio Island (7°46'45.45"S; 144°26'33.07"E) is a good example of a dynamic coastal sandbank. Locals recall its emergence in around 2000. It developed into an open sand bar, with small saplings, by 2003 (Pauza 2003). During this study, it was a vegetated, apparently stable island with the largest nesting activity of the coastal region.

The Kikori region climate is wet tropical. Mean relative humidity is high, at between 82% (at 15:00 hours) and 92% (at 09:00 hours) (Georges et al. 2008a). Temperatures range from a minimum of 18^{o}C to a maximum of 37^{o}C, with a mean daily minimum of 22.0^{o}C and a mean daily maximum of 33.5^{o}C. Mean daily temperature is 27.7^{o}C (Enesar 2005). Annual rainfall in the Kikori region is very high by global standards, with an average of 5,667 mm per year (Georges et al. 2008b). It typically rains in all months of the year, with a peak in the monthly average of 732 mm (range 124 – 1730 mm) for June and a minimum monthly average of 275 mm (range 0 – 536 mm) in December. The period of November to January is regarded as the ‘dry’ season, when river levels are low, forests are not flooded and water clarity is greatest. Not only is rain likely in every month, including those of the dry season, but rainfall is highly variable as are associated river flows. In November for example, monthly rainfall can be as low as 41 mm and as high as 880 mm (Georges et al. 2008a).

Data for the Australian populations are from the studies of Doody and Georges as cited throughout the text. Their study area was located within a 63 km stretch of the Daly River between Dorisvale Crossing and Oolloo Crossing (14°04'40"S; 131°15'00"E) (Doody & Georges 2002; Doody et al. 2002; Doody et al. 2003a; Doody et al. 2003c;). The Daly River (Australia) is a spring-fed system with turbid, deep water in the wet season and clear, shallow water during the dry season (Figure 2.1). It averages approximately 50-80 m across and 1.5 m in depth (maximum of 4 m) with a moderate flow during the dry season. During the wet season, water levels rise to an average peak of 13.6 m above dry season levels (5.8-21.7 m). The river substrate is largely bedrock and sand. The climate is typical of the wet–dry tropics of northern Australia (Taylor & Tulloch 1985). Mean relative humidity (at 15:00 hrs, 1966-1980) ranges from a low of 32% in August to a high of 73% in February. Mean monthly maximum air temperature ranges from 30.9°C in June to 36.8°C in October.

The Daly River experiences extremes of high rainfall during the monsoonal wet season and the near absence of rainfall in the dry season. The mean monthly rainfall is less than 7 mm from May to September and rises to a peak monthly average of 284 mm in February (Georges et al. 2002) (Figure 2.2). I used the daily rainfall data from Douglas Daly Research Farm (14° 4'40.00"S; 131°15'0.00"E), from 1968 to 1997 and Oilsearch Kopi Camp station (7°19'13.30"S; 144°10'58.42"E), from 1991 to 2009 to calculate the rainfall monthly mean, standard error, range and coefficient of variation for rainfall in the Daly and Kikori Rivers respectively (Figure 2.2).

The headwaters of the South Alligator River (Australia) flow across the lowlands in shallow valleys to discharge through an extensive floodplain into Van Diemen Gulf (figure 2.1). The drainage is characterised by high flows and extensive flooding in the wet season and little or no flow during the wet season (Story et al. 1976; Story et al. 1969). In the lower tidal sections of the main channel and in upstream sections fed by springs or seepage, the flow declines but does not stop. The studied *C. insculpta* population was located in the Pul Pul billabong in the upper reaches of the South Alligator River (132°35'E; l3°34'S). During the study period the river was approximately 400 m long and 20 m wide with a modal depth of 1.2 m and a maximum depth of 3.0 m (Georges & Kennett 1989). The river substrate consists of sand and gravel covered with a thin layer of fine silt and litter. Water flows through Pul Pul billabong throughout the year (Georges & Kennett 1989). The area climate is monsoonal, similar to the Daly River with rain and associated flooding varying considerably from year to year (Taylor & Tulloch 1985).

Materials and Methods

Coastal *C. insculpta* nesting sites were identified during the 2007-08 and 2008-09 nesting seasons with the help of locals. Local volunteers also recorded the number of nests of *C. insculpta* laid per night in Turuvio Island from the 2007-08 and 2008-09 nesting seasons (Figure 2.3). I validated the information recorded by direct surveys every month and measured nests' characteristics (depth to first egg, chamber depth and percentage of presumed infertile eggs). Presumed infertile eggs were considered those which did not develop an opaque patch five days after egglaying.

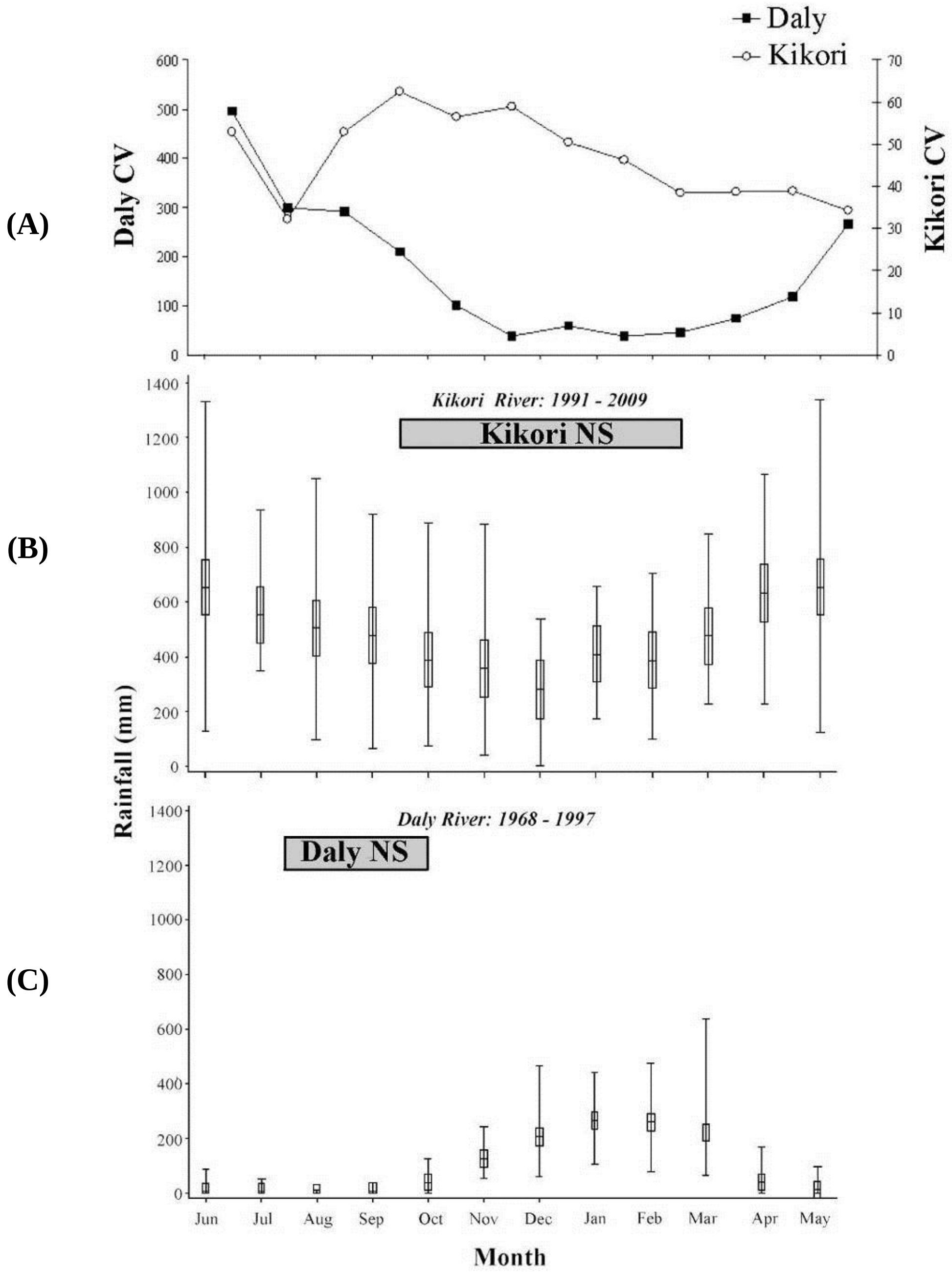


Figure 2.2 Monthly rainfall and interannual variation in monthly rainfall for the Daly and Kikori Rivers. (A): Coefficient of variation by month; (B): Monthly rainfall for Kikori (Oilsearch Kopi Camp Station); (C): Monthly rainfall for the Daly River (Douglas Daly Research Farm). Horizontal bars show the nesting seasons (Daly nesting season from Doody et al. 2004). Rainfall averages are given with their 95% confidence limits (vertical boxes) and ranges (vertical bars). The coefficient of variation is an order of magnitude higher for the Daly than the Kikori, so they are displayed using different scales.

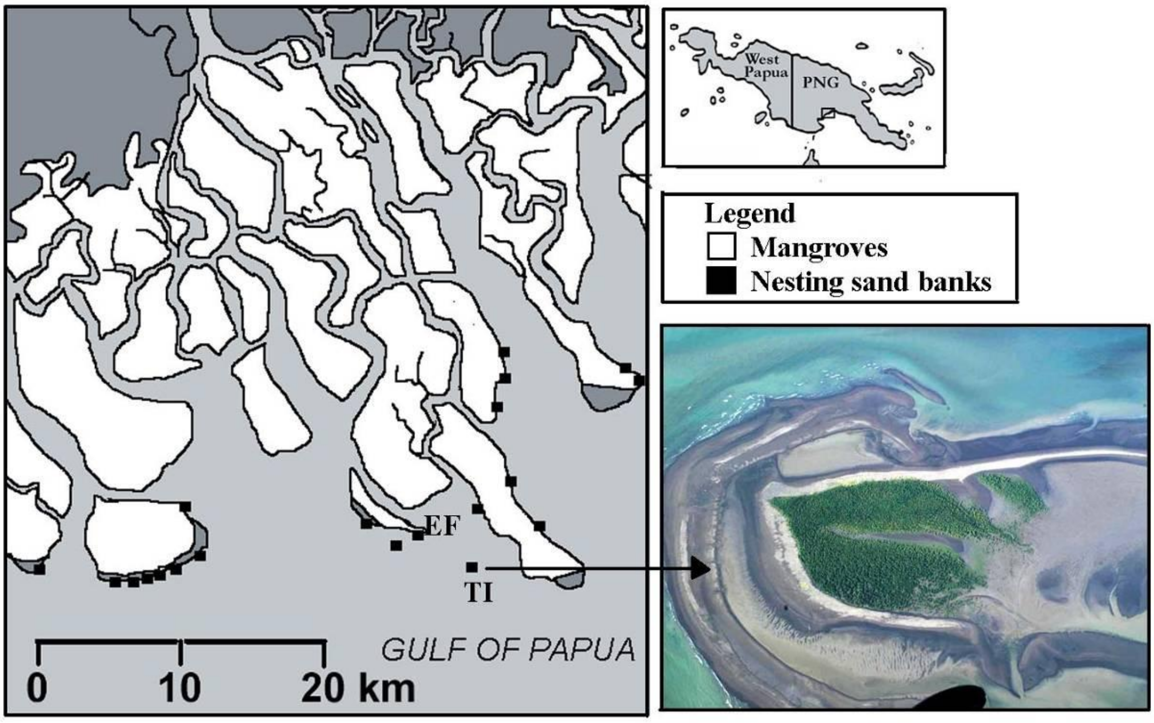


Figure 2.3 The Kikori coast study area, showing the sandbanks used for nesting by *Carettochelys insculpta*. EF: Eribibari fishing camp (site of salinity logger); TI: Turuvio Island (site of nest monitoring). Bottom right: Turuvio Island during low tide. Nesting of *C. insculpta* occurs in the narrow white sand of the central area.

Water level (mH^2O) and salinity (psu) were measured every hour, from 18-Oct-2008 to 13-Jan-2009, using a Star-Oddi DST CTD logger installed on the coastal site of Banana Island (Eribibari fishing camp: 7°45'59.22"S; 144°24'44.68"E). Banana Island is a nesting area of *C. insculpta* and it is located 3.6 km inland from Turuvio Island (Figure 2.3).

I estimated hatching time using the average temperature of twelve i-buttons (DS1922L-F5#, Thermochron iButton ±0.2°C from -40°C to +85°C) that recorded the temperature of four Turuvio nests (Bottom, middle and top of the nest) every 20 minutes. Each nest recorded the temperature during different periods from 17-Oct-2008 to 06-Jan-2009. Hatching time was then estimated by calculating the number of incubation days in relation to the measured temperature according to Young et al. (2004). Hatching estimates were based on the time embryo is fully formed and ready to hatch, but not necessarily when it emerges, since *C. insculpta* embryos aestivate in the egg until anoxia caused by rain or flood, stimulate the hatching (Georges 1992; Webb et al. 1986).

Data on the size of nesting *C. insculpta* were recorded from harvested individuals in 37 villages and associated fishing camps across the study site. When shells or live turtles were available, I measured the maximum curve carapace length (CCL) and information was sought on the locality of capture. Only the population maximum curve carapace length (CCL_{max}) was used in the comparisons with other populations. I used published data on Daly (Doody et al. 2003a) and Alligator Rivers (Georges & Kennett 1989) for the comparisons between *C. insculpta* populations.

I compared the leathery carapace length (LCL) between obligate and facultative freshwater species of the superfamily Trionychoidea, which includes the Trionychidae (Softshell turtles) and Carettochelyidae. This group was chosen because molecular and morphological data suggest that softshells are the closest relative of *C. insculpta* (Shaffer 2009). Scientific names were used according to Rhodin et al. (2009). *Chitra vandijki*, *Pelodiscus sinensi*, *Pelodiscus parviformis*, *Trionyx axenaria*, *Pelochelys signifera*, *Pelodiscus maackii* and *Rafetus swinhoei* were excluded from the analyses owing to the lack of data available on habitat and/or LCL for this species. For the comparisons among *C. insculpta* populations and Trionychidae species, I used data available from the published literature (Bonin et al. 2006; Doody et al. 2003a; Georges & Kennett 1989; Pritchard 2001). A test of means (t-test) and variance was performed to compare (1) the CCL between females nesting in coastal and riverine areas in the Kikori region and (2) the LCL between riverine exclusive and non-exclusive species inside the family Trionychoidea. Satterthwaite approximate t-tests were used for analyses with unequal variances. Statistical tests followed those recommended by Sokal and Rohlf (1981) and were performed using SAS 9.1 or by hand.

Indirect evidence of number of clutches per year was obtained from ten females on two occasions when they were killed and opened for local consumption. I measured clutch size, number of corpora lutea and number of ovarian follicles and from these data, estimated number of clutches laid or to be laid in the current season. On the first occasion, females were captured while nesting on 24-Oct-2007 in Turuvio Island (7°46'45.45"S; 144°26'33.07"E). On the second occasion females were captured by fishing line on 06-Oct-2008 in a coastal mangrove region close to Turuvio. In both cases females were killed one day after capture. Follicles less than 5 mm in diameter were abundant on all ovaries but were not studied. I estimated the clutch number and size by counting the number of corpora lutea, pre-ovulatory ovarian follicles and oviductal eggs larger in diameter than 27 mm (after Georges, 1983).

Results

Kikori coastal nesting

Coastal sandbanks were scattered through the Kikori estuary. *C. insculpta* nests in the narrow white sand parts in the central areas of small coastal islands or the upper parts of long beaches, both protected from most tides (Figure 2.3). These islands and sandbanks are usually adjacent to mangroves, which are dominated by *Sonneratia ssp* and *Nypa fructicans*. Nesting season period was distinct in riverine and coastal areas. Nesting started earlier on the coast, at the beginning of October and was over by the end of December (From 11-Oct to 14-Feb in 2007-08 and from 09-Oct to 24-Dec in 2008-09). Nesting started at the beginning of November in the river, but lasted until the middle of February (From 08-Nov to 13-Feb in 2007-08 and from 25-Oct to 27-Jan in 2008-09).

Temperatures in the top of the nests were higher and more variable (Nest 1: 31.37 ± 0.08; Nest 2: 30.99 ± 0 .06; Nest 3: 31.84 ± 0.06; Nest4: 34.70 ± 0.12), followed by temperatures in the middle of the nests (Nest 1: 31.20 ± 0.07; Nest 2: 31.02 ± 0.06; Nest 3: 31.89 ± 0.07; Nest 4: 33.62 ± 0.04). Temperatures in the bottom of the nests were lower and less variable (Nest 1: 30.84 ± 0.05; Nest 2: 30.60 ± 0.05; Nest 3: 31.44 ± 0.05; Nest 4: 33.48 ± 0.04).

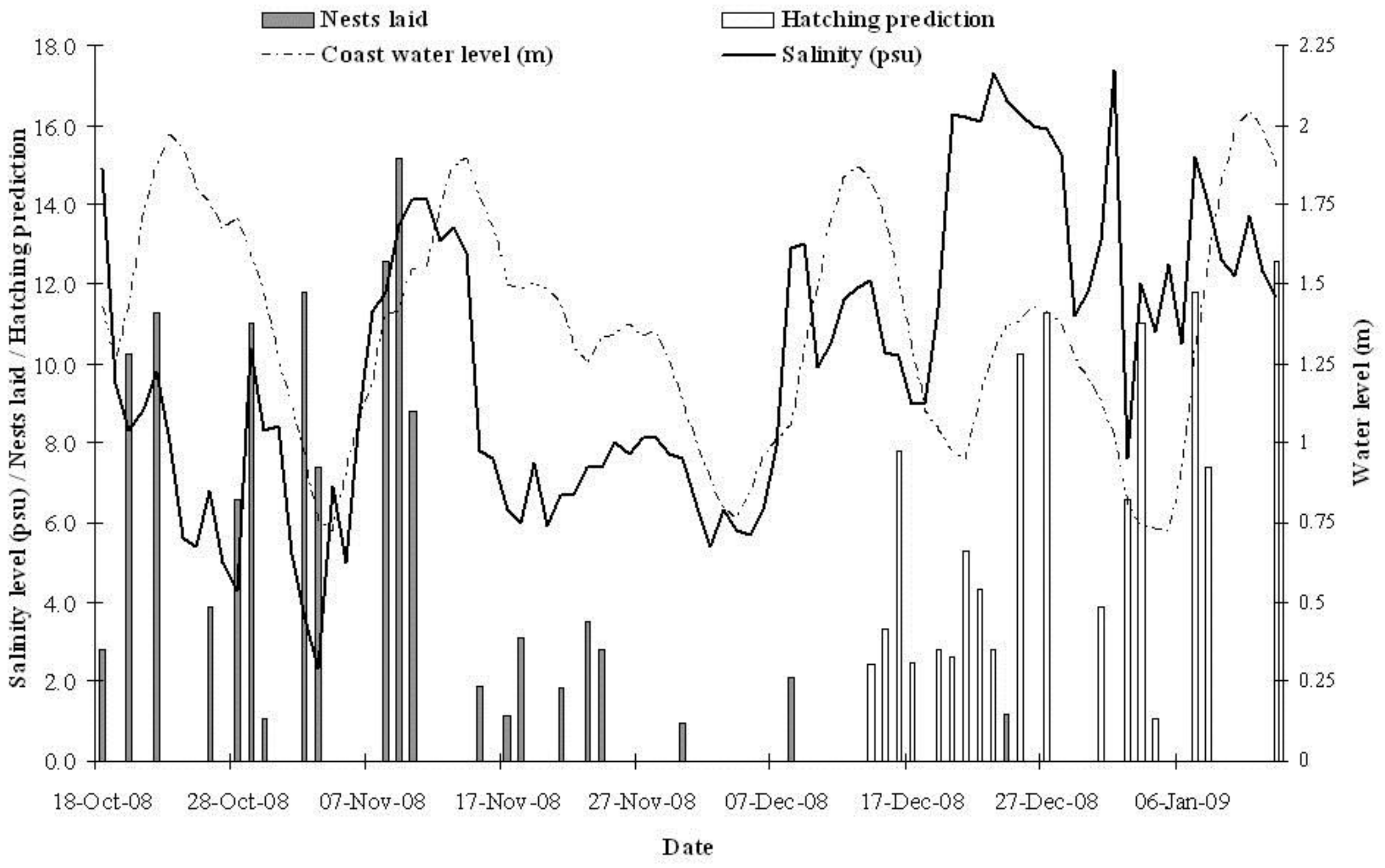


Figure 2.4 Daily number of *Carettochelys insculpta* laid nests and estimated number of nests hatching for Turuvio Island, Kikori coastal region, during the 2008-09 nesting season. Daily maximum water level (m) and salinity (psu) are also presented (ocean water has a salinity on the PSU scale of 35). Hatching estimates are based on the time embryo is fully formed and ready to hatch, but not necessarily when it emerges, since *C. insculpta* aestivates inside the egg until anoxia caused by rain or flood stimulates the hatching (Webb et al. 1986).

Total average temperature was 31.92°C ± 0.38; with a range from 30.60°C to 34.70°C. The temperature of 31.92°C corresponded to an estimated incubation period of 67 days (Young et al. 2004). The average daily maximum water salinity in coastal nesting areas (10.1 psu ± 1.0; n = 88; range: 1.55 – 17.4) was close to 30% of standard ocean water (ocean water has a salinity on the PSU scale of 35). However, both females and hatchlings would probably have to face a salinity that ranged from 7 to 50% of ocean water (Figure 2.4).

Nesting females CCL from the Kikori and Sirebi Rivers were not significantly different (t-test: $t = -0.15$; $df = 19$; $p = 0.89$) and consequently grouped together as “river” for further analyses. The size (CCL) of pig-nosed turtles nesting in riverine areas of the Kikori region show a significantly higher variance than coastal turtles ($F = 2.64$; $df = 36,20$; $p < 0\ .05$). Turtles nesting on the coast (54.31 ± 0.35; n = 37; range: 49.9 – 59.4) are also significantly bigger ($t = -2.67$; $df = 28.8$; $p < 0.05$) than turtles nesting on the river (52.10 ± 0.75; n = 21; range 45.2 – 57) (Figure 2.5).

Of the ten females examined, seven presented strong evidence of producing two clutches per season, including all four females that were collected while nesting in 2007 (Table 2.1). Of those captured on fishing line in 2008, and as such, a sample likely to include both nesting and non-nesting females, three of the six did not present any sign of egg production for that season. Although the sample size is small, I interpret this as confirmation of biennial breeding (indirect evidence of two clutches every second year) (Table 2.1).

Differences between C. insculpta populations

The Kikori region (458.64 ± 46.80; n = 12; range: 282.75 – 652.05) has a monthly average rainfall 400 mm higher than the Daly (58.61 ± 16.26; n = 12; range: 1.55 – 163.16) (Figure 2.2). On the other hand, the Daly River has a rainfall coefficient of variation (CV) on average 122.8 higher than the Kikori River. However, the CV is sensitive to small changes in the mean for values close to zero, as occurs in the Daly during the dry season (Figure 2.2). Pig-nosed turtle nesting season takes place during the dry season in both rivers, although the dry season in the Northern Territory (Australia) is more severe than in the Gulf Province, PNG (Figure 2.2).

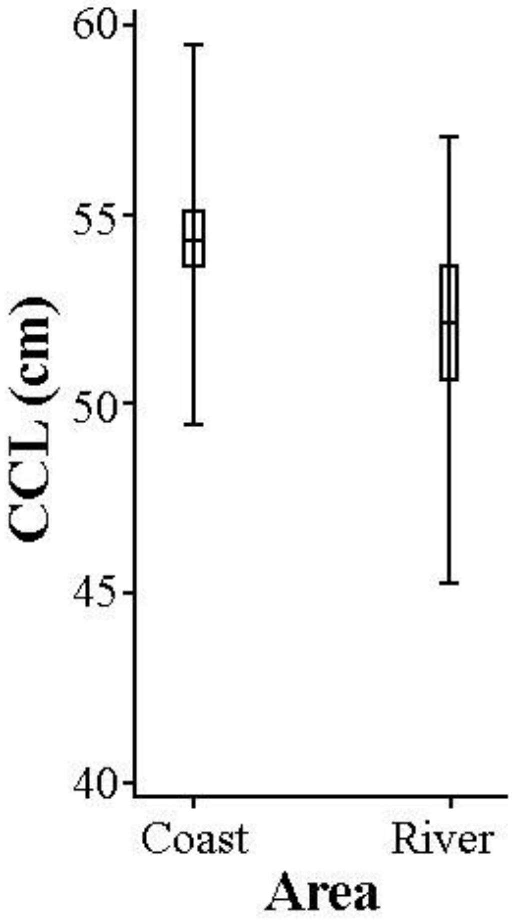


Figure 2.5 Comparison of the size of *Carettochelys insculpta* harvested while nesting at the coast and upriver. CCL: maximum Curved Carapace Length. Means are presented with 95% confidence limits (vertical boxes) and ranges (vertical bars). Females from coastal areas were significantly larger ($t = -3.07$; $df = 22$; $p < 0.01$) and less variable in length ($F = 6$; $df = 16,6$; $p < 0.05$) than females nesting in riverine areas.

Table 2.1 Occurrence of oviducal eggs (OE), corpora lutea (CL), ovarian follicles and estimated clutches (EC) of various sizes for *Carettocelys insculpta* nesting on Turuvio Island on 24-Oct-2007 and opened on 25-Oct-2007 or captured by fishing line on the 6-Oct-2008 and opened on the 7-Oct-2008. Follicles less than 5 mm in diameter were abundant on all ovaries but were not studied.

	Ovarian follicles (Diameter in mm)																
	5	*11*	*13*	*15*	*17*	*19*	*21*	*23*	*25*	*27*	*29*	*31*	*33*	*35*			
Year	*10*	*12*	*14*	*16*	*18*	*20*	*22*	*24*	*26*	*28*	*30*	*32*	*34*	*36*	**CL**	**OE**	**EC**
2007	25	1	0	0	0	0	2	3	0	5	16	0	0	0	26	23	**2**
	70	4	1	1	0	2	2	0	1	0	6	9	0	0	15	0	**2**
	28	0	0	1	1	1	0	1	0	1	5	15	10	0	23	23	**2**
	56	10	0	0	0	0	3	0	7	11	9	1	0	0	22	0	**2**
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	3	3	4	1	0	0	1	2	1	0	3	6	5	2	21	24	**2**
	25	2	3	2	0	0	0	1	1	0	1	4	8	1	30	27	**2**
	25	10	4	1	1	0	0	0	0	1	3	0	0	0	31	15	**2**

Carettochelys insculpta in the Kikori region reached larger sizes (CCL^{max}) and constructed nests with shallower depth to the first egg and deeper nest chamber depth than *C. insculpta* in the Alligator and Daly Rivers. Kikori turtles also showed 23.7% fewer presumed infertile eggs per nest than the Daly population (Table 2.2).

Superfamily Trionychoidea

On average a similar pattern was observed for other turtle species from the superfamily Trionychoidea. There was no significant difference in the variance between obligate and facultative freshwater species ($F = 4.16$; df = 17,6; $p = 0.09$). However, species that enter coastal areas (809.7 ± 67.2; n = 7; range: 582.0 – 1020.0) were significantly bigger than obligate freshwater species (596.2 ± 65.6; n = 18; range: 230.0 – 1220.0) ($t = -2.11$; df = 23; $p < 0.05$; Table 2.3; Figure 2.6).

Discussion

Throughout its range, *C. insculpta* nests during the drier months when lower water levels expose suitable sandbanks (Doody et al. 2003c; Doody et al. 2004; Georges et al. 2008b). The period of the year when nesting occurs is different in each area. Sea turtles also exhibit geographic variation in nesting season periods, which varies in response to distinct environments (Garcon et al. 2009; Whiting et al. 2008). For example, Hawksbill (*Eretmochelys imbricata*) nesting season is related to periods of higher rainfall, when wind velocity drops (Garcon et al. 2009).

The initiation of the breeding season is often related to weather and climate in chelonians. The start of the nesting season can be linked to ambient and water temperatures (Iverson & Smith 1993; Obbard & Brooks 1980; Rowe et al. 2003), rainfall (Booth 2002a; Burke et al. 1994; Wilson et al. 1999) or both (Bowen et al. 2005; Tucker et al. 1997). In many cases, timing of nesting is crucial to reproductive success and hatchling fitness (Bowen et al. 2005; Doody et al. 2004; Olsson & Shine 1997). In the gulf regions of PNG, sufficient rain falls during the dry season and sufficient residual flows remain from the wet seasons to dilute salinities in the estuaries of the larger rivers, such as the Fly, Kikori and Purari Rivers, during the nesting season.

Table 2.2 Nest attributes and female maximum curved carapace length found in the population (CCL_{max}) for *Carettochelys insculpta* from the Kikori region. Comparable data for the Daly River (Doody et al. 2003a, 2004) and the Alligator Rivers region of the Northern Territory (Georges & Kennett 1989), Australia, are included for comparison. Means are given with their standard errors, ranges (in brackets) and sample sizes.

Parameter	**Kikori**	**Alligator**	**Daly**
Female CCL_{max} (cm)	58.2* n = 134	52.3 n = 14	47.0 n = 210
Depth to first egg (mm)	11.3 ± 0.3 (0 – 19.0) n = 113	12.5 (12.0 – 13.0) n = 2	14.1 ± 0.5 (6.5 – 21.0) n = 36
Chamber Depth (mm)	22.2 ± 0.3 (9.7 – 29.3) n = 110	19.5 (18.0 – 21.0) n = 2	21.5 ± 0.1 (14.6 – 26.2) n = 166
Infertility (%)	1.1 ± 0.3 (0 – 22.2) n = 114	0.0 n = 2	24.8 ± 3.9 (0.0 – 85.7) n = 38

*includes Mark Rose unpublished data

Table 2.3 Body size and and habitat preference (enter coastal areas or not) for species of the superfamily Trionychoidea. LCL: Maximum leathery carapace length.

Family	**Sub-family**	**Species**[1]	**LCL**[2] **(cm)**	**Coastal** [3]
Carettochelyidae		*Carettochelys insculpta*	58.2*	Yes
Trionychidae	**Cyclanorbinae**	*Cyclanorbis elegans*	60.0	No
		Cyclanorbis senegalensis	35.0	No
		Cycloderma aubryi	36.5	No
		Cycloderma frenatum	53.5	No
		Lissemys punctata	37.0	No
		Lissemys scutata	23.0	No
	Trionychinae	*Amyda cartilaginea*	76.3	Yes
		Apalone ferox	67.3	Yes
		Apalone mutica	35.6	No
		Apalone spinifera	54.0	No
		Chitra chitra	122.0	No
		Chitra indica	110.0	No
		Dogania subplana	31.0	No
		Nilssonia formosa	57.0	No
		Nilssonia gangetica	94.0	No
		Nilssonia hurum	60.0	No
		Nilssonia leithii	63.5	No
		Nilssonia nigricans	91.0	No
		Palea steindachneri	50.0	No
		Pelochelys bibroni	102.0	Yes
		Pelochelys cantorii	100.0	Yes
		Rafetus euphraticus	68.0	Yes
		Trionyx triunguis	95.0	Yes

[1] Rhodin et al. (2009); Pritchard (2001); [3] Bonin et al. (2006); *Mark Rose unpublished data.

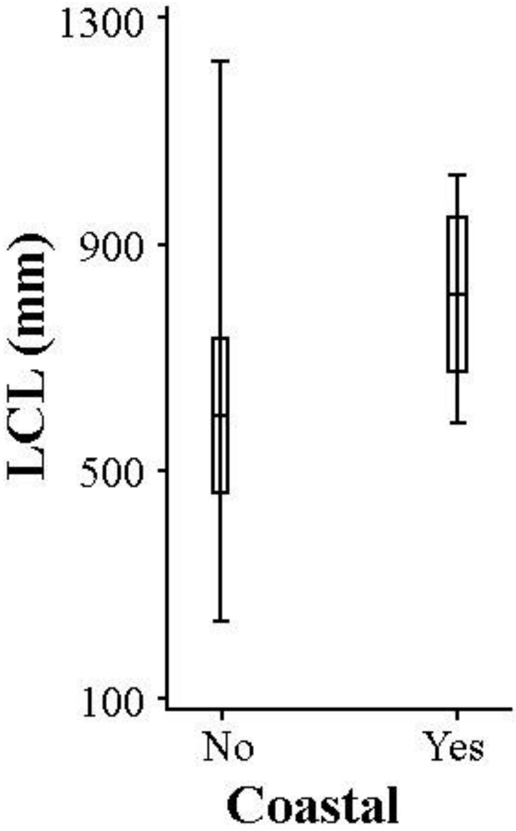


Figure 2.6 Variation in size for obligate and facultative riverine species of the superfamily Trionychoidea. LCL: Maximum leathery carapace length. Means are presented with 95% confidence limits (vertical boxes) and ranges (vertical bars). Species that enter coastal areas were significantly larger than exclusive riverine species ($t = -2.11$; $df = 23$; $p < 0.05$).

Estuarine habits and coastal nesting have not been recorded for the pig-nosed turtle in the Daly River of Northern Australia. In the Daly, dry seasons are characterised by extremely low rainfall and low river flow. Flows that do occur are groundwater fed. Substantial marine incursion occurs at this time in the estuaries and estuarine salinities are high (Wolanski et al. 2004). Incursions of many freshwater turtle species into estuarine areas are limited spatially to the low saline mouths of large rivers or temporally to periods of fresh water runoff generated by heavy rainfall (Dunson & Moll 1980). In big rivers, tidal salinity fluctuation allows periods of exposure to salinity levels below 50% sea-water, which is sufficient for rehydration and foraging (Davenport & Wong 1986; Kinneary 1992, Kinneary 1993).

It is probable that *C. insculpta* populations in the Gulf of New Guinea rely on similar mechanisms, since the water in the river mouth rarely reaches more than 50% of sea water. The Purari River, located in the Gulf province of PNG, also features a coastal nesting population of pig-nosed turtles (Pernetta & Burgin 1980). Its size and the degree of salinity intrusion are very similar to the Kikori River, with salinity never exceeding 10% of sea water (Thom & Wright 1983; Wright 1989). Additionaly, females usually nest between tidal peaks at the coast, which may be an energy conservation strategy and decreases the time spent in saline waters. Females may use the ingoing tidal currents to go to and come back from the coastal nesting areas. Similarly, *Trachemys venusta*, a freshwater turtle that nests on coastal beaches of Costa Rica, utilizes prevailing currents to reach coastal nesting beaches, optimizing movement over considerable distances while minimizing the time spent in saltwater (Moll 1994).

In the Daly, *C. insculpta*'s nests have a mean constant temperature equivalent (CTE) average of 32.0^{o}C (1996: 32.7 ± 1.1; n = 30; 1997: 31.9 ± 1.1; n = 29; 1998: 31.5 ± 1.1; n = 43) (Doody et al. 2004). Although CTE does not represent the mean (Georges 1989; Georges et al. 1994) it is possible to infer that Daly nests are exposed to a similar thermal environment to Turuvio Island nests, which had an average temperature of 31.9^{o}C. In comparison with Australian populations, Kikori nests have deeper chamber depths and the top eggs were closer to the surface. However, these differences are minimal and probably not biologically significant (average difference of 4 mm). On the other hand, Kikori females have a population maximum carapace length 5.9 cm and 11.2 cm larger than those of the Daly and Alligator Rivers, respectively. Larger size is often associated with a greater tolerance to saline exposure (Dunson & Seidel 1986). For example, the body mass of the North American turtle *Chelydra* *serpentina* is inversely proportional to body water efflux and net water loss in sea water (Dunson 1986). In this case, larger turtles have a considerable advantage over smaller ones while attempting to osmoregulate in saline waters. In addition, larger size may also confer additional protection against predators, such as the saltwater crocodile *Crocodylus porosus* and sharks and improve manoeuvrability in heavy seas (Davenport et al. 1992; Dunson & Mazzotti 1989; Moll 1994; Moll & Moll 2004; Pritchard & Trebbau 1984).

Carettochelys insculpta presents morphological characteristics which make them capable of dealing with coastal environments. They are relatively large turtles with similar flippers and mode of locomotion to marine turtles (Delfino et al. 2010; Walker 1973). However, permanent use of the coastal areas of the Daly and Alligator Rivers, where the salinity is close to 100% of sea water, would only be possible with very complex specializations, such as salt glands (Davenport & Macedo 1990; Dunson 1976; Dunson 1979). Since salt glands are probably absent in *C. insculpta*, incursions into the open sea of the Australian coast are unlikely. Large size is characteristic of all sea turtles and all of the previously mentioned sea-going freshwater species. Larger females would face fewer of the risks associated with travelling and, consequently, would be able to expend more time and cover longer distances seeking optimal nesting sites (Gibbons 1990; Moll & Moll 2004). The importance of larger sizes is clear when comparing the Kikori region coastal and riverine females. It is unlikely that females with curved carapace lengths less than 50 cm would be able to deal with the turbulent and saline coastal environments.

Inside the superfamily Trionychoidea, a maximum size of around 60 cm needs to be achieved in order to explore coastal environments. Trends towards larger sizes within and among populations and among species, suggest that the coastal environment and its requirements may play an important role in determining the size obtained by individuals, populations and species that occasionally frequent estuarine areas. However, larger sizes do not necessarily evolve as a response to coastal environments. Larger size could, instead, be a response to greater productivity, longer growing seasons, herbivory, the need to maximize reproductive potential in predator-rich environments and/or as a form of character displacement which facilitates the partitioning of resources between species (Moll 1994; Moll & Moll 1990; Moll & Legler 1971; Pritchard 2001; Pritchard & Trebbau 1984; Valenzuela 2001). In fact, optimum turtle size in a particular habitat is probably determined by a complex combination of factors (Moll & Moll 2004).

The small body size, low frequency of reproduction, extensive home ranges and lack of fat deposits in the dry season in the Daly River *C. insculpta* were previously linked to the low energy content of the ribbonweed (*Vallisneria sp.*); its main diet component during the dry season (Davies 2005; Doody et al. 2002; Doody et al. 2003a; Heaphy 1990; Welsh 1999). Although many studies identified food as the main cause of variation of home range size, growth rate and reproductive output in ectotherms (Ballinger & Congdon 1980; Dunham et al. 1988; Simon 1975), food abundance and nutrient value alone often failed to explain the total variation in the same traits (Christian & Tracy 1981; Jones et al. 1987; Stamps & Tanaka 1981). Anthropogenic (e.g. harvest, pollution) and environmental (e.g thermal, osmotic) factors also need to have been taken into account (Close & Seigel 1997; Dunham et al. 1989; Gamble & Simons 2004; Kinneary 1996; Souza & Abe 2000).

Exaptation is a term used to describe a character that assumes a new use and often facilitates a shift into a new habitat (Gould & Vrba 1982). Under this scenario, a large size is a possible exaptation that enables turtles to expand the scope of their habitat to include turbulent channels, major rivers and estuaries. Once a species invades these hostile environments natural selection will drive an increase in body size until an optimum size is reached (Kinneary 1996; Moll & Moll 2004). Australian *C. insculpta* populations are probably relatively recently derived from New Guinea populations (Cogger & Heatwole 1981). Since the Australian coast is not suitable for nesting owing to the high salinity, these populations probably became isolated in the upper parts of the catchments. A larger size in such an environment could be costly, since time to maturity usually increases and juveniles will have to face high developmental and growth costs (Blanckenhorn 2000). I propose that, due to the lack of opportunities for Australian *C. insculpta* populations to access tidal mangroves and coastal nesting beaches, the selection for larger body sizes was relieved and other selective forces favouring smaller size (e.g. low productivity, temperature) became more prominent. Consequently, the average population size decreased.

Coastal and riverine females in the Kikori region most likely represent the same population. *Carettochelys insculpta* is capable of long distance movements. Its home range can span up to 10 km in the Daly River (Doody et al. 2002). The long distance that separates the riverine and coastal sandbanks is therefore unlikely to be a barrier to Kikori *C. insculpta* females. Indeed the delta, which is located between the marine and riverine area, is probably where they aggregate between nesting seasons to feed (Chapter 5). Large riverine turtles, such as South

American turtles from the genus *Podocnemis*, also exhibit long distance migrations from feeding areas to reproductive sites (Fachín-Terán et al. 2006; Pritchard & Trebbau 1984).

In the Kikori region, the limited evidence suggests that females exhibit the same nesting pattern of two clutches every second year as in the Daly River (Doody et al. 2003b). In this case, the nesting female has two options. She could nest twice in the same area or she could lay her first clutch at the coast and migrate subsequently to riverine areas to lay her second clutch upstream. Kikori region nesting season timing (nesting starts first at the coast and followed later by nesting in the river) and local traditional knowledge supports the second option. Time between clutches in the Daly River is around 41 days (Doody et al. 2003b), which coincides with the difference between the onset of nesting in the coastal and riverine areas of the Kikori region. However, genetic and satellite/radio tracking studies are needed in the Kikori region to properly understand this nesting pattern and to confirm that *C. insculpta* females in this region are part of a single population.

Nevertheless, in both scenarios, migrations from the delta would be expensive energetically. These costs may be exacerbated by the uncertainty in locating consistent nesting beaches (Chapter 3) and the exposure to saline environments. *Carettochelys insculpta* in the Kikori region display a similar system to that of marine turtles, albeit on a smaller scale. Marine turtles are non-annual breeders, owing mostly to high migration costs (Broderick et al. 2003). They reduce the migration energy expenditure per egg with the multi-year breeding strategy (Kuchling 1999). According to Kuchling (1999), the freshwater turtle candidates for multi-year gonadal cycles would be large river turtles with extensive reproductive migrations and relatively large numbers of eggs, such as the Asian river turtles of the family Bataguridae and the Amazon turtles of the family Podocnemidae. The pig-nosed turtle in Kikori can also be placed under this category.

Adaptation of this sort in PNG *C. insculpta* populations may explain a trait observed in Australian populations that defies explanation. In the Daly River, where *C. insculpta* do not perform extensive migrations to nest, biennial reproduction was attributed to the energy-limited food available (Doody et al. 2003b). However, the two clutches every two years pattern may instead reflect the ancestral state in *C. insculpta*, which evolved in response to coastal-riverine nesting. These patterns may have been retained in Australian populations as an exaptation to a low nutrient environment, evolutionary inertia (neutral selection), or it could be a case of selection on biological traits lagging behind (evolutionary disequilibrium).

However, biennial reproductive cycles are not exclusive of turtles facing coastal environments. *Erymnochelys madagascariensis* (Podocnemidae), a species which does not have coastal populations, presents a two year cycle of vitellogenesis with the production from one to three clutches every second year (Kuchling 1993). Similar to the pig-nosed turtle in the Daly River (Doody et al. 2003b), the energetic constraints of *Erymnochelys* alimentary regime alone only explain partially its biennial cycle (Kuchling 1999). A similar energy investment per egg may be obtained by deferring laying eggs completely (Kuchling & Bradshaw 1993; Nieuwolt-Dacanay 1997) or by adjusting reproductive output parameters, such as egg size and clutch frequency and size (Bjorndal 1985; Georges 1983; Roosenberg & Dunham 1997; Swingland & Coe 1978; Turner et al. 1984). Kuchling (1999) suggested a possible phylogenetic component in the biennial ovarian pattern of *Erymnochelys*. Under this scenario, although no breeding migrations are known for *Erymnochelys*, its ancestors may have shown reproductive migrations or even lived in coastal areas.

While all living Podocnemidoidea are freshwater forms, there are many fossil evidences of freshwater and coastal species in the past. *Brasilemys josai*, a basal taxon of Podocnemidoidea, had freshwater habitats similar to the extant *Podocnemis* and *Erymnochelys* (Broin 2000). On the other hand, another branch, the Bothremydidae, was adapted to littoral environment from the Cenomanian of Israel (Haas 1978) up to the Miocene (Lapparent de Broin & Werne 1998). There is also evidence that *Bairdemys*, a clade of extinct podocnemidids known from the Tertiary of Africa, Asia and the circum-Caribbean (Gaffney et al. 1996), lived in marine or brackish waters (Sánchez-Villagra et al 2000; Gaffney & Wood 2002). Indeed, nesting site and egg morphology, suggestes that *Bairdemys venezuelensis* probably laid its eggs in beaches and lived in a marine or nearshore marine environment (Winkler & Sánchez-Villagra 2006), which resembles the pig-nosed turtle nesting habitat in the Kikori coast. Furthermore, *Podocnemis expansa*, the Amazonian giant river turtle, are found nesting in estuarine areas in the Brazilian states of Amapá and Pará (Portal et al. 2005).

Exaptation, neutral selection and evolutionary disequilibrium may also explain the *C. insculpta* hatching response to inundation. Fully developed embryos delay their emergence from the egg until anoxia stimulates hatching (Georges 1992; Webb et al. 1986). According to Doody et al. (2001), anoxia, caused by rain events and river level rise, signals the beginning of the wet season and facilitates turtle hatchling emergence and dispersal in the Daly River.

However, in the Kikori riverine areas, where rain and flooding are unpredictable, this reaction is probably not a positive trait (Chapter 3). *Carettochelys insculpta* hatchlings must be fully developed to successfully hatch and survive flooding (Doody et al. 2004). I observed during laboratory experiments (Chapter 3) that *C. insculpta* in the last stages of incubation can respond to severe hypoxia, prematurely pipping the shell. *Crocodilus porosus* embryos close to hatching respond to hypoxia in a similar way (Booth 2000).

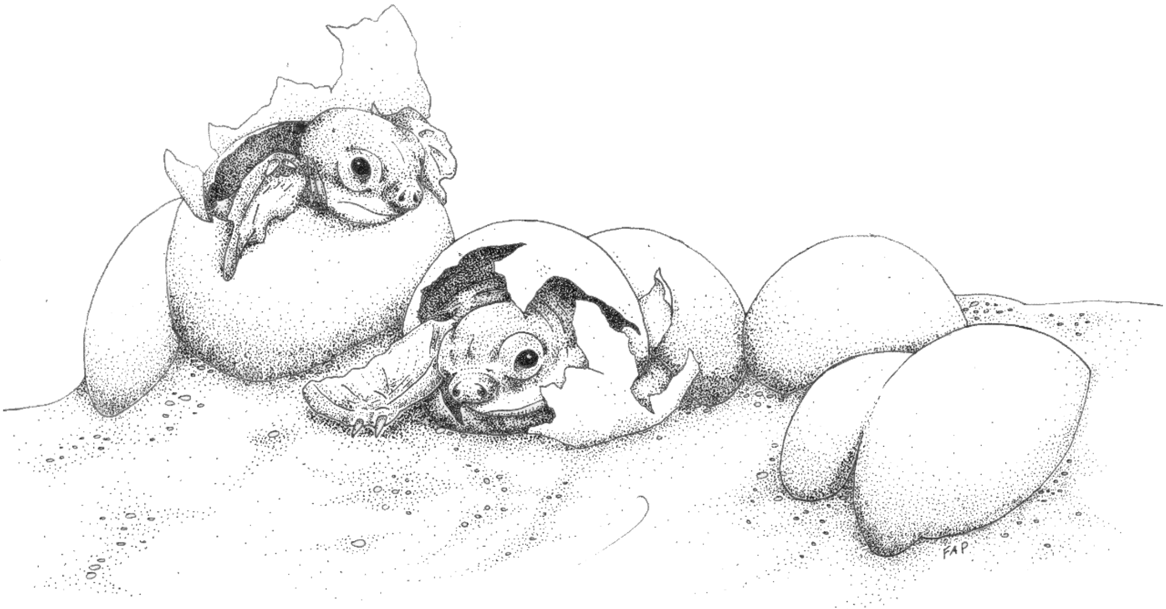
The premature hatchling is exposed to the environment when it still has large vitelline sacks, which severally restrict its movements. In my experiments, premature hatching always resulted in death. The later stages of embryogenesis are often the most vulnerable to flooding (Tucker et al. 1997). In contrast, on the Kikori coast, nests are laid high on the beaches and emergence following inundation by the highest tides would afford considerable advantage. Hatchling migration from the nest to the water is a major source of sea turtle mortality due to predation and high sand temperatures on the surface (Mrosovsky 1968; Witherington et al. 1990). This may again be a case of a trait evolving in one ecological context (coastal beaches) and being maintained because of different advantages from those that drove its evolution in other parts of its range in first place (wet-dry tropics of Australia).

Variations in life history tactics, among species and populations, are relatively common (Shine 1987; Vitt & Congdon 1978). There is usually a trade-off between alternative tactics and different environments (Blanckenhorn 2000). Different populations can show phenotypic variations in their life history patterns with both genetic and environmental origins (Brown et al. 1993; Gadgil & Bossert 1970; Maurer et al. 1992). I propose that the differing climatic regimes between the wet-dry tropics of northern Australia and the wet tropics rivers of southern New Guinea explain partially the differences in nesting patterns and contribute to the difference in body size and life history attributes between these landmasses.

However, many aspects of *C. insculpta* riverine nesting ecology can only be properly understood when the adaptations to a marine nesting phase are taken into account, even if these behaviour was later lost in some populations. The colonisation of the Daly River by *C. insculpta* is most likely recent and the population probably still retains many characteristics evolved initially to deal with coastal environments. Of course the reverse could be true, but my study provides an example of the caution required when placing evolutionary interpretations on life history traits whose manifestation is studied only within a restricted portion of a species range. Different populations may vary in terms of habitat type and time of origin (for example, time of colonisation of a new area) and phenotypic variation can mask the full repertoire of life history responses to environmental conditions. When only part of a species' range has been studied, variability in life history traits must be taken into account and the overall conclusions that can be drawn are limited.

CHAPTER 3

A Coastal-riverine Nesting Dichotomy: Choice and Tradeoffs



The study species – The pig-nosed turtle (*Carettochelys insculpta*)
Illustration by Fernando Perini

“Real story about the turtle and lizard: Once upon a time all the animals came together for the running race competition on a very long sand. The competition was hosted by bird of paradise the princes of all the animals living around Papua New Guinea. The princes got up and chose lizard and turtle to run for the first round. The lizard was male and the turtle was female. So they started to run on the sand. While they ran the lizard ran faster than turtle, lizard ran for a long distance and turned back to see if turtle was coming closer to him, but turtle was far away from him. So the lizard lied down to have a rest. When the lizard lied down to have a rest he forgot all about the turtle and slept. When turtle saw the lizard sleeping on the sand she passed the lizard very quickly. As soon as the turtle passed the lizard she ran as fast as she could and reached the end of the sand and all the animals shouted and said turtle, turtle you are the winner. When lizard wake up and look back to see the turtle, he didn’t saw the turtle. So now turtle and lizard are enemies. Whenever lizard found the turtle eggs he usually eats them."

(Kupere; Kopi Village; Rumu tribe; Recorder: Jonah Kupere)

CHAPTER 3

A Coastal-riverine Nesting Dichotomy: Choice and Tradeoffs

Abstract

The nest environment is a key factor driving reproductive success in oviparous reptiles. Cases of riverine turtles nesting on coastal beaches are particularly intriguing. Freshwater turtles are hypo-osmoregulators in seawater which presents a physiological challenge and suggests a strong counterbalancing selective advantage for coastal nesting. Here, I address the question of the evolution and maintenance of nesting patterns in the pig-nosed turtle (*Carettochelys insculpta*) and in particular, of a coastal-riverine nesting dichotomy in the Kikori region of Papua New Guinea. The Kikori region is a very productive area that supports a substantial adult and juvenile population. In the nesting season, I observed females nesting both on the coast and upstream. What are the balancing selective forces that maintain this dichotomy? Nesting starts earlier on the coast, before the dry season, while riverine sandbanks are still under the water. The height of available sandbanks did not differ significantly between coastal and riverine areas, but females nested closer to the highest point of the sandbank in areas with more frequent inundation events. In riverine areas, flooding is highly unpredictable, often remodelling the distribution of sandbanks after the eggs are laid. In any one year, riverine inundation can last for several days, increasing the risk of egg mortality from hypoxia; or, depending on rainfall, may not happen at all. Riverine inundation is often a result of rain in the upper catchment remote from the nesting area and so there is a spatial mosaic in the impact of flooding across sub-catchments. In contrast, on the coast, inundation is caused by tides and is spatially universal and more frequent, but is predictable and of short duration. In addition, coastal sandbanks are usually located on islands where monitor lizards (*Varanus indicus)*, the major nest predator at riverine sites, are absent. Females nesting on the coast avoid the extremely high nesting predation rates that occur from non-human predators in riverine areas. In this chapter, I present data in support of the above conclusions and identify the advantages and disadvantages of coastal nesting over riverine nesting in the context of spatial and temporal variability of nesting opportunity.

Keywords: Inundation, predation, salinity, life history, nesting time, nesting site, natural selection, phenotypic plasticity, environmental constraints.

Introduction

Trait variation in a population is usually a result of interactions between genotype and environmental effects. The strong influence of mothers on the phenotypes of their offspring is a noticeable example of this interaction (Bernardo 1996; Mousseau & Fox 1998; Rossiter 1996). Maternal investment is very restricted in oviparous species, especially those species that also lack parental care. It may only occur through egg nutrient allocation, which provides the necessary material for embryo development and the selection of nesting time and site, which influence the incubation environment (Bernardo 1996; Janzen 1994; Mousseau & Fox 1998; Roosenburg 1996; Satake et al. 2001). This investment is not insignificant. The embryo stage is often the most vulnerable part of the life cycle in oviparous species (Bosque & Bosque 1995; Fitch & Fitch 1967; Shine 1983).

Nest environment is a key element in turtle reproduction. Embryological mortality and offspring survival are influenced by biotic and abiotic factors, such as predation, type of substrate, porosity, temperature, moisture content, salinity, slope of the beach, nest elevation, rainfall and inundation (Bilinski et al. 2001; Donlan 2004; Foley et al. 2006; Mortimer 1990; Wood & Bjorndal 2000). The temperature and the hydric environment inside the nest during the incubation period can affect hatchling sex, morphology, locomotor performance, behaviour and post-hatching growth (Bobyn & Brooks 1994; Booth 1998; Deeming 2004; Finkler et al. 2000; Janzen 1995; Miller 1993; Packard 1999; Rhen & Lang 1999; Valenzuela 2005; Valenzuela & Lance 2005).

The relationship between the environment and timing of reproduction is often critical to reproductive output and success (Kudo & Hirao 2005; Olsson & Shine 1997; Satake et al. 2001). Incubation success often relies on nesting timing adaptations to local and predictable hydrologic regimes (Bowen et al. 2005; Tucker et al. 1997). In many species of chelonians, the onset of the nesting season is related to ambient and water temperatures (Iverson & Smith 1993; Obbard & Brooks 1987; Rowe et al. 2003), rainfall (Booth 2002b; Burke et al. 1994; Wilson et al. 1999) or both (Bowen et al. 2005; Tucker et al. 1997). Important environmental factors can change as the season progresses; thus, embryonic survival, development and sex are affected by the day of oviposition (Doody et al. 2001; Doody et al. 2003c; Doody et al. 2004; Fowler 1979), The selection of nest site also has important consequences for reproductive fitness (Janzen 1994; Packard 1999; Spencer 2002; Wilson 1998). Nest site selection can influence offspring fitness and reproductive success in the long-term (Booth 2006; Deeming 2004; Packard et al. 1999; Valenzuela & Lance 2005). This is true especially in species with temperature-dependent sex determination (TSD), whose sex is defined by temperature during the incubation period (Bragg et al. 2000; Davenport 1997; Schwarzkopf & Brooks 1985; Valenzuela & Janzen 2001; Vogt & Bull 1984). In the short-term, nest site selection can affect embryonic development and mortality through predation levels and stochastic events such as inundation (Brown & Macdonald 1995; Burke et al. 1998; Fowler 1979; Iverson 1991a; Thompson 1983). In turtles, the nesting site is selected actively and non-randomly (Burger & Montevecchi 1975; Cox & Marion 1978; Ehrenfeld 1979; Foley et al. 2006; Kolbe & Janzen 2002; Plummer 1976; Schwarzkopf & Brooks 1985; Wilson 1998).

Temperature, vegetation, slope, interspecific competition and human disturbance are considered to be important factors that influence female nesting site selection (Hays et al. 1995; Kolbe & Janzen 2001; Mortimer 1990; Mrosovsky 1983; Stoneburner & Richardson 1981; Whitmore & Dutton 1985; Witherington 1992) and nest selection probably occurs at both micro and macrohabitat levels (Janzen & Morjan 2001; Schwarzkopf & Brooks 1985; Spencer 2002; Spencer & Thompson 2003; Wilson 1998). Female choice at a macrohabitat level (i.e. choice among different areas or sandbanks) is usually related to the risk of predation or desiccation posed for the females, nests and offspring (Spencer 2002; Spencer & Thompson 2003).

Nesting on coastal beaches by riverine turtles is a particularly intriguing case of nest site selection. Freshwater turtles are hypo-osmoregulators in seawater (Kinneary 1992; Moll & Moll 2004) which presents a physiological challenge and suggests a strong counterbalancing selective advantage for coastal nesting (Kinneary 1996; Moll 1994). Nesting habitat availability is usually considered the major factor involved in the indirect selection of a marine phase in riverine turtles (Moll 1994; Obbard & Brooks 1987). The suitability of thermal environment for nesting was considered a major factor driving *Trachemys venusta* to nest on coastal beaches (Moll 1994). This species has TSD and requires very specific thermal nesting habitats, which are only found naturally in the marine area of its distribution, to produce both males and females (Wibbels et al. 1998), although, Panama human-disturbed areas, where tree cover has been removed, are occasionally utilized as nesting sites (Moll &

Legler 1971). Coastal nesting may also be favoured owing to the lower incidence of egg, hatchling and female predation in these areas (Hendrickson 1958; Kinneary 1996).

Freshwater turtles nesting on coastal beaches could represent a stage of gradual evolution from freshwater to the sea (Dunson & Seidel 1986; Kinneary 1996). Reptiles physiologically adapted to estuarine environments are likely to become habitat endemics owing to the rigorous abiotic features of this habitat type (Dunson & Mazzotti 1989; Kinneary 1992). However, another option should also be considered for species that maintain both marine and riverine nesting habits in the same region. Aside from representing an intermediate stage in the process of speciation, coastal nesting may also be a response to a particular habitat, where nesting on the coast complements riverine nesting and where both areas are essential to the existence and maintenance of the population. The pig-nosed turtle (*Carettochelys insculpta*) is a good model species to explore these possibilities.

Carettochelys insculpta is a freshwater turtle with TSD (Georges 1992; Webb et al. 1986) which nests in open sand sandbanks largely free of vegetation in riverine areas of the Daly and Alligator Rivers in the Northern Territory (Australia) and in riverine and coastal areas in the southern rivers of the New Guinea Island (Doody et al. 2003b; Doody et al. 2003c; Georges & Kennett 1989; Georges et al. 2008b; Rhodin & Rhodin 1977). Multiple evolutionary processes influence nest site choice and timing in the Daly River population of *C. insculpta*. Natural selection, physical constraints and phenotypic plasticity are among these processes (Doody et al. 2004).

In the Daly population, flooding and predation by monitor lizards (*Varanus panoptes*, *V. mertensi*) are the major sources of embryonic mortality and are strongly influenced by nesting time and nest site choice (Doody et al. 2003b; Doody et al. 2003c; Doody et al. 2004). The duration of the *C. insculpta* nesting season is affected by the energy accumulated by females during the wet season (phenotypic plasticity), which determines the onset of nesting and by the risk of flood mortality at the start of the wet season (natural selection), which marks the end of the nesting season (Doody et al. 2001; Doody et al. 2004). Females select median elevation sites for nesting, which avoids flood mortality at lower sites and non-cohesive sand at higher sites (Doody et al. 2004). Females, most likely, do not practice beach homing behaviour. Beaches are ephemeral and few last for successive years. Nesting area suitability may change even between the first and second clutch in the same season (Doody et al. 2003b; Doody et al. 2003c).

There are many studies of *C. insculpta* nesting biology in Australian rivers (Doody et al. 2001; Doody et al. 2003a, Doody et al. 2003b; Doody et al. 2003c; Doody et al. 2004; Georges & Kennett 1989). In contrast, little is known of the ecological and evolutionary processes influencing nesting site and nesting timing selection in pig-nosed turtle populations that nest in both coastal and riverine areas. In this chapter, I examined the key ecological mechanisms behind the evolution and maintenance of the pig-nosed turtle coastal-riverine nesting dichotomy in the Kikori region of Papua New Guinea (PNG). I evaluated the ecological traits of coastal and riverine areas (mid-river-kikori, mid-river-sirebi and up-river) by comparing water inundation patterns and attributes of nests (infertility, depth until the first egg, chamber depth and elevation above water) and sandbanks (slope, area, length, width and maximum height).

I tested a possible female behavioural response to areas with different inundation patterns by examining the relationship between the number of hours a sandbank spent submerged and how close to the maximum elevation of the sandbank the female chose to nest. I compared different areas in relation to inundation, predation and persistence of sandbanks and nests. I tested the survival rate of eggs inundated in different stages of development and for different periods of time. Finally, I compared the homogeneity of nest distributions within sandbanks among different areas and identified different configurations of sandbank use.

Material and Methods

Study area

The Kikori drainage extends from the alpine grasslands of Doma Peaks of the Southern Highlands Province to the extensive mangrove wetlands of the Gulf Province. Annual rainfall in the Kikori region is very high by global standards with an average of 5667 mm per year (Georges et al. 2008a). The river system is highly confined within its limestone bed and meanders and oxbows are absent. The delta is a large alluvial plain below 40 m elevation, dissected by a tributary system of river channels and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain. The coast comprises the delta islands exposed to the Gulf of Papua (Enesar 2005). Wind and wave action creates coastal beaches, sand bars and sand islands in what is a very dynamic system (Enesar 2005).

No pig-nosed turtle nesting occurs in the delta area owing to the lack of sandbanks. This represents a gap between the river and coastal nesting areas (Georges et al. 2008a). The minimum distance a pig-nosed turtle would have to swim between the two closest sandbanks from the coast to the river would be of approximately 32 km. Beaches and sand bars in the Kikori region can emerge to provide new nesting areas in some places and erode, with a consequential lost of nesting habitat, in others. My study site extended from Kaiam Village (Kikori River) to Dopima Island on the western side and from Kuru-Sire Junction (Sirebi River) and Veraibari Village on the eastern side, essentially encompassing the coastal region, delta and limestone plains of the Kikori lowlands. A map of the study area and sandbank locations is presented in Figure 3.1. A more detailed description of the Kikori region is presented in Chapter 2.

Methods

Local volunteers recorded the number of *C. insculpta* nests laid per night in coastal and riverine areas in the 2007-08 and 2008-09 nesting seasons (from October to February). I validated this information by a direct survey every week. In both seasons, I measured nest depth to first egg, chamber depth, percentage of presumed infertile eggs and nest height and recorded the time when measurements were taken. Presumed infertile eggs were considered those which did not develop an opaque patch five days after egglaying. I measured sandbank parameters (length, width and maximum elevation above water) once at the end of each nesting season.

I surveyed sandbanks monthly for signs of nests, predated nests and to verify nest persistence. Human predation was not included in the predation analyses. I used two water level devices (Hobo Water Level Logger – Range: 0 to 30.5 m) to collect water level information (pound-force per square inch – psi) once every hour from 9-Oct to 16-Feb in both nesting seasons. One device was installed on the left side of the Kikori River close to Oil Search Kopi Camp (7°19'13.30"S; 144°10'58.42"E) and the other on the mangrove side of Turuvio Island on the coast (7°47'38.83"S; 144°26'31.92"E; Chapter 2).

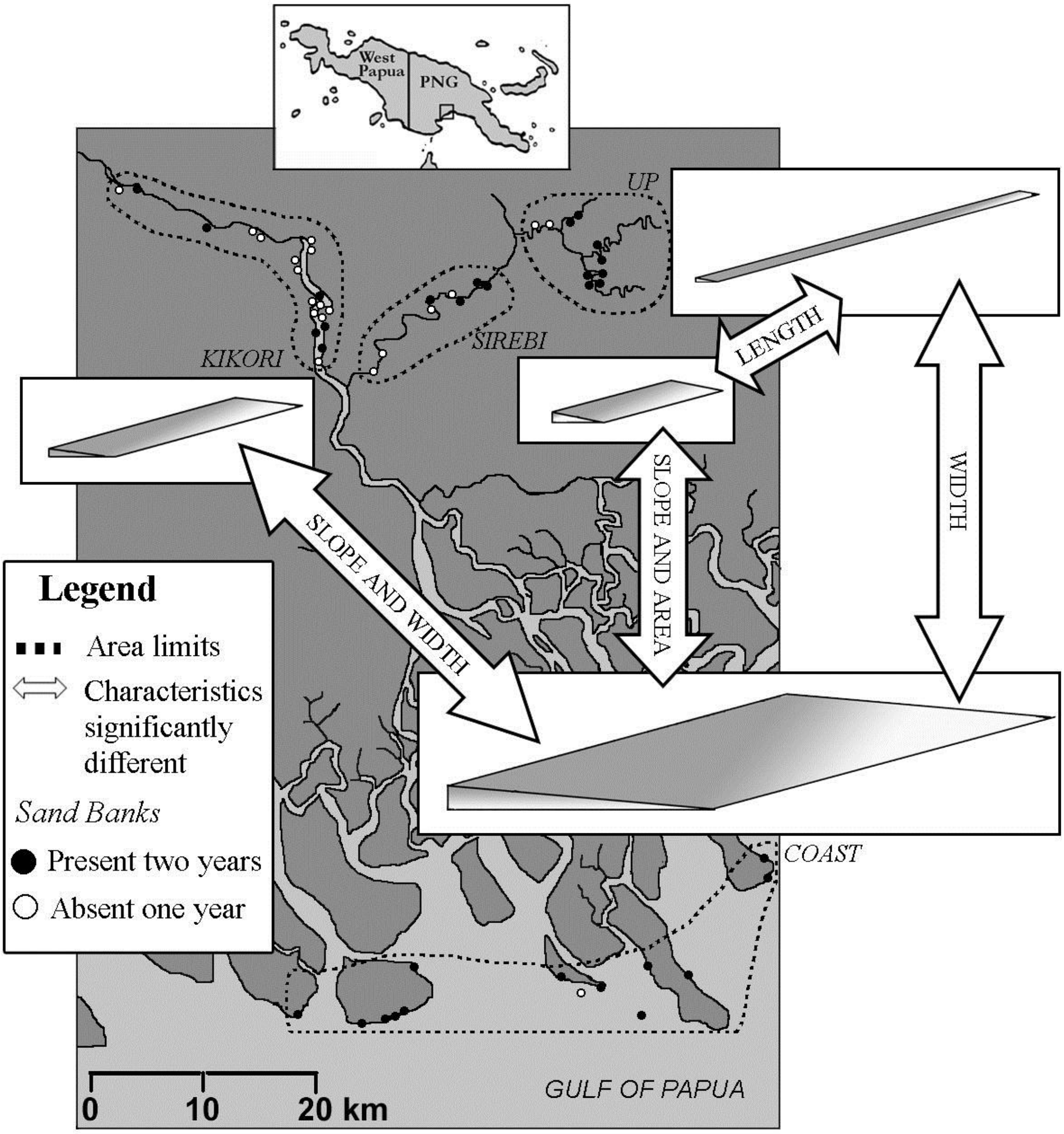


Figure 3.1 Sandbanks used by *Carettochelys insculpta* females for nesting in the Kikori region. Four nesting areas are shown: mid-river-kikori, mid-river-sirebi, up-river and coast. Three dimensional figures represent the average dimensions of the sandbanks observed in each nesting area. Width and height are based on the average water level during the nesting season (relative width and height). The arrows indicate significant differences in sandbank attributes ($p < 0.05$) between nesting areas, based on Tukey-Kramer analysis. Sandbank locations are represented as black circles when the sandbank was present in both years studied (2007-08 and 2008-09) and as white circles when the sandbank was absent in one year.

It was not possible to estimate nest site height on the actual night of egg-laying because nests were found in different stages of development. Water level changes considerably on the coast and river and may vary by the day and hour. This variability needs to be considered when measuring the height and width of sandbanks and nest sites. To obtain comparable data for river and coastal sandbanks/nests measured at different times, I used the water level at the time of measurement in relation to the average water level for the whole nesting season.

Measurements were then converted into meters of water (mH^2O). The relative height (mH^2O) was calculated with the following formula:

$$RH = (WLD - WA - SAP) * PM) + NSH$$

Where:
RH = Relative height
WLD = Water level at the time of nest/sandbank measurement (psi)
WA = Water level average (psi)
SAP = Standard atmospheric absolute pressure = 14.47725 psi
PM = 0.703: coefficient used to convert pound-force per square inch (psi) to meters of water (mH^2O)

NSH = Measured height of the nest or sandbank to the water.

Sandbank relative width (SRW) was calculated using sandbank relative height (SRH):

$$SRW = (SRH * SW) / NSH$$

SW = Measured width of the sandbank to the water

Sandbank slope was calculated using the following trigonometry function:

$$Slope = ((Arcsine (SRH / SRW)) *360) / 2\pi$$

The total sandbank area for the coast, mid-river-kikori, mid-river-sirebi and up-river was calculated using the sum of the individual sandbank areas (length * relative width). Three dimensional sandbanks illustrations were constructed using the average relative height, relative width and slope for each area (Figure 3.1). A Kruskal-Wallis test was performed to analyse the differences in the proportion of presumed infertile eggs per nest among areas. Differences in nest and sandbank parameters among areas were tested with single factor

ANOVA. To test the relationship between the inundation regime and the height of turtle nesting, I performed a regression between the number of hours a sandbank stayed under the water and the difference between its relative height and the average relative height of nests laid on it.

A categorical ANOVA (logistic model) using CADMOD procedure (SAS 9.1) was used to test for differences among areas in relation to sandbanks (1) with predated nests, (2) with nests in both seasons and (3) persistent sandbanks (present in two seasons). The logistic model is the most appropriate analyses for binary dependent variables (Rhen & Lang 1998; Sokal & Rohlf 1981), like sandbanks with, or without, predated nests. I constructed histograms for the distribution of nests within sandbanks and calculated the evenness index for each area according to Zar (1984). This index refers to the homogeneity or relative diversity. If sandbanks have an equal number of nests the index is 1.00. This index was used to understand the importance of the most used sandbanks in relation to all of the sandbanks in each area.

I estimated the chances of inundation for coastal and riverine nests by investigating the relationship between nest site heights in each area and season with the water level for the 98 day period which corresponded to the main nesting season period for each area. The main nesting period was from 9-Oct to 14Jan on the coast and 12-Nov to 17-Feb on the river (2007-08 and 2008-09). This estimation was possible because there was no significant relationship between the nesting day and the relative height of nest sites for either areas or seasons (coast 2007-08: F = 3.77; df = 1,24; R^2 = 0.14; p = 0.06; coast 2008-09: F = 0.00; df = 1,23; R^2 = 0.00; p = 0.99; river 2007-08: F = 1.35 ; df = 1,22; R^2 = 0.06; p = 0.25 and river 2008-09: F = 1.81; df = 1,27; R^2 = 0.06; p = 0.19). I used this estimation to plot the water level which corresponded to 25%, 50%, 75% and 100% of the nests sites inundated in riverine and coastal areas.

For the inundation survivor experiment, I used eight nests of *C. insculpta* laid on the night of 19-Jan-2009 and removed on the next day from a Sirebi River sandbank (7°11'37"S; 144°17'4"E). These clutches were transported by boat to the Oil Search Kopi Camp station and allocated randomly in 2-L plastic boxes containing vermiculite (4 g water per 3 g vermiculite) inside hova-bator incubators at a constant temperature of approximately 32^{o}C. Temperature and moisture content of the substrate were monitored weekly and held constant. The eight clutches were randomly distributed in eight groups of eight or seven eggs. Groups did not have more than one egg from a clutch. Each group was placed under the water simulating eight different flood scenarios during different stages of development and for different periods of time.

Inundation experiments were performed three (23-26-Jan-2009), thirteen (2-5-Feb-2009), 23 (12-15-Feb-2009) and 33 (22-25-Feb-2009) days after egglaying, representing early, middle and late incubation periods. For each one of these development stages, a group was inundated for 24, 48 and 96 hours. I used a control group of eggs for each stage of development, which was moved from the incubator and returned immediately after to simulate the movement other eggs were facing prior to the inundation and could cause mortality. Presumed infertile or non-developing eggs were considered those which did not develop an opaque patch during the first 48 hours after egglaying (Young et al. 2004) and where excluded from the experiment. Hatchling mortality was checked 60 days after egglaying by embryo movement inside the egg against the light and by stimulating hatching by water immersion (Georges 1992; Webb et al. 1986).

Analyses of Variance (ANOVA) and regressions were preceded by analysis of residuals and the data were transformed as appropriate to meet the assumptions of normality and homogeneity of variances. Multiple comparisons following significant results in the ANOVA were undertaken using the Tukey-Kramer procedure. Statistical tests followed those recommended by Sokal and Rohlf (1981) and were performed using SAS 9.1 or by hand.

Results

With the exception of relative height ($F = 1.89$; df = 3,31; $p = 0.16$), all measured sandbank attributes were significantly different among areas. Coastal sandbanks were significantly broader in relative width than mid-river-sirebi and up-river ($F = 4.60$; df = 3,26; $p < 0.05$; Table 3.1). On the other hand mid-river-kikori and mid-river-sirebi sandbanks presented significantly steeper slopes than those at the coast ($F = 3.95$; df = 3,32; $p < 0.05$; Table 3.1). Mid-river-siberi sandbanks also exhibited significantly shorter lengths than up-river sandbanks ($F = 3.99$; df = 3,32; $p < 0.05$; Table 3.1) and significantly less area than coastal sandbanks ($F = 3.95$; df = 3,24; $p < 0.05$; Table 3.1). The coast had the largest total nesting area (856,720 m^2) followed by up-river (1,5941 m^2), mid-river-kikori (5,706 m^2) and lastly mid-river-sirebi with only 1,763 m^2 (Figure 3.1).

There was no significant difference in the depth to first egg (F = 1.71; df = 3,109; p = 0.17; Table 3.2), chamber depth (F = 1.90; df = 3,106; p = 0.13; Table 3.2) and the proportion of presumed infertile eggs per nest among areas (X^2 = 2.44; df = 3; p = 0.49; Table 3.2). However, there was a significant difference among areas in relation to the relative elevation of nests (F = 123.07; df = 3,195; p < 0.001; Table 3.2). Further Tukey-Kramer analysis showed that mid-river-kikori nests were located at significantly lower relative heights than mid-river-sirebi nests, but at significantly higher relative heights than up-river. Coastal nests were located at significantly lower relative heights than riverine area (mid-river-kikori, mid-river-sirebi and up-river) nests (Figure 3.2).

A significant linear relationship was found between the number of hours a sandbank stayed under the water (NUW) and the difference between sandbank relative height and nest average relative height (NARH) (F = 9.20; df = 1,34; R^2 = 0.21; p < 0.01; Figure 3.3). Females nested closer to the maximum possible height of sandbanks that spent more time under the water (NUW = 0.15 - 0.40 * NARH) compared with those that spent less time under water. Inundation on the coast occurred for short periods during high tides. Riverine inundation was less predictable, usually lasting for longer periods and it was related to rain in the upper parts of the catchment. The period and unpredictability of inundation increased from the coast to the headwaters (Figure 3.4). Mid-river-kikori and up-river did not have more than 50% of nests sites inundated at any one time during the 2008-09 nesting season. Samples for mid-river-sirebi were not sufficient in number to allow inclusion of this area in these analyses.

Nesting season started earlier on the coast (early October) and continued until mid December. The season started later on the river (in late October) but continued until the middle of March (Figure 3.5). Nesting usually occurred between tidal peaks on the coast and when the water level subsided on the river. Nesting climax usually occurred when the daily maximum water level was below the 25% of nests-sites-under-the-water estimation (Figure 3.5).

Egg survival rate varied from zero to 75% between developmental stages and periods of inundation, with an average of 41% of eggs surviving through incubation period and hatching (Table 3.3). Egg mortality was probably high due to the rough conditions of transportation during the first days of development. However, at least one egg survived and hatched in each group, with exception of the group inundated for 96 hours after three days of egglaying.

Table 3.1 Attributes of sandbanks suitable for *Carettochelys insculpta* nesting in the Kikori region. Means are given with their standard errors, ranges (in brackets) and sample sizes; NAH: height difference between sandbank relative height and nest average relative height. Relative width and height are based on the average water level of the nesting season.

Area	**Coast**	**Mid-river-kikori**	**Mid-river-sirebi**	**Up-river**
Slope (degrees)	5.22 ± 1.95 (0.52 – 25.26) n = 12	9.62 ± 1.54 (1.82 – 19.72) n = 11	11.00 ± 1.90 (5.74 – 15.43) n = 5	6.53 ± 1.43 (1.86 – 14.66) n = 8
Area (m^2)	48,051 ± 45,757 (179 – 55,1341) n = 12	342 ± 71 (125 – 669) n = 7	280 ± 67 (13 – 378) n = 5	2729 ± 1317 (54 – 5,277) n = 4
Length (m)	249.5 ± 178.6 (20.0 – 2,200.0) n = 12	39.6 ± 10.2 (14.0 – 115.0) n = 11	25.0 ± 6.5 (2.0 – 40.0) n = 5	131.9 ± 35.1 (30.0 – 320.0) n = 8
Relative width (m)	54.75 ± 18.90 (3.97 – 250.61) n = 12	8.67 ± 4.57 (-5.96 – 47.80) n = 11	10.83 ± 1.76 (6.43 – 15.31) n = 5	4.30 ± 4.49 (-8.64 – 29.26) n = 8
Relative height (m)	2.02 ± 0.16 (1.05 – 3.01) n = 12	1.92 ± 0.28 (-0.32 – 2.97) n = 11	2.65 ± 0.20 (2.10 – 3.11) n = 5	1.20 ± 0.62 (-1.02 – 3.83) n = 8
Number of hours under the water	107 ± 58 (0 – 691) n = 12	303 ± 295 (0 – 3250) n = 11	0 ± 0 (0 – 0) n = 5	1401 ± 627 (0 – 3843) n = 8
Average nest relative height (m)	1.73 ± 0.11 (1.05 – 2.35) n = 12	1.51 ± 0.25 (-0.32 – 2.47) n = 11	2.31 ± 0.25 (1.70 – 3.02) n = 5	0.92 ± 0.57 (-1.02 – 3.83) n = 8
NAH (m)	0.29 ± 0.12 (0 – 1.35) n = 12	0.41 ± 0.13 (0 – 1.29) n = 11	0.34 ± 0.16 (0 – 0.86) n = 5	0.27 ± 0.13 (0 – 0.92) n = 8

Table 3.2 Attributes of *Carettochelys insculpta* nests in the Kikori region. Means are given with their standard errors, ranges (in brackets) and sample sizes. Relative height is based on the nesting season average water level.

Parameter / Area	**Coast**	**Mid-river-kikori**	**Mid-river-sirebi**	**Up-river**
Infertility (%)	1.38 ± 0.44 (0 – 10.00) n = 41	0.66 ± 0.39 (0 – 7.14) n = 23	1.31 ± 1.31 (0 – 22.22) n = 17	0.90 ± 0.42 (0 – 11.11) n = 33
Depth to first egg (mm)	10.8 ± 0.5 (0 – 16.0) n = 40	12.9 ± 0.8 (6.5 – 19.0) n = 22	10.2 ± 0.9 (0 – 14.3) n = 16	11.3 ± 0.5 (5.4 – 17.5) n = 35
Chamber Depth (mm)	21.5 ± 0.6 (9.7 – 29.0) n = 40	23.5 ± 0.5 (20.1 – 29.3) n = 22	22.8 ± 0.9 (11.9 – 27.0) n = 16	22.3± 0.4 (16.8 – 25.0) n = 32
Relative height (m)	0.33 ± 0.03 (-0.38 – 1.20) n = 87	1.26 ± 0.11 (0 – 2.74) n = 40	1.88 ± 0.14 (1.09 – 3.14) n = 20	1.67 ± 0.07 (0.60 – 3.35) n = 52

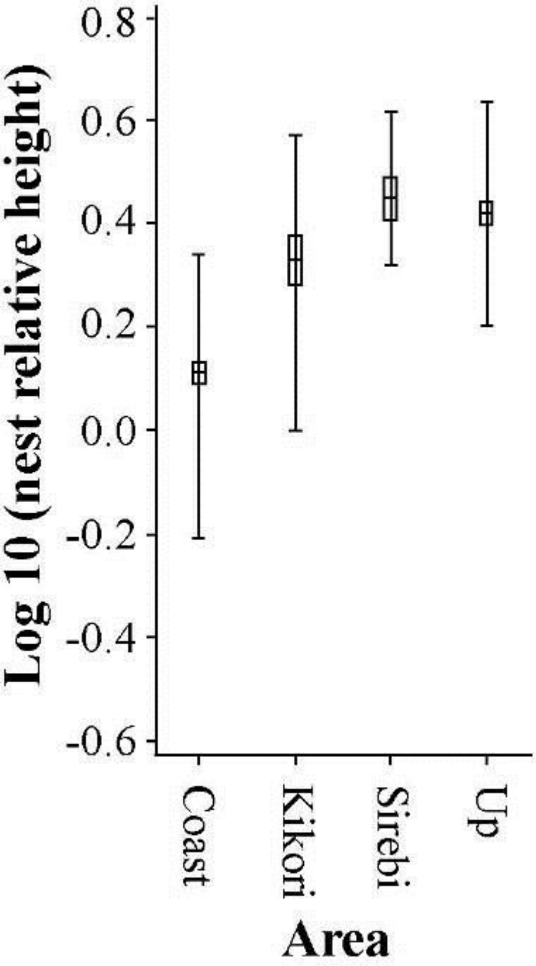


Figure 3.2 Variation in relative height of nests of *Carettochelys insculpta* in different areas of the Kikori region. Abbreviations: Coast: coastal areas; Kikori: mid-river-kikori, Sirebi: mid-river-sirebi; Up: up-river. Means are given with 95% confidence limits (boxes) and ranges (vertical bars). Variation among areas is significantly different (F = 123.07; df = 3,195; $p < 0.0001$). Relative height is measured from the average water level of the nesting season.

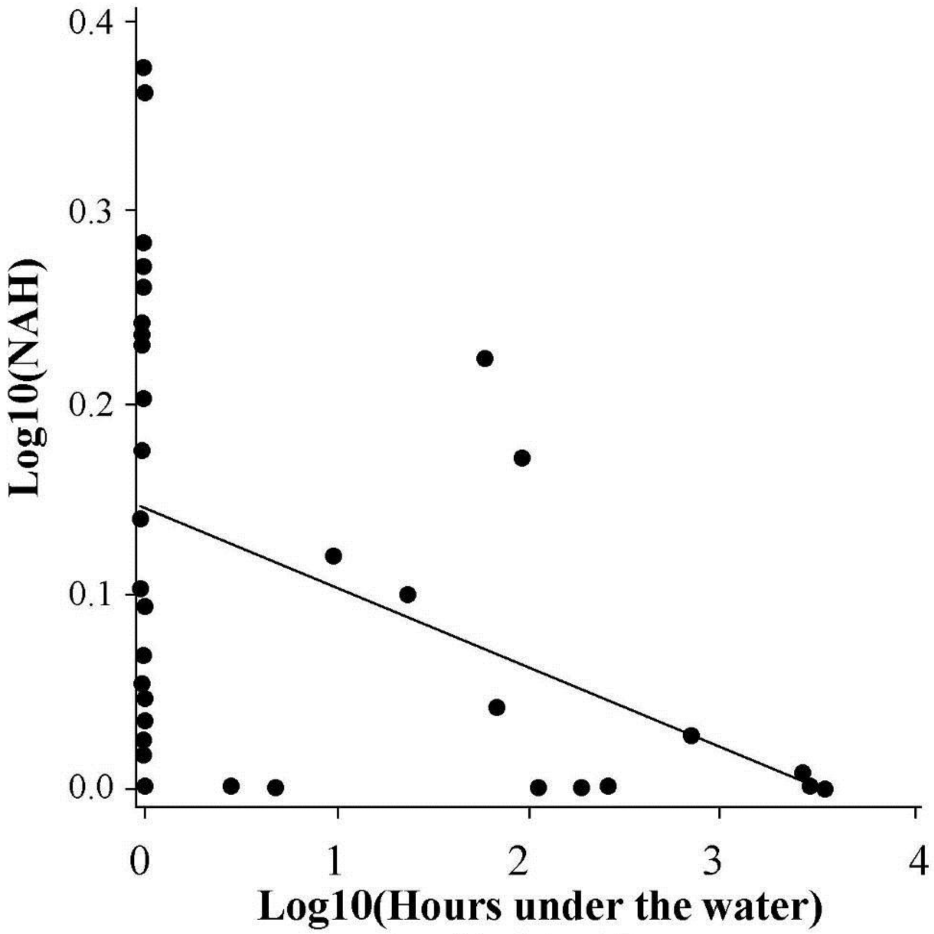


Figure 3.3 Number of hours of sandbank inundation versus average relative nest height for *Carettochelys insculpta* sandbanks. Abbreviations: NAH, relative nest average height The relationship was significant ($F = 9.20$; df = 1,34; $R^2 = 0.21$; $p < 0.01$).

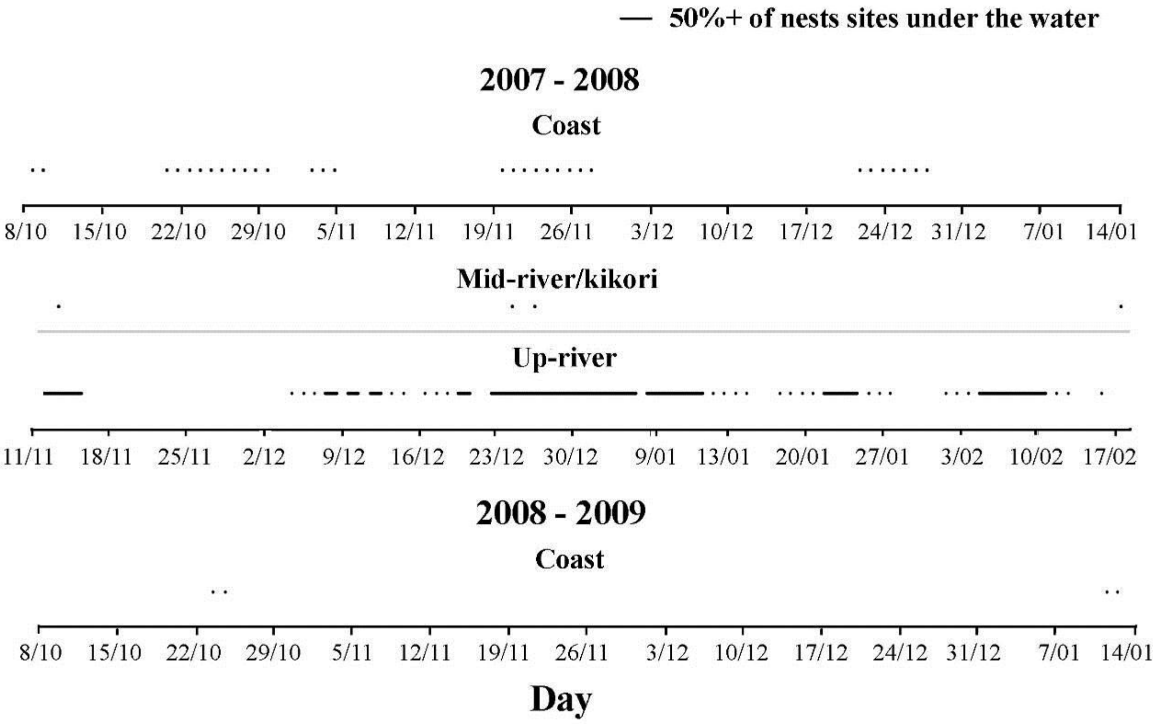


Figure 3.4 Estimates of nest inundation (50% of the nests sites or more) for *Carettochelys insculpta* nest sites during the 2007-08 and 2008-09 nesting seasons. Estimates of inundation for both coastal and riverine nest sites were obtained using height of nest sites in each area per season and their relationship to the water height for the period of 98 days corresponding to the main nesting season period in each area. The mid-river-kikori and up-river areas did not have more than 50% of the nests inundated at any time in the 2008-09 nesting season. Dots represent short periods of inundation (less than one day) and short bars long periods of inundation (more than one day).

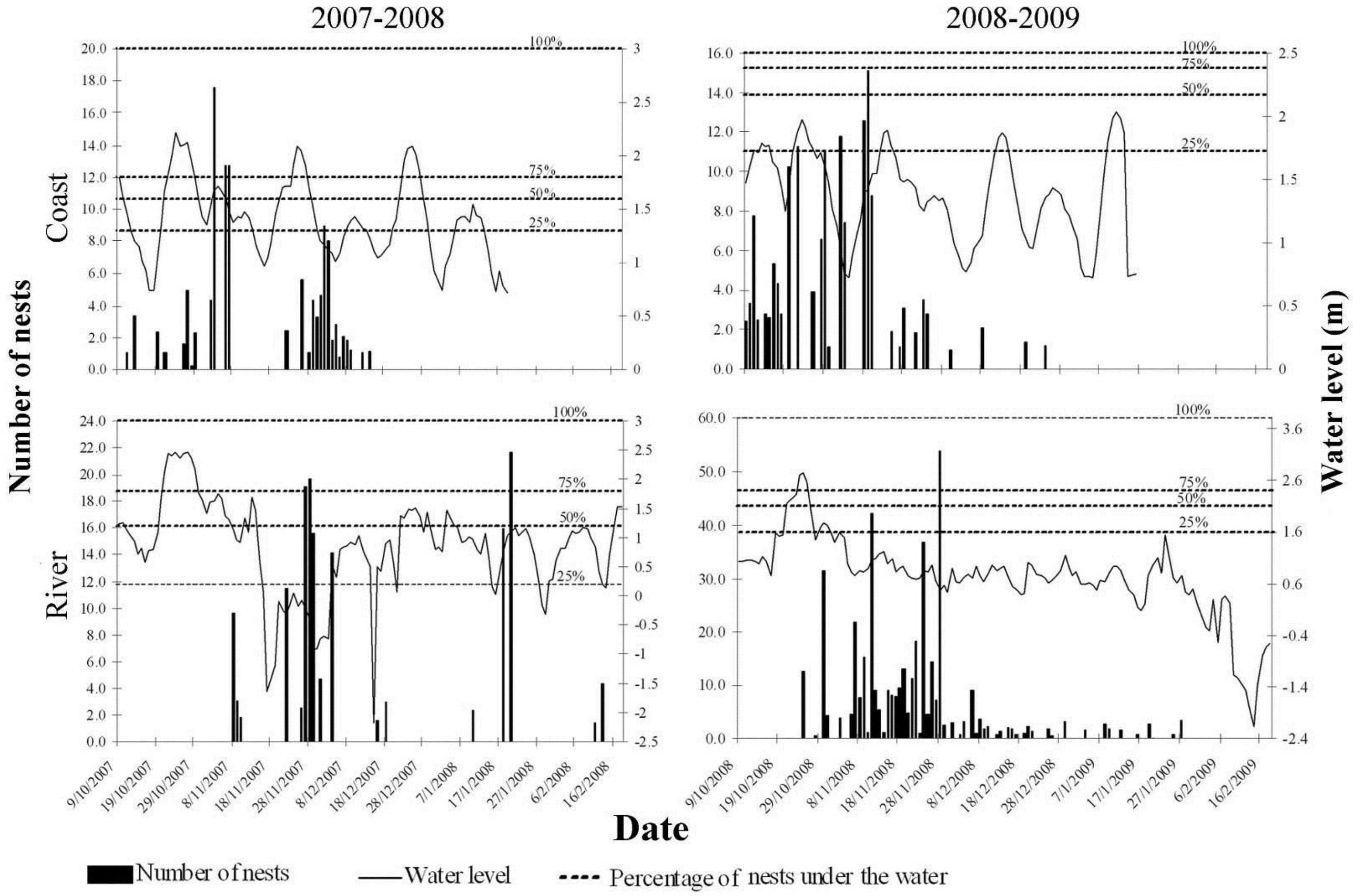


Figure 3.5 *Carettochelys insculpta* nesting season (daily number of nests) and water level (mH^{2}O). The percentage of nest sites inundated was estimated using the nests site height per season for each area and its relationship to the water level for the period of 98 days, corresponding to the main nesting season (9-Oct to 14-Jan on the coast and 12-Nov to 17-Feb on the river). This estimation was plotted as the water level at which 25%, 50%, 75% and 100% of nests sites would be under the water.

Table 3.3 Survival rate (% of survived eggs) for eight groups of *Carettochelys insculpta* eggs inundated in different periods of development (incubation days before inundation) and for different periods of time (hours under the water).

Incubation days before inundation	**Hours under the water**	**% of survived eggs**
3	0 (control)	75.0 (n = 8)
	24	37.5 (n = 8)
	48	50.0 (n = 8)
	96	0.0 (n = 8)
13	0 (control)	25.0 (n = 8)
	24	62.5 (n = 8)
	48	12.5 (n = 8)
	96	37.5 (n = 8)
23	0 (control)	42.9 (n = 7)
	24	37.5 (n = 8)
	48	50.0 (n = 8)
	96	62.5 (n = 8)
33	0 (control)	42.9 (n = 7)
	24	62.5 (n = 8)
	48	37.5 (n = 8)
	96	12.5 (n = 8)

Most of the nests on the coast and in up-river areas were laid on few sandbanks with more than 50% of nests laid on a single sandbank (Figure 3.6). Mid-river-kikori and mid-river-sirebi nests were more evenly distributed across sandbanks and presented similar higher evenness index (0.861 and 0.828 respectively). On the other hand, nests on the coast and up-river were less homogeneously distributed between sandbanks (Evenness index 0.617 and 0.586 respectively; Figure 3.6).

Mangrove monitors (*Varanus indicus*) were the major non human predators of *C insculpta* nests. There was no significant difference among mid-river-kikori, mid-river-sirebi and up-river areas in terms of the number of sandbanks that were persistent ($X^2 = 2.41$; df = 2; p = 0.30), predated ($X^2 = 3.55$; df = 2; p = 0.17), or with presence of nests in both years ($X^2 = 0.70$, df = 2; p = 0.71). These three areas were grouped together as "river" for further analyses of these parameters. River sandbanks were not significant differently than coastal sandbanks in relation to presence of nests in both seasons ($X^2 = 2.28$; df = 1; p = 0.13; Table 3.3). However sandbanks in the river had significantly more predation (81%) than on the coast (14.3%) ($X^2 = 6.86$; df = 1; $p < 0.01$; Table 3.3). Sandbanks on the coast (92.9%) also persisted significantly more than sandbanks on the river (42.4%) ($X^2 = 13.88$; df = 1; $p < 0.01$; Table 3.4).

Discussion

The nesting environment for pig-nosed turtles varies considerably in the Kikori region. Sandbanks exhibit distinct physical and biological characteristics in different areas. I have observed that predation of nests in riverine sandbanks is high and can reach 65% of the nests in a particular sandbank (Chapter 4). Sandbanks on the coast are usually located on islands where monitor lizards (*V. indicus)* are absent. On the coast, inundation is caused by tides and is spatially universal and more frequent than for the river, but also predictable and of short duration. In riverine areas, flooding is highly unpredictable, often remodelling the distribution of sandbanks after the eggs are laid. In any one year, the inundation can last for several days, risking increased egg mortality from hypoxia or, depending on rainfall, may not happen at all. Flooding here often results from rain in the upper catchment, remote from the nesting area and so there is a spatial mosaic in the impact of flooding across sub-catchments.

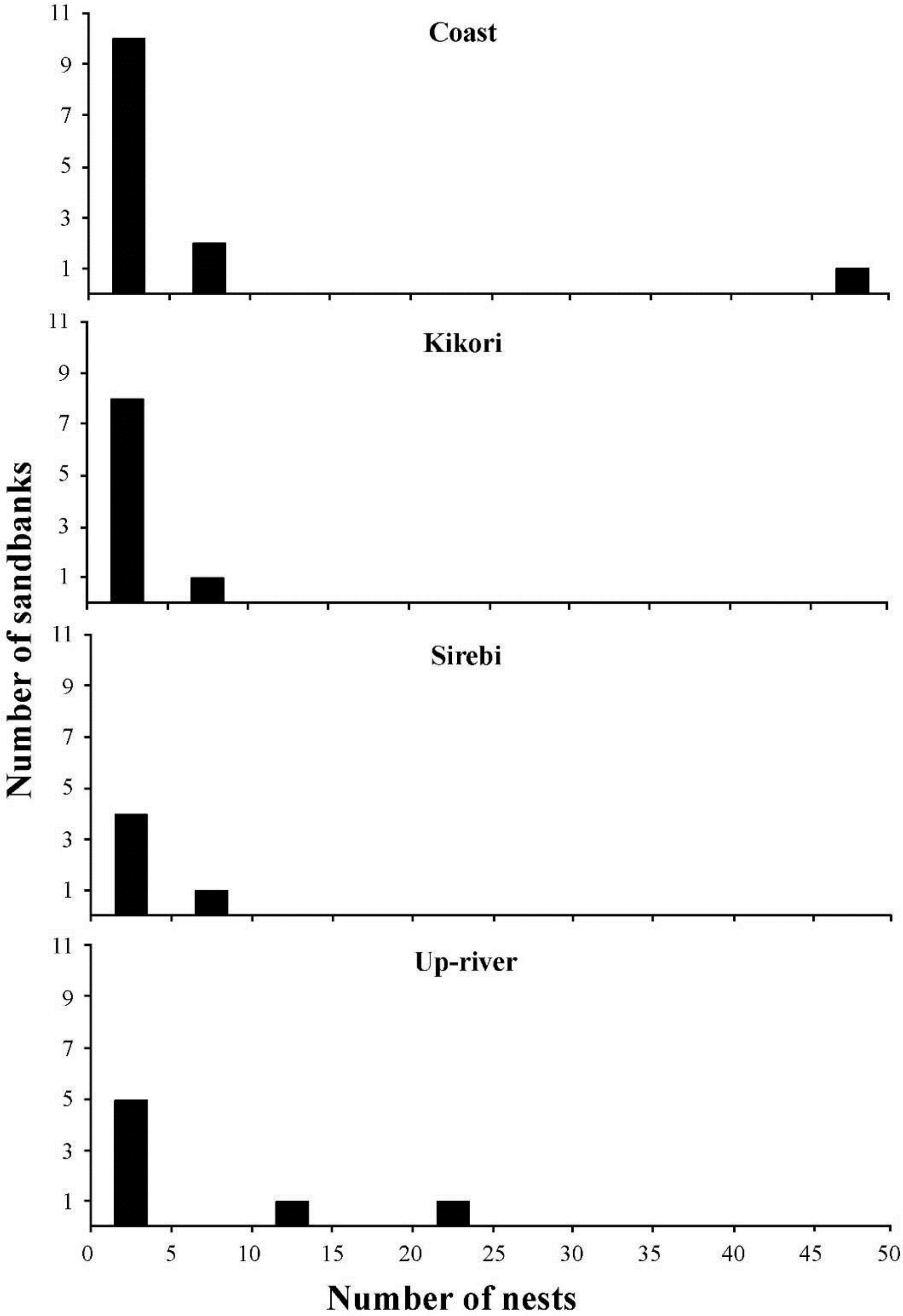


Figure 3.6 Total number of *Carettochelys insculpta* nests per sandbank in the 2007-08 and 2008-09 nesting seasons for the coast, mid-river-kikori (Kikori), mid-river-sirebi (Sirebi) and up-river. Mid-river-kikori and mid-river-sirebi presented similarly high evenness indices (Evenness index 0.861 and 0.828 respectively). Nests on the coast and up-river were more heterogeneously distributed among sandbanks (Evenness index 0.617 and 0.586 respectively).

Table 3.4 Comparison of sandbank attributes with the percentage of nests of *Carettochelys insculpta* that suffered predation, sandbank persistence and presence of nests in two seasons. Categorical ANOVA was used to test the difference between the four nesting areas of the Kikori region. Mid-river-kikori, mid-river-sirebi and up-river were not significant differently and grouped together for further analyses as “river”.

Sandbank	**% with predated nests**	**% with nests in two nesting seasons**	**% present (persistent) in two field seasons**
Up-river	60.0 (n = 10)	50.0 (n = 4)	66.7 (n = 6)
Mid-river-kikori	89.5 (n = 19)	50.0 (n = 6)	31.6 (n = 19)
Mid-river-sirebi	87.5 (n = 8)	75.0 (n = 4)	50.0 (n = 8)
River	81.1 (n = 37)	57.14 (n = 14)	42.4 (n = 33)
Coast	14.3 (n = 14)	84.6 (n = 13)	92.9 (n = 14)
Maximum likehood analysis of variance Coast *vs*. River	df = 1 $X^2 = 6.86$ $p < 0.01$	df = 1 $X^2 = 2.28$ $p = 0.13$	df = 1 $X^2 = 13.88$ $p < 0.001$

There is also a difference in the temporal scale of sandbank reliability between coastal and riverine areas. Riverine sandbanks are very ephemeral; however a sandbank that is destroyed is usually replaced by a new one in the same vicinity. On the other hand, the coastal environment creates beaches that last for many years, although they may at times disappear for decades without the appearance of substitutes in the surrounding area. Turuvio Island provides a good example of the unreliability of coastal sandbanks in the long-term. More than 50% of the nests laid in coastal areas during both nesting seasons of my study were laid on this island. Locals recalled the emergence of Turuvio as an open sandbank around the year 2000. During my study, it was a vegetated, apparently stable island, with the most nesting activity in the coastal region. I observed that only a few beaches were heavily used by *C. insculpta* on the coast. Most old coastal sandbanks were in the process of being eroded, with a subsequent decrease in the number of nesting sites. Locals also recalled that the number of sandbanks used by *C. insculpta* at the coast had been declining drastically in the 20 years before the emergence of Turuvio Island. Egg consumption data for villages that harvest old sandbanks corroborate partially these anecdotal reports (Chapter 4).

The height of available sandbanks did not differ significantly between coastal and riverine areas, but I observed that females nested closer to the highest points of the sandbank in areas with more frequent inundation events. The likelihood that a nest will be flooded is often related to its elevation above the water level and distance from the shoreline (Doody et al. 2003c; Escalona & Fa 1998; Plummer 1976). Females may avoid inundation of their nests by selecting elevated sites (Cox & Marion 1978; Plummer 1976; Tucker et al. 1997), but nesting higher and further inland could increase the risk of chance desiccation, misorientation and predation of mothers, embryos and hatchlings (Bustard & Greenham 1968; Caut et al. 2010; Fowler 1979; Marchand et al. 2002; Spencer 2002; Whitmore & Dutton 1985; Wood & Bjorndal 2000). In the Daly River, *C. insculpta* avoids the lowest elevation beaches owing to flooding mortality (Doody et al. 2003c).

Coastal sandbanks are usually located on islands where monitor lizards (*Varanus indicus),* the major nest predator at riverine sites, are absent. Females nesting on the coast avoid the extremely high nesting predation rates that occur from non-human predators in riverine areas. The chance of offspring survival increases if the female chooses to nest in an area with fewer nest predators (Martin 1993; Spencer & Thompson 2003). Therefore, nest predation is a strong factor influencing the evolutionary process of female nest site selection (Brown &

Macdonald 1995; Burke et al. 1998; Downes & Shine 1999; Escalona & Fa 1998; Iverson 1991a; Thompson 1983; Yerli et al. 1997).

Physical aspects of the sandbank (i.e. slope and vegetation density) potentially affect maternal nest site selection, since they can affect egg incubation environment (i.e. temperature, humidity) (Plummer et al. 1994; Schwarzkopf & Brooks 1985). Incubation temperature affects embryo developmental rate and, in TSD species, hatchling sex ratios (Burger 1976; Georges 1989; Janzen 1994; Roosenburg 1996; Schwarzkopf & Brooks 1985; Vogt & Bull 1984). In the Daly River, beach temperature was related to its slope aspect or direction. Females can also influence the nest temperature through the nest chamber depth, where deeper eggs experience colder and less variable temperatures (Burger 1976; Congdon & Gibbons 1990; Doody et al. 2003c; Packard & Packard 1988; Thompson 1988). However, this does not seem to be the case for *C. insculpta* in the Kikori region, since I observed no difference in nest attributes (infertility and nest chamber characteristics) among different areas and both sexes were produced in coastal and riverine areas (Eisemberg, unpubl. data). This is consistent with data from the Daly River where nest site selection did not influence the sex ratio of *C. inscupta* (Doody et al. 2004) and females were not manipulating offspring sex through choice of nesting beach and site (Doody et al. 2003c; Doody et al. 2004).

Coastal nesting choice by freshwater turtles is probably a compromise between natural selection factors and environmental constraints (Dunson & Mazzotti 1989; Dunson & Moll 1980; Kinneary 1996). According to Doody et al. (2004), the timing of nesting and nest site selection of the Daly River *C. insculpta* population reflects multiple processes, including natural selection, physical constraints and phenotypic plasticity. Coastal and riverine females in the Kikori region most likely represent the same population (Chapter 2). Trade-offs between nesting on the coast or river for the Kikori *C. insculpta* population are summarised in Table 3.5 and Figure 3.7. Nesting on coastal sandbanks alone is probably not sufficient to maintain the *C. insculpta* population in the long-term. Nesting sandbanks could disappear for decades in coastal areas. The long-term unpredictability of coastal sandbanks could explain the absence of species that exhibit high nest-site fidelity in this area, such as marine turtles (Caut et al. 2010; Hatase et al. 2002; Lahanas et al. 1994). Likewise, as in the Daly River population (Doody et al. 2003b; Doody et al. 2003c), pig-nosed turtle nest site fidelity in the Kikori region is highly unlikely. Another constraint for exclusive marine nesting is the minimum size for reproduction. *Carettochelys insculpta* have to reach larger sizes to nest on the coast than on the river (Chapter 2). A larger size could be costly, since time to maturity usually increases and juveniles will have to face high developmental and growth costs (Blanckenhorn 2000).

Low nest predation on the coast may be easily compensated for by higher female and hatchling mortality owing to high salinity and marine predators (Kinneary 1993; Kinneary 1996; Moll & Moll 2004). However, water salinity does not appear to be a major issue for hatchlings of riverine turtles nesting in other coastal areas (Dunson & Moll 1980; Dunson & Seidel 1986; Kinneary 1992) and Kikori estuarine water is relatively dilute (Chapter 2). In marine environments, tide inundation may expose the embryo to chloride toxicity owing to high salinities (Bustard & Greenham 1968). Water inundation in both coastal and riverine areas may decrease the survival rate of reptilian embryos by causing erosion (Patino-Martinez et al. 2008; Plummer 1976), oxygen depletion (Whitmore & Dutton 1985) and disturbance of the egg temperature, water content and respiratory gases (Ackerman 1981; Foley et al. 2006; Hewavisenthi & Parmenter 2002; Özdemir et al. 2008; Packard & Packard 1988). Beach-hatched *Trachemys venusta* hatchlings go to freshwater habitats via overland travel utilizing temporary residence in intermediate swamps (Moll 2004).The return route of *Callaqur* hatchlings to freshwater habitats is not known (Dunson and Moll 1980).

Long periods of inundation in riverine environments are probably lethal to *C. insculpta* embryos and water salinity on the coast may be toxic and decrease the chances of developmental success. *Carettochelys insculpta* embryos can survive at least 96 hours of freshwater inundation at any stage of development. In fact, short periods of inundation could have a positive effect on reptile eggs, facilitating embryogenesis and protecting the egg against desiccation and bacterial and fungal infections (Heger & Fox 1992; Kam 1994; Packard & Packard 1988). However, embryonic mortality is usually unavoidable during long periods of submersion (Magnusson 1982; Plummer 1976; Webb et al. 1977).

Selection of timing of nesting may be a selective force to avoid nest flooding. Timing is particularly important in tropical species which have their nesting period tuned to the decreased water levels. Low water levels usually occur, for a short period, during the dry season (Alho & Pádua 1982; Doody et al. 2004; Thorbjarnarson et al. 1993).

Table 3.5 Comparison of nesting traits for Carettochelys insculpta from coastal and riverine areas (mid-river-kikori, mid-river-sirebi and up-river).

Characteristics		**Coastal area in relation to river areas**
Sandbank	Length	No difference
	Height	No difference
	Area	More total area and more area per sandbank
	Slope	More gently sloping sandbanks
	Width	Wider sandbanks
	Use by year	No difference
	Predation	Less nest predation
	Short-term constancy	More reliable sandbanks
	Long-term constancy	Less reliable sandbanks
	Distribution of nests	Less homogeneous
Nest	Infertility	No difference
	Depth to first egg	No difference
	Chamber Depth	No difference
	Height	Lower nests in relation to average water level
Inundation	Predictability	More predictable inundations
	Period	Shorter inundations
Nesting season	Duration	Shorter nesting season
	Onset	Earlier nesting season, before the driest month
Female size		Larger curve carapace length
Salinity		Saline environment, possible osmoregulatory problems for eggs, females and hatchlings

Coast	***Vs.***	**River**
1. Greater nesting area available		1. Longer nesting season
2. Decreased nest predation		2. No osmoregulatory problems
3. Inundation more predictable and shorter		3. Inundation absent in some years
4. More reliable sandbanks in the short-term		4. More reliable sandbanks in the long-term

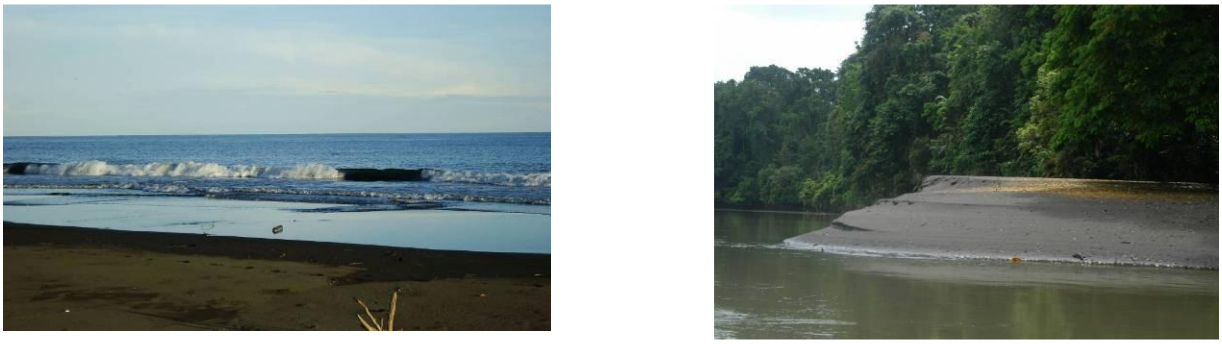


Figure 3.7 Trade-offs between coastal and riverine *Carettochelys insculpta* nesting in the Kikori region, Papua New Guinea. Coastal photo taken from Turuvio Island and Riverine photo taken from a sandbank in the Kikori River.

In exclusively riverine populations *C. insculpta* is restricted to nesting only in the short periods of the dry season, when sandbanks are available (Doody et al. 2001; Doody et al. 2004; Georges et al. 2008a; Georges et al. 2008b). Riverine areas in the Kikori region present similar nesting period limits. On the other hand, coastal areas exhibit different temporal and physical constraints. Sandbanks are constantly available, but, as the dry season advances, the salinity of the river mouth increases (Chapter 2), which may present problems for both females and hatchlings. December is the driest month in the Kikori region and also the time when the coastal nesting season ends.

Females in the Kikori region probably do not face the same constraints of energy-poor food as those in the Daly River (Doody et al. 2003a; Heaphy 1990; Welsh 1999) and so can start nesting earlier on the coast, when riverine sandbanks are not yet available. Overall, the total nesting season in the Kikori region is three times longer than that of the Daly River (Doody et al. 2004; Chapter 2). My data suggest that the coastal nesting exhibited by the pig-nosed turtle does not represent a stage of gradual evolution from freshwater to the sea. Differences in nest traits among areas are responses to environmental variations, where phenotypic plasticity and natural selection shapes female choice in relation to optimum nest site location and time of nesting (Doody et al. 2004). I propose that coastal nesting exhibited by *C. insculpta* is probably a response to highly stochastic environments, such as the Kikori region. Coastal nesting is complementary to riverine nesting, increasing the nesting season period and providing predator-free nesting areas.

CHAPTER 4

Decline of *Carettochelys insculpta* and Challenges for Conservation

Pig-nosed turtle (*Carettochelys insculpta*) eggs and meat being sold by a lady from Lalau (Rumu Tribe) in the Sirebi Market.

Photo by Carla Eisemberg

"Once upon a time there lived a chicken and rat. The chicken's friend was a pig nosed turtle. One day the chicken decided to cross the river then she came to the nearest neighbour which was the rat. The rat has the taro canoe with him, than they decided to go. The hen has her food but the rat hasn't his food for lunch. While they were paddling across the hen started to have her lunch while the rat was paddling the canoe across until the hen finished her lunch. The rat was very hungry so what he thought was to eat up the tarro canoe. He started eating the taro canoe until the canoe was filled up with water and started to sink. Hen wasn't able to swim so she just floats down the river but the rat swan to the ground and ran away. While she was floating down, was shouting for help in fear, at least her friend the turtle came and lift her with its big backbone and carry her to the ground. Finally she was safe."

(Frank Pivoru; Kopi Village; Recorder: Hebbie Jeffery)

CHAPTER 4

Decline of *Carettochelys insculpta* and Challenges for Conservation

Abstract

Papua New Guinea is among those nations with astonishing species richness and levels of endemism. Its cultural diversity, coupled with a strong community reliance on the land and its biota for subsistence, add complexity to monitoring and conservation and in particular, the demonstration of declines in wildlife populations. I provide, for the first time, concrete evidence of a substantive decline in populations of the pig-nosed turtle (*Carettochelys insculpta*); an important source of protein for local communities. My study combines matched village and market surveys separated by 30 years, trends in nesting female size and assessment of levels of harvest, all of which are essential to making a definitive assessment of population trends. Opportunities for an effective response by local communities to these declines needs to consider both conservation and fisheries perspectives because local communities consider the turtle a food resource, whereas the broader global community views it as a high priority for conservation. Both have sustainability as a key objective, which will require a holistic approach that integrates all biological, socioeconomic and political disciplines. I believe that my study in the Kikori region is representative of harvest regimes in most rivers within the range of the species in Papua New Guinea and provides lessons for conservation of many other wildlife subject to harvest. Without community-led action informed by applied research and environmental education and wildlife protection, the declines are likely to continue.

Keywords: Carettochelyidae, market surveys, population trends, Gulf Province, management, exploitation, levels of harvest, female size

Introduction

Papua New Guinea (PNG) is one of seventeen megadiverse countries that account for 70% of global biodiversity (Mittermeier et al. 1997). The biodiversity of many of these nations is under threat, particularly in tropical countries that allow and encourage aggressive mining, forestry and agricultural practices driven by immediate financial imperatives rather than longer term sustainable economic considerations (Laurance et al. 2001; Sodhi et al. 2004).

PNG has remarkable species diversity and high levels of endemism. Its biodiversity is of particular international concern and attracts considerable conservation funding in support of government initiatives to prevent overexploitation of their biological assets (Connell 1997).

Charting a path to a sustainable future is complicated by the equally astonishing cultural diversity of the Papuan human population, many of whom still live traditional lives in villages distributed through the New Guinea highlands and coastal plains (Foley 1986). This cultural diversity, coupled with a strong community reliance on the land and its biota for subsistence, presents a number of challenges for monitoring and managing wildlife populations. Wildlife management is complicated by a shift from subsistence to a cash economy, increasing human population size and the introduction of modern fishing and hunting techniques. These changes can intensify the pressures placed on natural resources (Groombridge & Wright 1982).

The Kikori delta provides a microcosm of the issues faced by tribal communities in New Guinea. The many tribes that coexist in this region (Busse et al. 1993; David 2008) differ in their language, use of natural resources and perceptions about the state of the environment. These factors complicate conservation efforts which invariably rely upon community support and involvement. One efficient way of community integration in conservation programs is through long-term monitoring involving flagship species behind which to marshal community support (Low et al. 2009; Marcovaldi & Marcovaldi 1999; Townsend et al. 2005). One such flagship species, widely distributed in southern New Guinea, is the pig-nosed turtle (*Carettochelys insculpta*).

Long-lived animals, such as freshwater turtles, are important sources of protein for indigenous communities and have been for many centuries (Milner-Gulland & Bennett 2003; Smith 1979). The pig-nosed turtle from the Kikori region is no exception (Georges et al. 2008a). It is of conservation concern because it is the sole survivor of a once widespread family, because it has a restricted distribution and because it is subject to intense harvest pressure (Groombridge & Wright 1982).

Highly prized as food, these turtles are caught and their eggs are collected for consumption by local villagers or trade in local markets (Georges et al. 2008a). Local villagers harvest *C. insculpta* eggs with close to 90% efficiency (Pauza 2003). Growth in human populations, a greater propensity for villages to establish on riverbanks following the cessation of tribal warfare and the introduction of new technologies, particularly outboard motors, have brought added pressure to turtle populations in recent decades. This has led to the widespread view that populations of *C. insculpta* have suffered severe population declines (Georges et al. 2008b; Groombridge & Wright 1982; Pauza 2003). There is however, remarkably little direct evidence of these declines and what there is remains unpublished. The IUCN (International Union for Conservation of Nature) listing of the species as vulnerable (IUCN 2009) rests largely on a precautionary approach to evaluation of its status. This uncertainty has in turn led to reduced commitment to act to conserve *C. insculpta* despite its international profile as a distinctive relic species.

Such direct evidence is very difficult to obtain. Indirect evidence through market surveys typically span too few years to be of value and in any case can underestimate the extent of harvest (Milner-Gulland & Bennett 2003). To eliminate some of these potential biases, it is necessary to combine market surveys with surveys of households and direct surveys of wildlife populations (Milner-Gulland & Bennett 2003). Long-term monitoring is particularly important for long-lived species, whose decline can be masked by the presence of older individuals and take years to detect and overcome (Bodie 2001; Browne & Hecnar 2007).

In this chapter, I reported the results of matched market and village surveys of *C. insculpta* over almost 30 years in the Kikori delta which provide the first evidence of population declines of this iconic species. I compared the nesting female size between the two periods to evaluate the effect of selective harvesting towards females nesting on the sandbank. I monitored the nesting survivorship in natural sandbanks to assess the level of poaching pressure. Finally, I identified opportunities for an effective community level response to these declines with a view to establishing more sustainable harvest practices for this important food species.

Material and methods

Study Site

The Kikori drainage extends from the coastal region and delta to the limestone plains of the Kikori lowlands (Löffler 1977) in the Gulf Province of Papua New Guinea (Figure 4.1). The river system is highly confined within its limestone bed and meanders and oxbows are absent. In this case, riverine areas include mid-river-kikori, mid-river-sirebi and up-river. The delta is a large alluvial plain below 40 m elevation, dissected by a tributary system of river channels and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain. The coast comprises the delta islands exposed to the Gulf of Papua. Wind and wave action creates coastal beaches, sand bars and sand islands in what is a very dynamic system (Enesar 2005). A more detailed description of the Kikori region is presented in Chapter 2.

Before interaction with Europeans, the upstream sections of the Kikori River were characterised by a few sparsely-distributed small villages whereas the delta region had many villages each with more than 1000 people (David 2008). Currently, there are 51 villages and fishing camps, from three major language groups, distributed over much of the lowland area. The Rumu language group comprises approximately 700 people living in villages mainly in the limestone plains upstream of the main Kikori Township. The Porome language group comprises approximately 600 people residing in villages of the delta region. The Kerewo language group is the largest, comprising approximately 1,500 people whose lands are in the deltas and coastal regions of the Omati and Kikori River systems. Each of these groups is subdivided into networks of clans and lineages with their own territorial estates (Busse et al. 1993).

Methods

A daily survey of pig-nosed turtle eggs passing through the Kikori (7°24'44.45"S; 144°14'51.78"E) and Sirebi Markets (7°12'23.36"S; 144°14'47.80"E) was conducted during the turtle nesting seasons (September to February) in the years 1980-81, 1981-82, 2007-08, 2008-09. Only the Kikori market operated in the years 1980-82. A second market was established at the Sirebi Forestry Camp in 2007 and continued to operate until early 2009. Comparisons among years were based on the Kikori market in 1980-82 versus the combined totals for both markets in 2007-09. Data recorders were comprised of volunteers from local villages, who visited Kikori and Sirebi markets every day of operation and recorded the number of pig-nosed turtle eggs for sale and obtained estimates of counts of eggs that had already been sold. I regularly visited the markets to undertake spot surveys as a cross check on the veracity of the accounts from the recorders.

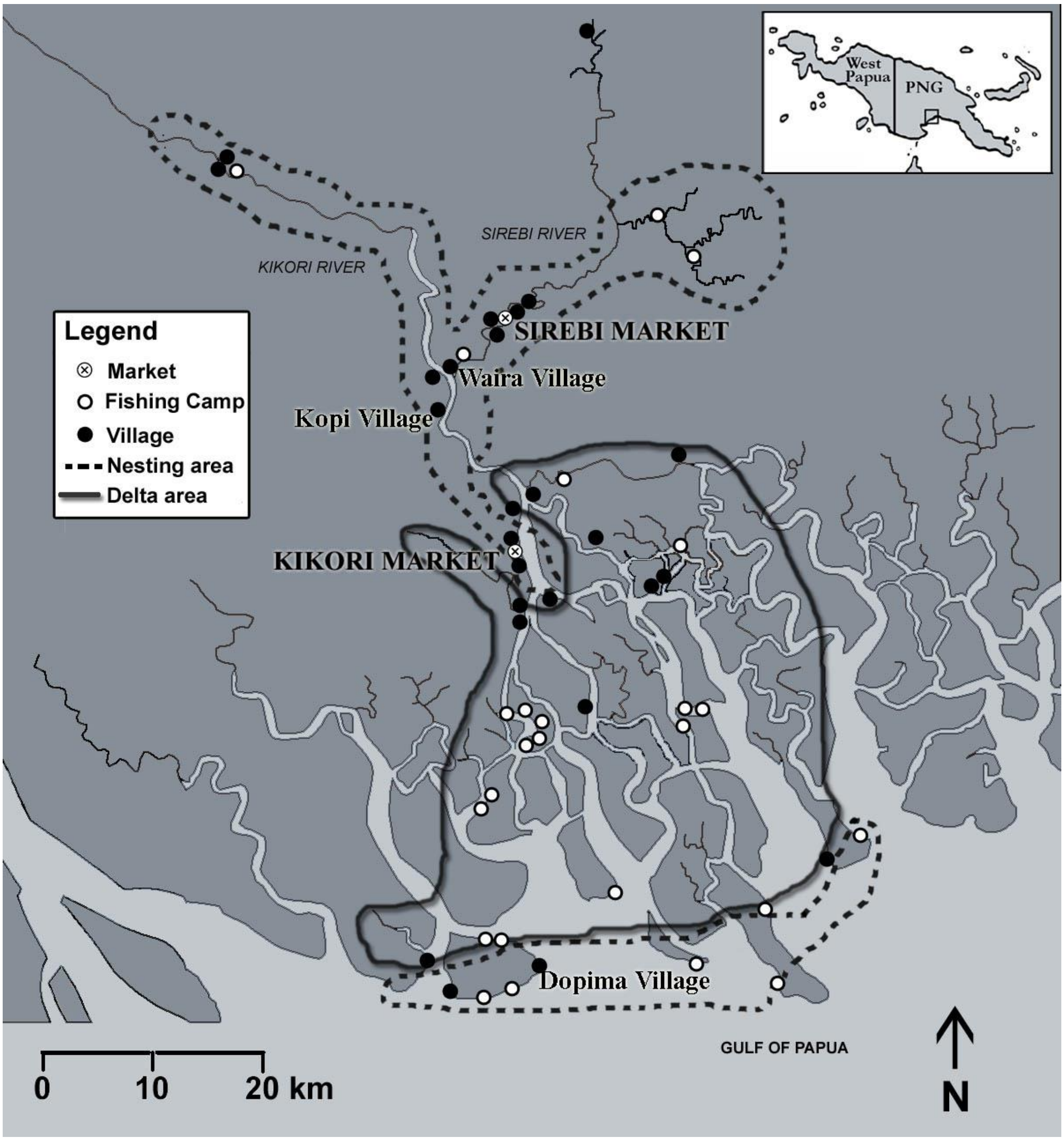


Figure 4.1 Map of the Kikori region showing permanent settlements (villages), temporary settlements (fishing camps) and markets. Areas with sandbanks, where *Carettochelys insculpta* females lay their eggs, are delimited by dashed lines. The Kikori region is divided into delta, riverine (area upstream of the delta) and coast. Riverine areas include mid-river-kikori, mid-river-sirebi and up-river.

Two riverine villages (Kopi and Waira) and one coastal village (Dopima) were selected for intensive monitoring of egg and turtle numbers consumed in the 2007-08 and 2008-09 nesting seasons. These villages were selected because of comparable data collected there in the nesting season of 1981-82. Data on household consumption were recorded by volunteer village residents. Four volunteers in Kopi, two in Waira and one in Dopima visited all village families every week to access the number of eggs harvested per day. When shells or live turtles were available, I measured the curved carapace length (CCL) using a measurement tape.

Nest survival rate was recorded for the two most remote nesting areas (Turuvio Island and Wau Creek sandbank) in the 2007-08 and 2008-09 nesting seasons. Data on nest fate were collected by local volunteers and validated by direct survey every month. Nest characteristics (clutch size, egg diameter and hatchling weight) were measured in all years. To ensure comparability of data, only data from nesting females, nests, eggs and hatchlings from nests laid in the riverine sandbanks in December were used for the t-test comparisons between years. Price for *C. insculpta* meat and eggs was also recorded from villages and markets.

Data on egg diameter and hatchling weight were averaged by clutch to avoid pseudoreplication arising from lack of independence of eggs within clutches. Statistical tests followed those recommended by Sokal and Rohlf (1981) and were performed using SAS 9.1 or by hand. Chi-square tests were performed on counts of clutches as the independent entities satisfying the underlying multinomial assumptions. Where I had only egg counts, not clutch counts, the number of clutches was estimated by dividing the number of eggs by the average clutch size of 21.3, so that these data could be included in the statistical analyses. I used the difference between the total number of eggs consumed (market and villages) in the 1981-82 nesting season and the average from the 2007-08 and 2008-09 nesting seasons to estimate the level of decline.

Results

The number of turtle eggs passing through the markets in 2007-09 was substantially lower than in 1980-1982 ($X^2 = 269.04$, df = 3, $p < 0.0001$; Figure 4.2). The proportion of eggs sold in market decreased from 28.5% (1980-81) to 19.7% (2007-08) and subsequently to 8.4% in the next year ($X^2 = 1704.29$; df = 2; $p < 0.00001$; Figure 4.3). However, fewer eggs overall were consumed in the 2007-08 and 2008-09 nesting seasons in the villages of Kopi (X^2 = 72.67; df = 2; $p < 0.0001$), Waira (X^2 = 62.65; df = 2; $p < 0.0001$) and Dopima (X^2 = 84.27; df = 2; $p < 0.0001$) when compared with the numbers consumed in 1981-82 in the same villages (Figure 4.4). On the basis of these data, my best estimate of the level of decline is 57.2% since 1981.

Nest survival was exceptionally low on the nesting beaches of Turuvio Island during the nesting seasons of 2007-08 (3.3% of 120 nests survived) and 2008-09 (2.9% of 104 nests survived) and Wau Creek 2008-09 (2.0% of 100 nests) and did not differ significantly among any monitored location (X^2 = 0.37; df = 2; p = 0.70). Humans were the only predator responsible for nest mortality in Turuvio Island while monitor lizards (*Varanus* sp.) uncovered and removed the eggs of 65% (n = 65) of the 100 nests in Wau Creek, with a further 33% (n = 33) harvested by humans.

The average size of nesting females, clutch size and egg diameter was smaller in the 2007-09 than in the 1980-82 nesting season. On the other hand, egg and meat price increased and hatchlings were heavier (Table 4.1). However, only the size of nesting females was statistically significant (t = 2.53; df = 16.2; $p < 0.05$). Nesting females in 1980-82 had an average curved carapace length 3.9 cm larger than in 2007-09 (Figure 4.5). Clutch size (t = 0.91; df = 164; p = 0.36), egg diameter (t = 1.25; df = 52; p = 0.22) and hatchling weight (t = -1.22; df = 21.3; p = 0.24) did not differ significantly between periods.

Discussion

Is the species in decline?

Reports over the last thirty years have suggested dramatic declines in *C. insculpta* natural populations in New Guinea (Georges et al. 2008a; Georges et al. 2008b; Groombridge & Wright 1982; Pauza 2003) but these have largely derived from anecdotal information or inference drawn from observations on the intensity of harvest. I provide for the first time concrete evidence of a substantive decline in these pig-nosed turtle populations based on matched village and market surveys spanning 30 years, trends in nesting female size and assessment of levels of harvest, all of which are essential to make a definitive evaluation of the population trends in this species.

Table 4.1 Nesting female sizes, nest and market attributes for *Carettochelys insculpta* from the Kikori region in the 1980-82 and 2007-09 nesting seasons. Means are given with their standard errors, maximums, minimums and counts. CCL: maximum Curved Carapace Length in cm.

Parameter	**1980-1982**	**2007-2009**	**Trend**
CCL (cm)	58.2 ± 1.0 (52.2 – 61) n = 9	54.3 ± 0.7 (46.8 – 57.1) n = 20	Decrease
Clutch size	22.8 ± 0.5 (11.0 – 33.0) n = 73	22.2 ± 0.6 (7.0 – 37.0) n = 93	Decrease
Egg diameter (cm)	4.37 ± 0.02 (4.19 – 4.50) n = 25	4.33 ± 0.02 (4.11 – 4.54) n = 36	Decrease
Hatchling weight (g)	30.10 ± 0.88 (23.00 – 34.30) n = 17	32.41 ± 1.10 (25.76 – 35.07) n = 11	Increase
Egg price (Kina)	0.03 ± 0.00 (0.01 – 0.05) n = 128	0.49 ± 0.01 (0.40 – 0.50) n = 8	Increase
Turtle price (Kina)	3.54 ± 0.18 (1.00 – 5.00) n = 54	23.75 ± 3.78 (10.00 – 55.00) n = 12	Increase

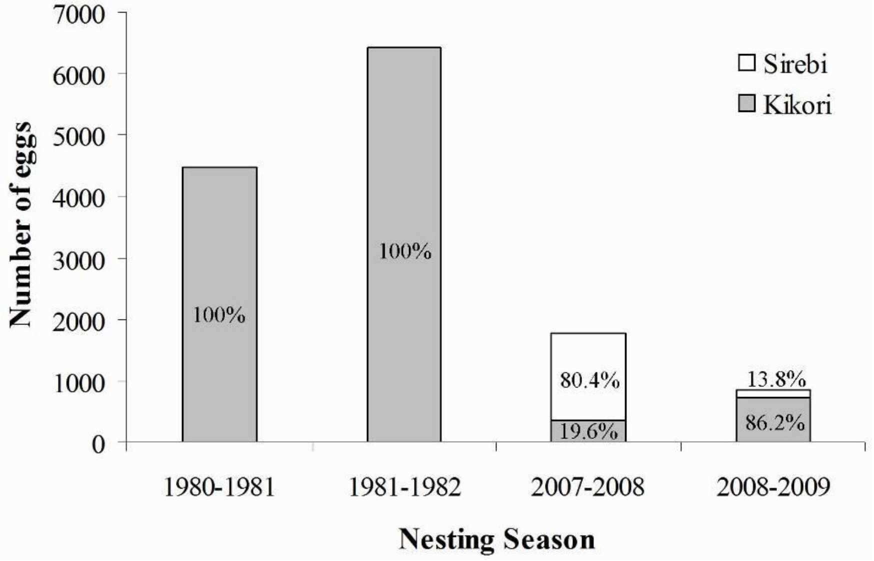


Figure 4.2 Number and percentage *of Carettochelys insculpta* eggs passing through the active markets of the Kikori lowlands (Kikori and Sirebi markets) in the nesting seasons of 1980-81, 1981-82, 2007-08 and 2008-09. There was a significant decline in trade between 1980-82 and 2007-09 ($X^2 = 269.04$; df = 3; $p < 0.0001$).

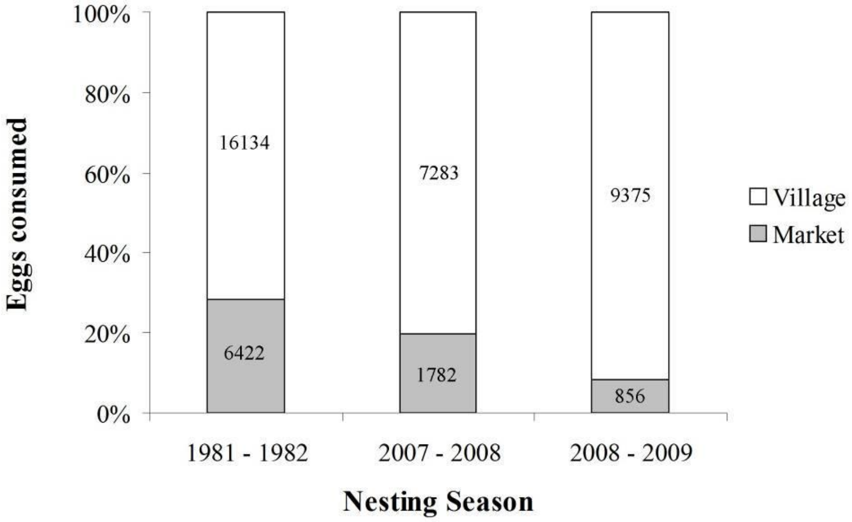


Figure 4.3 Percentage and number of *Carettochelys insculpta* eggs passing through the active markets and villages of the Kikori lowlands (Kikori and Sirebi markets) in the nesting seasons of 1980-81, 1981-82, 2007-08 and 2008-09. There was a significant increase in percentage of eggs consumed in the villages between 1980-82 and 2007-09 ($X^2 = 1704.29$; df = 2; $p < 0.00001$).

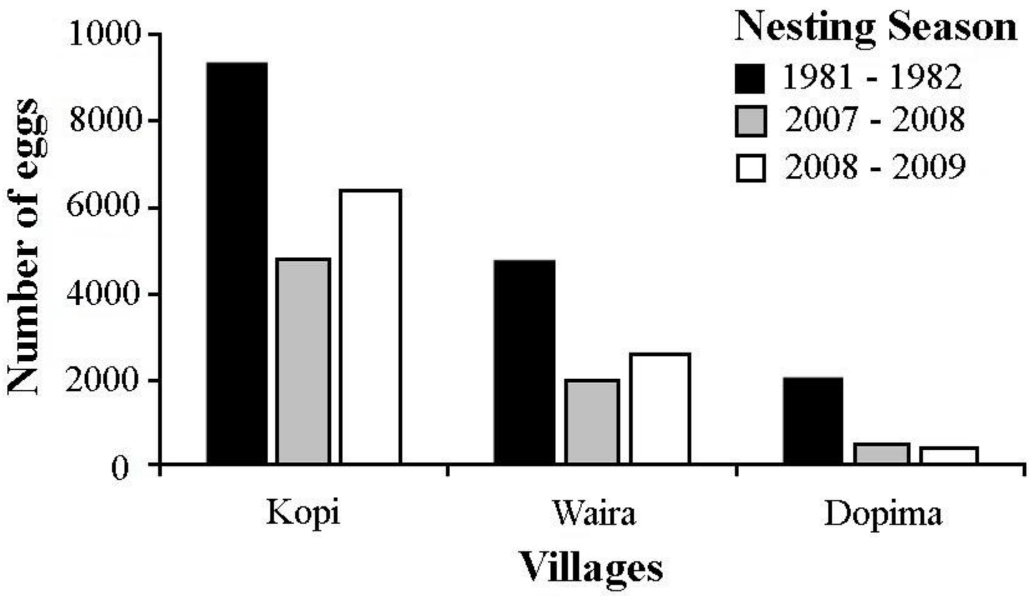


Figure 4.4 Number of *Carettochelys insculpta* eggs consumed in the villages of Kopi, Waira and Dopima in the nesting seasons of 1981-82, 2007-08 and 2008-09. There was a significant decline in consumption between 1981-82 and 2007-09. (Kopi: X^2 = 72.67; df = 2, $p < 0.0001$; Waira: X^2 = 62.65; df = 2; $p < 0.0001$; Dopima: X^2 = 84.27; df = 2; $p < 0.0001$).

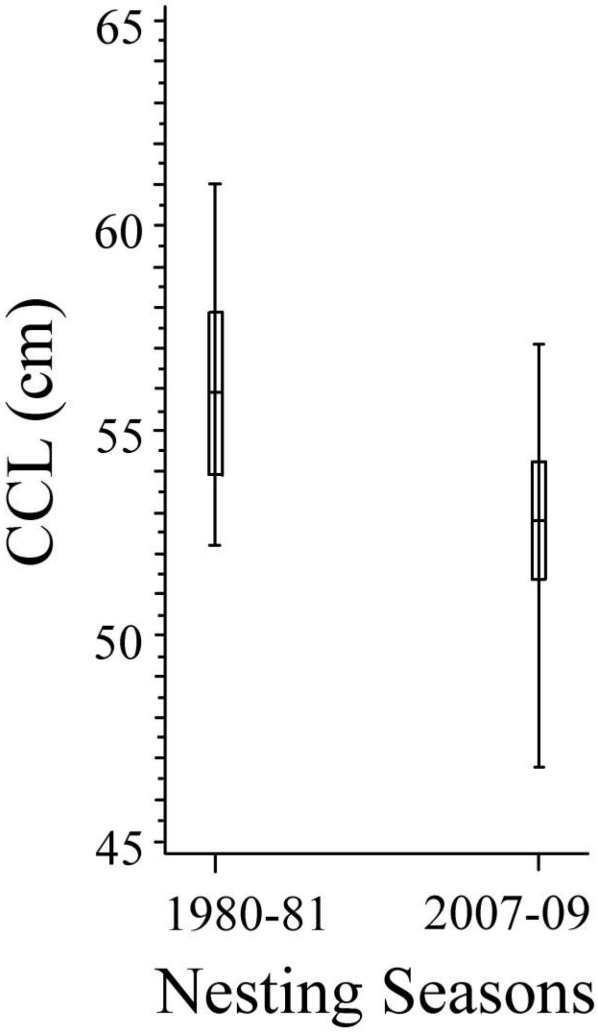


Figure 4.5 Comparison of the body size of nesting females of *Carettochelys insculpta* for different nesting seasons of the Kikori. CCL, Maximum Curved Carapace Length in cm. Means are given with 95% confidence limits (boxes) and ranges (vertical bars). Nesting females were significantly smaller in 2007-09 when compared with 1980-81 ($t = 2.53$; $df = 16.2$; $p < 0.05$).

Including both village and market surveys is essential because the combined data capture consumption in the villages, exchange among local villagers and informal sales in addition to formal trade through markets (Milner-Gulland & Bennett 2003) and so are robust to shifts in patterns of consumption. Growth in human populations can be expected to shift the balance between village consumption and sales and so distort assessments made on market surveys alone. Indeed, I demonstrated such an increase in the relative importance of consumption in villages over market trade between 1981-82 and 2007-09, illustrating the need to couple market sales with data on local village consumption.

Perhaps more difficult to assess is the effect of shifting emphasis from a subsistence economy to a cash economy as more villagers come to engage in resource development through mining, forestry industries and associated infrastructure development, or indeed employment in support of conservation efforts (Georges et al. 2008a; Georges et al. 2008b). The impact of a cash economy is a double-edged sword. One cannot assume that economic development will reduce demand for wild meat. The opposite could easily happen in the short-term (Milner-Gulland & Bennett 2003). In the presence of well established transport infrastructure and legal or illegal trade networks, a cash economy can have devastating impacts on high profile species because of high returns and opportunities derived from a global market (van Dijk et al. 2000).

The impact of such trade on native turtle populations because of high demand in China arising from the combination of traditional practices and new found wealth is well documented (van Dijk et al. 2000). The initial stages of such trade in *C. insculpta* are seen in neighbouring Indonesia. International pet trade has largely driven the recently intensified egg collection in West Papua (Maturbongs 1999). The level of harvest involved is unlikely to be sustainable, but there are no rigorous monitoring programs in West Papua to assess the impact. This trade is also affecting the exploitation and conservation status of the species in PNG (Rhodin & Genorupa 2000). Georges et al. (2008a) found no evidence of trade in turtles, eggs or turtle products with markets outside Kikori, only an anecdotal report of live *C. insculpta* being shipped out of the region on logging boats for sale in the Asian market. However, I recorded crocodile skin (*Crocodylus novaeguineae* and *C. porosus*) and numerous species of shark fin being actively collected for the international trade, which demonstrates the existence of a trade system that could potentially include turtles.

An efficient transport infrastructure is absent in the Kikori region, which can only be accessed by air or boat. Fuel is also a critical limiting factor for local villagers, which greatly limits any net returns (Chapter 5). The global trade networks that have been established in West Papua (Samedi & Iskandar 2000; Samedi & Iskandar 2002) and which extend across the border into the western province of Papua New Guinea (Georges et al. 2006; Rhodin & Genorupa 2000) are not connected to the local networks in the Kikori region. In this context, a shift from a subsistence economy to a cash economy and an accompanying shift toward reliance on processed foods would be expected to reduce local demand for turtles. I assessed the impact of this possible confounding effect on my surveys by a concurrent study of the impact of harvest on nest survivorship. My results show an astonishing level of human harvest on eggs, which confirms an earlier unpublished report of nest harvest rates of 85.6% (Pauza 2003). My results demonstrate that, if there has been a reduction in harvest effort and hunting acumen by local villagers as a result of the developing cash economy, it has not yet translated to a reduction in the outcome of the harvest – the rate remains exceptionally high.

A third indication of the impact of harvest comes from the analysis of body size. Human harvest can alter demographic parameters of turtle populations (Close & Seigel 1997; Fenberg & Roy 2008; Fordham et al. 2007; Gamble & Simons 2004; Wolak et al. 2010). When a pristine population comes under harvest pressure, one of the first indicators is a reduction in body size (Bhupathy & Saravanan 2006; Daza & Páez 2007; Múnera et al. 2004), both because the larger individuals are more likely to be targeted or retained and because of reduction in life expectancy, which in a species with indeterminate growth, translates to a lower average body size in the population.

The combination of matched market and village surveys, the sustained and exceptionally high efficiency of human harvest and the significant reduction in the body size of harvested female turtles all point to the firm conclusion that *C. insculpta* has suffered a substantial decline in population size in the past three decades in the Kikori region.

Such a decline is likely to be widespread as the species is under similar pressures elsewhere in PNG. In the Fly River, pig-nosed turtle eggs and meat provide an important source of protein to complement agricultural produce (Georges et al. 2006) and they are heavily harvested there (Rose et al. 1982). Intensive egg harvest was also documented in the Purari River (Pernetta & Burgin 1980) and West Papua (Cann 1978). Around 1970, egg harvest increased substantially in the Eilanden River (West Papua) when the region became more secure (Cann 1998).

Recently, it was estimated that 1.5–2 million eggs are annually harvested in the Merauke Regency (Samedi & Iskandar 2000). In the Vriendschap River only adult turtles were usually captured for consumption. However, egg collection has expanded massively since 1997 due to the influx of eggs harvested from outside West Papua (Maturbongs 1999).

There is a possibility that the increasing human population in Kikori is not occurring in other areas of the species' range, therefore the increased pressure and resulting decline of *C. insculpta* could be localized. In many rural areas, the absence of employments and basic social services, such as school and hospitals, may lead to a migration to the cities, where these facilities exist (Koczberski et al. 2001). In some areas of PNG, there is a high rate of labor-related migration, especially men, from their original region to mine sites and plantations (Wardlow 2007). For example, since the early eighties around 45% of men aged 20 to 39 years were absent from their homes in Tari, Southern Highlands (Lehman 2002). However, this high rate of migration is probably counterbalanced by the decrease of children mortality and consequent increase in the rate of population growth (Heywood, 1983). The rural population still accounts for 85% of the nation's population (Gibson & Rosele 2003). Nevertheless, studies with artisanal multi-species coral reef fishery in different sites in Papua New Guinea, suggest that the pressure on a fishery and its condition is determined more by the regional and global market demands than human population density (Cinner and MacClanahan 2006). My data demonstrating a decline in the Kikori gives indirect substance to claims of decline elsewhere within its range.

Conservation Icon or Fishery?

The global and local perspectives of the pig-nosed turtle are dramatically different. There is a potential for tension during the implementation of a conservation and management program for the pig-nosed turtle in the Kikori among indigenous people, wildlife managers, researchers and conservationists. Internationally, *C. insculpta* is listed in the IUCN Red List as Vulnerable (IUCN 2009) because of suspected dramatic declines over most of its range and is listed in Appendix II of CITES. The IUCN/SSC Tortoise and Freshwater Turtle Specialist Group assigned the species an Action Plan Rating of 1 (known threatened species in need of specific conservation measures) (Fund 2002; Georges et al. 2008b). The species has been listed in the Northern Territory of Australia as "Near Threatened" under their Parks and Wildlife Conservation Act (NTPC 2005). While the Australian EPBC Act has the potential to take broader national and international perspective on the conservation of *C. insculpta* and its habitat than is possible at the State level, a recent bid to have the species listed nationally as “Vulnerable” failed (TSSC 2005).

In Australia, federal legislation prohibits the exploitation of native fauna by all but Aboriginal people. However, such legislation does not protect the species from habitat destruction or modification (Georges & Wombey 1993). Until recently, Australia’s most substantial populations of *C. insculpta*, in the middle reaches of the Daly River, lay outside formal protected areas. Kakadu National Park is currently a compromise between conservation, mining, recreation and other interests and there are continual, albeit intermittent, moves to annex important regions for mining (Georges et al. 2008b). Turtle exportation in PNG is strictly regulated by law as prescribed by the Fauna (Protection and Control) Act (Parker 1981). Papua New Guinea is also a CITES signatory and has been since 1975. In the West Papuan District of Indonesia, harvest of eggs for incubation and subsequent export of hatchlings as ‘captive-bred’ is managed by a quota system. However, protective measures to prevent exploitation of mature animals are rarely enforced (Georges et al. 2008b; Samedi & Iskandar 2000).

A substantial proportion of eggs harvested in West Papua are incubated in captivity and the hatchlings are exported into the pet trade. Being hatched from wild collected eggs, this trade is in a grey zone of legal/illegal trade under Indonesian legislation. Hatchlings are usually shipped to Jakarta, Ujung, Pandang, Surabaya, or Denpasar where they were illegally exported to Taiwan, China, or Singapore (Samedi & Iskandar 2002; Samedi & Iskandar 2000). In Indonesia, Jakarta is the hub for illegal trade of wildlife. Most pig-nosed turtles that are smuggled into Jakarta are not sold locally but exported to other international destinations (Shepherd & Nijman 2007).

Pig-nosed turtles also have recently been reported for sale in Singapore, Japan, Thailand, China, USA and Europe (Ades 2002; Auliya 2003; Goh & O'Riordan 2007; Shepherd & Nijman 2007; USFWS 2003). In Australia, reptiles were the most targeted group for illegal trade. They are favoured by illegal traders because of their higher prices on the black market for pets and the easy transportation as live specimens (Alacs & Georges 2008). As a result of this documented trade at levels thought to be unsustainable, the international perspective of *C. insculpta* is one of a distinctive and therefore iconic species for whom suspected declines in populations and the levels of harvest that are driving those declines are of great concern. The results reported in this chapter give substance to those concerns and are likely to result in a re-evaluation of the status of the species in New Guinea and globally.

From the point of view of the local community, *C. insculpta* remains an important and traditional source of food, particularly protein. A conservation ethic has yet to penetrate community perspectives and many villagers believe that the turtles are abundant, have always been abundant and will continue to be so. Those in the community who are concerned about the decline of the species are more concerned for sustainability of the resource (for future generations) rather than as an endangered species issue in the western sense. The local villagers view the species more as a fishery to be managed sustainably than a species to be conserved from the perspective of the international conservation movement.

From a fishery management perspective, decline in abundance is an inevitable consequence of exploitation and is not of concern unless and until the decline threatens sustainability of the resource. Indeed, a fishery stock ranging from 30 to 60 percent (depending on the resilience of the species) in relation to its virgin levels could be regarded as a normal and satisfactory outcome following the development of the fishery (Restrepo et al. 1998). From a conservation perspective, any substantial decline in abundance of a globally restricted species such as the pig-nosed turtle is likely to trigger concern. So the two perspectives, indigenous and western, differ not in their common desire to see populations of the species persist in perpetuity, but in their response to demonstrated decline in abundance and in the level at which the population can decline and still be regarded as acceptable. This diversity in perspective is an important consideration in crafting a conservation plan for *C. insculpta* in PNG.

Achieving Sustainability

Programs to manage wildlife resources should be sustainable in the long-term, as well as biologically, economically and culturally acceptable (Bennett & Robinson 2000; Campbell 2002). Because conservation is about sustaining values and because the value of *C. insculpta* for the local population is centred on its use as food, not the more esoteric concerns of the international community, a focus on education to achieve sustainability of *C. insculpta* as a fishery would seem most appropriate.

There is a potential for utilizing *C. insculpta* under a sustainable yield management to provide a valuable protein source for local inhabitants (Rose et al. 1982). The central question here is whether it is possible to achieve sustainability given the combination of life history attributes of the turtles (e.g. late maturing, slow-growing, long-lived) and harvesting practices (focus on nesting females and eggs). Organisms with these life history attributes are particularly susceptible to chronic disturbance and overexploitation (Congdon et al. 1993), especially when large reproducing females are removed (Tucker & Moll 1997). The situation becomes even more complicated when the adult females engage in stereotyped nesting behaviour as does *C. insculpta* (Groombridge & Wright 1982; Rose et al. 1982) because the predictability in their availability exacerbates the effectiveness of the harvest. The local knowledge about the time and place where the females will lay their eggs makes adult females particularly vulnerable to human predation compared to the vulnerability of males and juveniles.

According to Frazer (1992) it is necessary to recognize the extreme limitation of the evolution of longevity in relation to the inability of a long-lived population to respond to increased mortality. An extreme level of iteroparity (repeated reproduction) is required in species with low seasonal probability of reproductive success (Congdon et al. 1993; Heppell 1998). This concept promotes the perception that sustainable harvest of adult turtles is virtually impossible. However, it has been demonstrated that long-lived reptiles can be sustainably harvested when appropriate management institutions are implemented both for crocodiles (Bradshaw et al. 2006) and turtles (Fordham et al. 2007).

Chelodina rugosa has been traditionally harvested by indigenous communities in northern Australia. This species can compensate for low rates of adult survival by adjusting life history parameters. A decrease in the abundance of adults increases juvenile survival and post-maturity growth and decreases size at maturity, which promotes juvenile recruitment and age-specific fecundity (Fordham et al. 2007). However, it is not known where *C. insculpta* is situated in the ‘slow-fast’ (recruitment, growth, maturity) continuum of life history characteristics. The question as to whether any level of harvest in the Kikori region is sustainable remains open. Answering this question is a priority for the future, perhaps in an adaptive management framework.

Although a definitive answer to this question is not known, I do know that reptiles, especially turtle eggs and meat, are an important and seasonal source of protein for many rural populations in developing countries (Klemens & Thorbjarnarson 1995; Mittermeier et al. 1992). Complete elimination of pig-nosed turtle harvest in Kikori could potentially aggravate their already protein-deficient diet (Foley 1986). Exclusionary and restrictive conservation practices in developing countries have often alienated local people and failed to protect the wildlife (Pimbert & Pretty 1998). It is unlikely that any efforts to dramatically curtail the harvest of pig-nosed turtles would be acceptable to the local community and any attempt to do so could lead to counterproductive attitudes to conservation on broader agendas. A viable alternative for a remote area, such as the Kikori Region, would be to encourage a gradual decrease in consumption together with the implementation of alternative sources of protein and income. New job opportunities related to the protection of beaches and turtles, as well as the creation of no-take areas, could be implemented with the help and participation of the local villagers.

Conservation programs with marine turtles on the north coast of PNG are a good example of how community engagement can play an important role. This includes the creation of a leatherback no-take area as a community marine reserve (Magun 2006; Monitoring & Network 2006). The chances of a conservation project being successful increases with participatory, voluntary, decentralised and community-level-based management. It should also provide substantial economic benefits to communities (Campbell 1998; Klemens & Thorbjarnarson 1995). A sense of ownership is also critical to the success of such programs (Milner-Gulland & Bennett 2003). Villagers from the Kikori region need to be informed of the consequences *C. insculpta* over harvest and the benefits of sustainable management.

Iverson (1991b) recommended that conservation programs should primarily protect early life stages. In contrast, more recent models suggest that management approaches should ensure adult survival over hatchling survival (Congdon et al. 1993; Doak et al. 1994; Heppell 1998). Marine turtles' conservation projects recommend protection of nesting areas and in some cases relocation of eggs (Marcovaldi & Marcovaldi 1999; Townsend et al. 2005). Intensive beach management is considered a valuable tool in developing countries to reduce both human and natural nests losses (Garcia et al. 2003). However, nest protection and relocation will not be effective in the long-term if the adult mortality is high. Although it can help to extend the life of a population while more effective conservation methods are implemented (Tomillo et al. 2008). Nevertheless, the most effective conservation program will protect all life stages (Congdon et al. 1993; Tomillo et al. 2008). Management plans that cover all range of ages will be more effective than recovery methods focusing on a single age group (Heppell et al. 1996).

My study in the Kikori region is likely representative of harvest regimes in most areas within the species range in PNG, from the Purari River in the east to the Fly River in the west and provides lessons for conservation of many other wildlife species subject to harvest. This type of scenario calls for a holistic approach that integrates all biological, socioeconomic and political disciplines (Campbell 2002; Frazer 1992; Ludwig 1993; Milner-Gulland & Bennett 2003). Without community-led action informed by applied research and environmental education and supported by wildlife protection, the current declines may continue to yield unsatisfactory outcomes from both a fishery and a conservation perspective.

CHAPTER 5

Spatial and Temporal Patterns of Harvest

Locals from Dopima Village (Kerewo Tribe), paddling more than 50 km up river to sell and buy products in the Kikori Market.

> *"There lived a turtle, the turtle was a female turtle and she lived on an island alone. One day she went up the sand to lay her eggs, to her surprise she gave birth to a baby boy. Then she started to look after the baby in the hole that she dug to lay her eggs. She feed the baby with uncooked fish, every day until the baby started to crawl. One day she left the baby and went diving. While she was diving a ghost lady come down and found the baby. But the ghost lady left the baby and went away. The next day the ghost lady thought about the baby and came back to check if the baby was there. The baby was still there. The ghost lady looked around to see if there was any sign of human being, but the only thing she saw was the foot prints of the turtle. So the ghost lady carried the baby and took the baby to her house. The ghost lady fixed a step for the turtle to climb on and come into the house. When the turtle finished diving she came up to check her baby, but her baby was not there. She searched for the baby but she didn't find the baby. Than she saw the foot prints and followed the foot prints until she come to where the ghost lady lived. The turtle lady climbed up the step and went into the house and there she saw her baby lying. The turtle lady was very happy to see her baby. The ghost lady asked her, is this your baby, did you give birth to this baby. The turtle lady nodded her head and the ghost lady said the baby is our baby now we both will look after this baby. The turtle lady agreed with what the ghost lady said and they lived together with the ghost lady."*
>
> (Abaa Gaimui; Wowobo Village; Recorder: Delilah Peter)

CHAPTER 5

Spatial and Temporal Patterns of Harvest

Abstract

Management of wildlife use by communities living a traditional or partially traditional lifestyle is usually more successful in delivering positive outcomes when the interactions between those communities and the environment, both spatially and through time, are well understood. I mapped pig-nosed turtle (*Carettochelys insculpta*) hunting areas for six language-groups in the Kikori region, Papua New Guinea (PNG) and measured the relative numbers of harvested animals. I examined hunting methods, turtle size, sex ratio and the percentage of harvest sold in the market and compared these attributes for different areas (river, delta and coast), periods (1980-82 and 2007-09) and language-groups. Turtle harvest extended from the headwaters to the coast, but no small juveniles (< 15 cm) were found outside the delta. Hand capture of female turtles during nesting was the most common hunting method in the coastal and riverine areas, whereas in the delta, owing to the lack of nesting sandbanks, the most common method of capturing turtles was by fishing line. Hunting methods in the delta and river in 2007-09 were significantly different from those employed in 1980-82. The proportion of captures using fishing line was greater in 2007-09 (10.3%) and use of nets, non-existent in 1980-82, was responsible for 8.9% of the captures in 2007-09. The proportion of *C. insculpta* meat sold at market differed between the two periods of study among language-groups. The impact of the introduction of outboard motors was greatly moderated by the scarcity and cost of fuel. I propose a pig-nosed turtle conservation project that includes long-term beach management protection, release of juveniles captured by net and fishing line in the delta villages and strict but community led control of the harvest of nesting females in coastal and river regions. However, equivalent economic benefits, such as job creation related to the pig-nosed turtle project, needs to be provided to local communities to counterbalance the restriction of this important commodity. This approach would decrease harvest by approximately half and not exacerbate hunting rights of any group

Keywords: Population structure, hunting methods, sex ratio, language groups, fishing technologies, management, conservation.

Introduction

Increase of wild meat consumption in developing countries is of great conservation concern. Modern hunting technologies, loss of traditional hunting controls, increases in human populations, commercialization and greater access to biological resources through road building and forest fragmentation are among the main factors that have contributed to increased wild meat harvest (Bennett & Robinson 2000). A consequence of these diverse impacts is a decline in wildlife. Declines, in turn, affect the livelihood of local people from rural and poor communities, by reducing available animal protein and removing one of their few trade commodities (Milner-Gulland & Bennett 2003; Robinson & Bennett 2000).

In remote areas occupied by indigenous communities living a traditional or partially traditional lifestyle, conservation programs that manage wildlife use, rather than attempt to entirely prohibit it, are usually more successful in delivering positive outcomes (Cinner et al. 2005; Cinner et al. 2006; McClanahan et al. 2002). Such programs involving wildlife-dependent communities rely on sustaining but manipulating the interactions of those communities with the environment both spatially and through time. The social and economic costs and benefits of trade and consumption of wild meat and its associated cultural values may be in a state of flux. Institutional arrangements need to be accommodated in the conservation program (Campbell 2002; Mascia et al. 2003). These social factors can influence whether or not a resource will be exploited. The level of exploitation, in its extreme, may lead to extermination (Nazarea et al. 1998). These factors mean that culturally diverse countries, such as Papua New Guinea, present challenges for those seeking positive outcomes from conservation and sustainable-use programs.

Papua New Guinea (PNG) is unique among tropical centres of biodiversity because 97% of the land is privately owned (Lynch & Marat 1993). Any resource planning and control by the national government is constrained to a great degree and needs to be introduced with sensitivity (Stubbs 1989). The land is held by kinship groups or individuals according to the customary system of each tribe. PNG is one of the most culturally diverse countries in the world, with over 500 different languages (Foley 1986). Despite the added complexity this astonishing cultural diversity brings, PNG is considered one of five countries (along with China, India, Madagascar and South Africa) highly suitable for the implementation of conservation programs when biodiversity, socio-economic and political indicators are considered together (O'Connor et al. 2003).

Conservation of freshwater species is particularly difficult because their habitats are undoubtedly among the most threatened in the world (Saunders et al. 2002). This is particularly true for freshwater species that are subject to harvest, especially for those with life-history attributes that make them susceptible to population decline (Klemens & Thorbjarnarson 1995; Musick 1999; Powles et al. 2000). Among freshwater species, chelonians are of special concern (Congdon et al. 1993; Iverson 1991b). Freshwater turtles have been an important source of protein for indigenous communities for many centuries (Milner-Gulland & Bennett 2003; Smith 1979).

The pig-nosed turtle, *Carettochelys insculpta*, widely distributed in southern PNG, is no exception (Georges et al. 2008a; Georges et al. 2008b). This is a species of great conservation concern because it is the sole survivor of a once widespread family of turtles, it has a very restricted distribution in a global sense and it is subjected to intensely high harvest pressure though much of its range (Groombridge & Wright 1982). Highly prized as food, it is the most exploited turtle in New Guinea (van Dijk 2009). Both turtle and eggs are collected for trade or consumption by villagers (Georges et al. 2008a). During the nesting season, their eggs are harvested with efficiency close to 90% (Pauza 2003; Chapter 4).

Carettochelys insculpta populations have declined substantially in the last thirty years in the Kikori region of the Gulf Province of Papua New Guinea (Chapter 4). This region can be viewed as a microcosm of the complex issues that come into play when trying to achieve conservation objectives. Many tribes coexist in the region and differ in language, use of natural resources and response to cultural changes resulting from recent western influences. Interactions between Kikori indigenous communities and Europeans began in the late nineteenth century (David 2008). The Kikori basin has since become the first major oil development site in PNG. Upcoming developments include the construction of a gas pipeline, the country’s largest industrial enterprise and a new road connecting Kikori to other major towns, for the first time.

Growth in human populations, a greater propensity for villages to become established on riverbanks following the cessation of tribal warfare and the introduction of new technologies, particularly outboard motors, are cited as the main causes for an increase in the harvest pressure on *C. insculpta* (Groombridge & Wright 1982). It can be very difficult to assess specific impacts of environmental and anthropogenic factors on the life history and demography of animal populations and it is even more challenging to characterise the interactions of these two (Wallace & Saba 2009). Formulation of a *C. insculpta* management and conservation plan calls for an understanding of the diverse ways in which humans interact with turtles, especially as these interactions differ across the different ethnic groups that inhabit specific sections of the rivers. It is also important to identify how each human group has responded to western influences and the introduction of new technologies.

In this chapter, I identified pig-nosed turtle hunting areas for each language-group in the Kikori delta and measured their relative numbers of harvested animals. I investigated the correlations among the hunting methods and harvest turtle size and sex ratio with different areas and language-group aggregations. I assessed the effects of new fishing technologies, comparing the proportion of capture methods utilised recently with those common thirty years ago. I evaluated the effect of change from a subsistence economy to a cash economy in different tribes, comparing the percentage of *C. insculpta* sold at market today with the percentage sold thirty years ago. Finally, I identified effective options for a community level response to the pig-nosed turtle decline which takes in account the Kikori cultural diversity, with a view to establish more sustainable harvest practices for this important food species.

Material and Methods

Study Site

The Kikori drainage extends from the alpine grasslands of Doma Peaks of the Southern Highlands Province of PNG to the extensive mangrove wetlands of the Gulf Province (Figure 5.1). The river system is highly confined within its limestone bed and meanders and oxbows are absent. The delta is a large alluvial plain below 40 m elevation, dissected by a tributary system of river channels and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain. The coast **c**omprises the delta islands exposed to the Gulf of Papua (Enesar 2005). Wind and wave action creates coastal beaches, sand bars and sand islands in what is a very dynamic system (Enesar 2005).

The *C. insculpta* nesting season occurs from September to March during the “dry” season (Georges et al. 2008b). A more detailed description of the Kikori region and its tribes are presented in Chapter 2 and 4. There are 51 villages and fishing camps in this area. They are divided into six distinct ethnic groups with different languages and fishing areas (Figure 5.1).

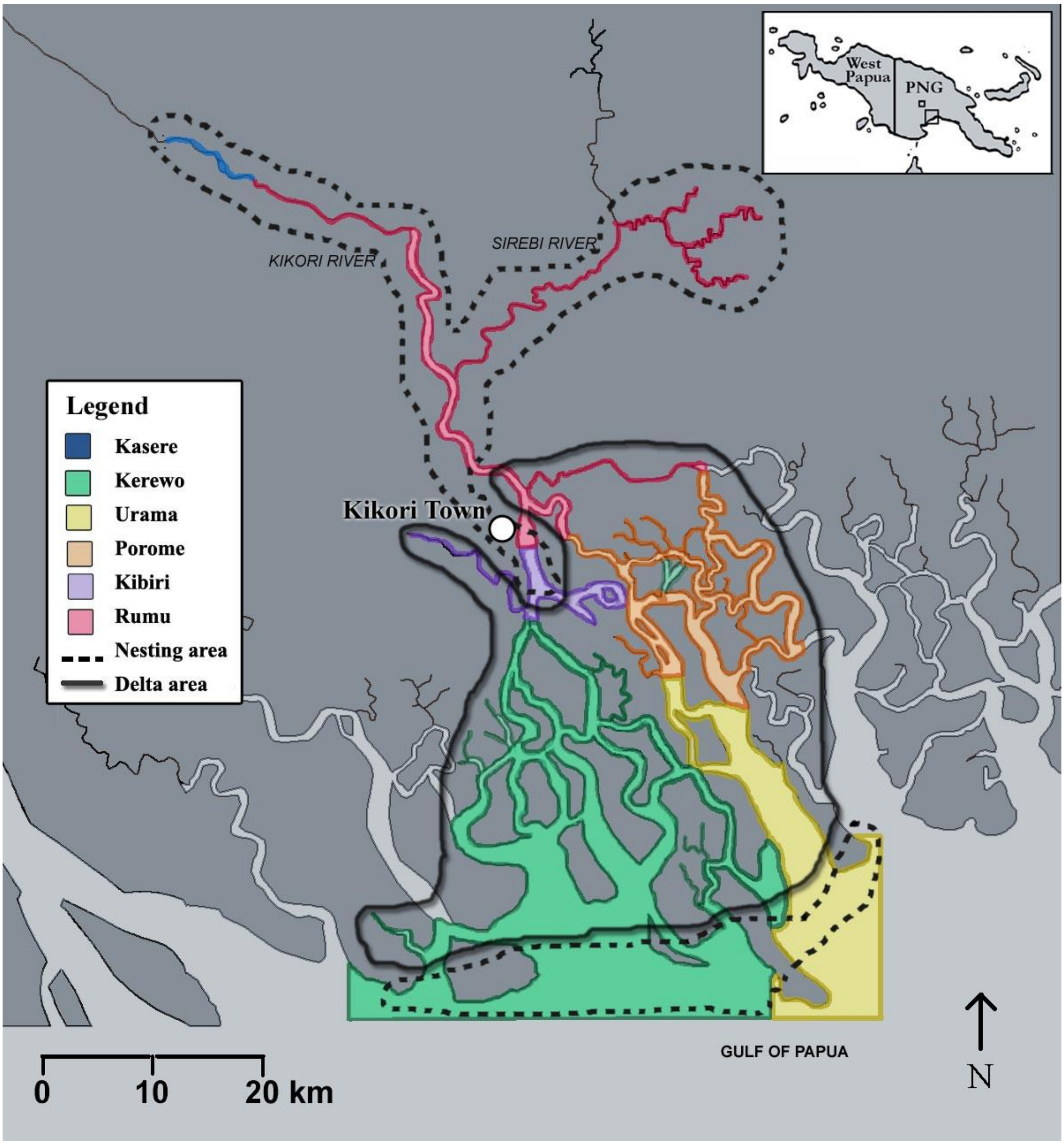


Figure 5.1 Map of the Kikori region showing the fishing area for each tribal group. The regions in which sandbanks are present and *Carettochelys insculpta* females lay their eggs are inside dashed lines); the Kikori delta is shown inside solid lines. Riverine areas include mid-kikori, mid-sirebi and up-river.

Methods

Data on the *C. insculpta* harvest were collected from 37 villages and associated fishing camps across the study site. Each village was visited at least twice in the 2007-08 and 2008-09 nesting seasons. Volunteers were recruited in each village to record information on harvesting and to keep turtle shells after consumption. When shells or live turtles were available, I measured the maximum linear carapace length (MLCL). Linear carapace length was preferred over curved carapace length because linear measurements are more accurate in small turtles. Information was sought on the location of capture, mode of transport used by hunters (canoe, motor boat or walking) and hunting method (fishing line, net, spear or capture of female nesting on the sandbank). Where possible, the sex and maturity status (female, male or juvenile) of the animal were recorded. Hunting method and sex ratio were tabulated by area (river, delta and coast) (Figure 5.1) and compared by nesting season (1980-82 and 2007-09). Only animals captured by fishing line and net were used in the maturity/sex ratio analyses.

I recognised the following language-groups and dialects, confirmed by reference to the Ethnologue (Gordon & Grimes 2005), the Pacific Language Mapping Project (Blundell 2006) and other reports (Wurm & Hattori 1981): Rumu, Kasere (Ikobe), Kerewo (Goarebari), Urama (Kiwai NE) and Porome (which can be subdivided in Kibiri and Porome). The hunting area used by each language-group (Figure 5.1) was determined from the recorded locations of harvest of *C. insculpta*. Rate of turtle consumption was calculated as the number of turtles caught from Sep-2007 to Mar-2009 divided by the number of inhabitants in each language-group surveyed (Census 2000) and expressed as turtles/100 residents. New settlements and the main town of Kikori comprise a mixture of language-groups that primarily speak the common language Motu. Those locations were omitted from the analyses. For the purposes of market analyses, I aggregated language-groups on the basis of their location as follows: Rumu-Kasere (riverine villages), Porome-Kibiri (delta villages) and Kerewo-Urama (delta and coastal villages).

Statistical tests were performed using SAS 9.1 or by hand following the recommendations and procedures of Sokal and Rohlf (1981). Chi-square tests were performed on counts of turtles as the independent entities satisfying the underlying multinomial assumptions. Analyses of Variance (ANOVA) were preceded by an analysis of residuals and the data transformed as appropriate to meet the assumptions of normality and homogeneity of variances. Multiple comparisons following significant results in the ANOVA were undertaken using the Tukey-Kramer procedure.

Results

Kasere (n = 1) and Rumu (n = 8) villages were located on the river, whereas Kibiri (n = 2) and Porome villages (n = 2) were primarily from the delta. Kerewo villages (n = 8) occupy both delta and coastal areas; the single Urama village was on the coast. The number of inhabitants of each language-group was positively correlated with the number of villages, with departures from this trend represented by Porome and Kibiri language-groups with ca 900 inhabitants from only two villages. Rumu and Kerewo language-groups together were responsible for 75.8% of the total *C. insculpta* harvest in the 2007-08 and 2008-09 nesting season. On the other hand, Kibiri and Kerewo language-groups had the highest proportion of turtles consumed per inhabitant (7.53 and 7.88 per annum respectively) (Table 5.1).

The relative importance of hunting method differed across areas (X^2 = 68.17; df = 6; $p < 0.0001$). Capture of nesting female turtles was the most common hunting method in the coastal (62.5% of 56 captures) and riverine areas (64.1% of 39 captures); whereas in the delta, only 3.9% of 51 harvested turtles were captured nesting females. In the delta, the most common method of capturing turtles was by fishing line (74.5%, n = 51) (Figure 5.2). Hunting method did not differ significantly between 1980-82 and 2007-09 on the coast (X^2 = 5.22; df = 3; $p = 0.16$). Hunting methods in the delta and river in 1980-82 were significantly different from those employed in 2007-09 (X^2 = 14.87; df = 3; $p < 0.01$ and X^2 = 13.89; df = 2; $p < 0.01$, respectively). In 1980-82, no pig-nosed turtles were caught using nets, while in 2007-09, 8.9% (n = 146) of the hunted animals were captured using nets. The proportion of turtles captured using fishing lines were 10.3% greater in 2007-09 (n = 146) compared to 1980-82 (n = 117) (Figure 5.2).

The proportion of females, males and juveniles harvested differed among regions (X^2 = 14.41; df = 4; $p < 0.01$). Juveniles were primarily found in the delta, while most of the individuals found on the coast were females (Figure 5.3). A greater frequency of smaller individuals in the delta was reflected in smaller average sizes of turtles from the delta compared to those from the river and coast (ANOVA followed by Tukey-Kramer; F = 26.02; df = 2,141; $p < 0.0001$; Figure 5.4). Indeed, no small juveniles (< 15 cm MLCL) were found outside the delta. The minimum size was 51 cm at the coast and 19 cm in the river.

Table 5.1 Language-group, human population count, number of villages and the number of *Carettochelys insculpta* caught (in parenteses) from Sep-2007 to Mar-2009 per capita (TC/PS). Each language-group represents one ethnic group, except the common language, Motu, which is spoken in the Kikori Town and new settlements. Census data were provided by WWF-PNG (PNG Census 2000).

Language group	**Census**	**Number of villages**				**TC/PS (x 10^2)**
		Coast	**Delta**	**River**	**Total**	**(number of turtles)**
Kasere	100	0	0	1	1	1.00 (1)
Kerewo	1053	4	4	0	8	7.88 (83)
Kibiri	146	0	2	0	2	7.53 (11)
Motu	2734	0	1	3	4	0.18 (5)
Porome	908	0	2	0	2	1.98 (18)
Rumu	997	0	0	8	8	3.91 (39)
Urama	332	1	0	0	1	1.20 (4)
Total	**6270**	**5**	**9**	**12**	**26**	**161**

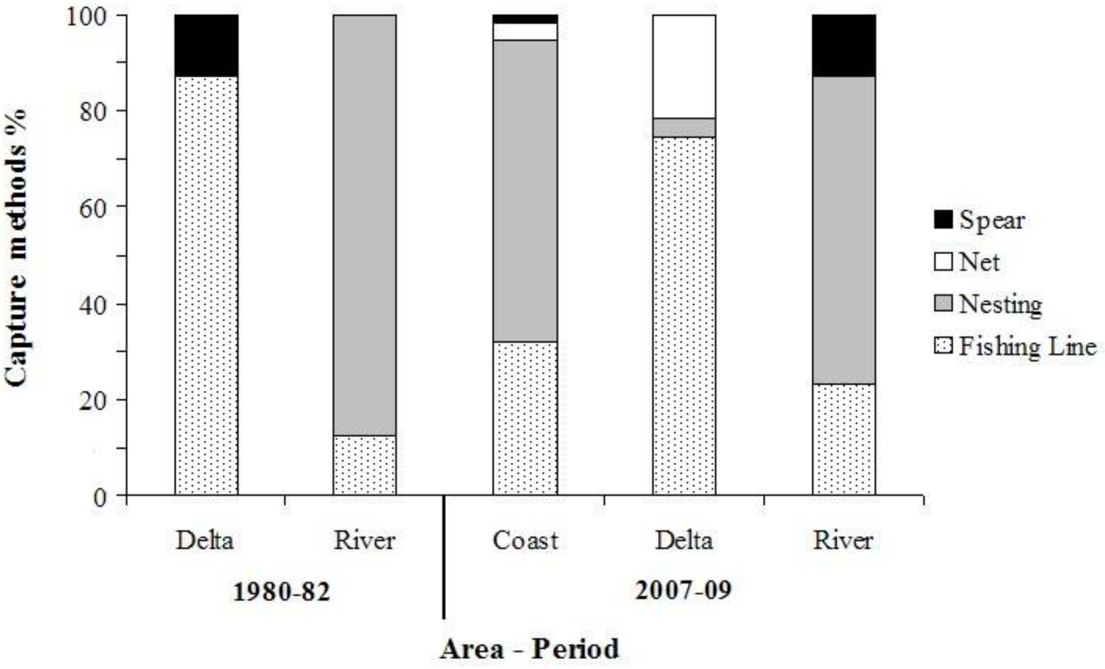


Figure 5.2 Comparison of methods of hunting *Carettochelys insculpta* across areas in the Kikori region during the 2007-09 nesting seasons (X^2 = 68.17; df = 6; $p < 0.0001$) and between 1980-82 and 2007-09 in the delta (X^2 = 14.87; df = 3; $p < 0.01$) and river (X^2 = 13.89; df = 3; $p < 0.01$).

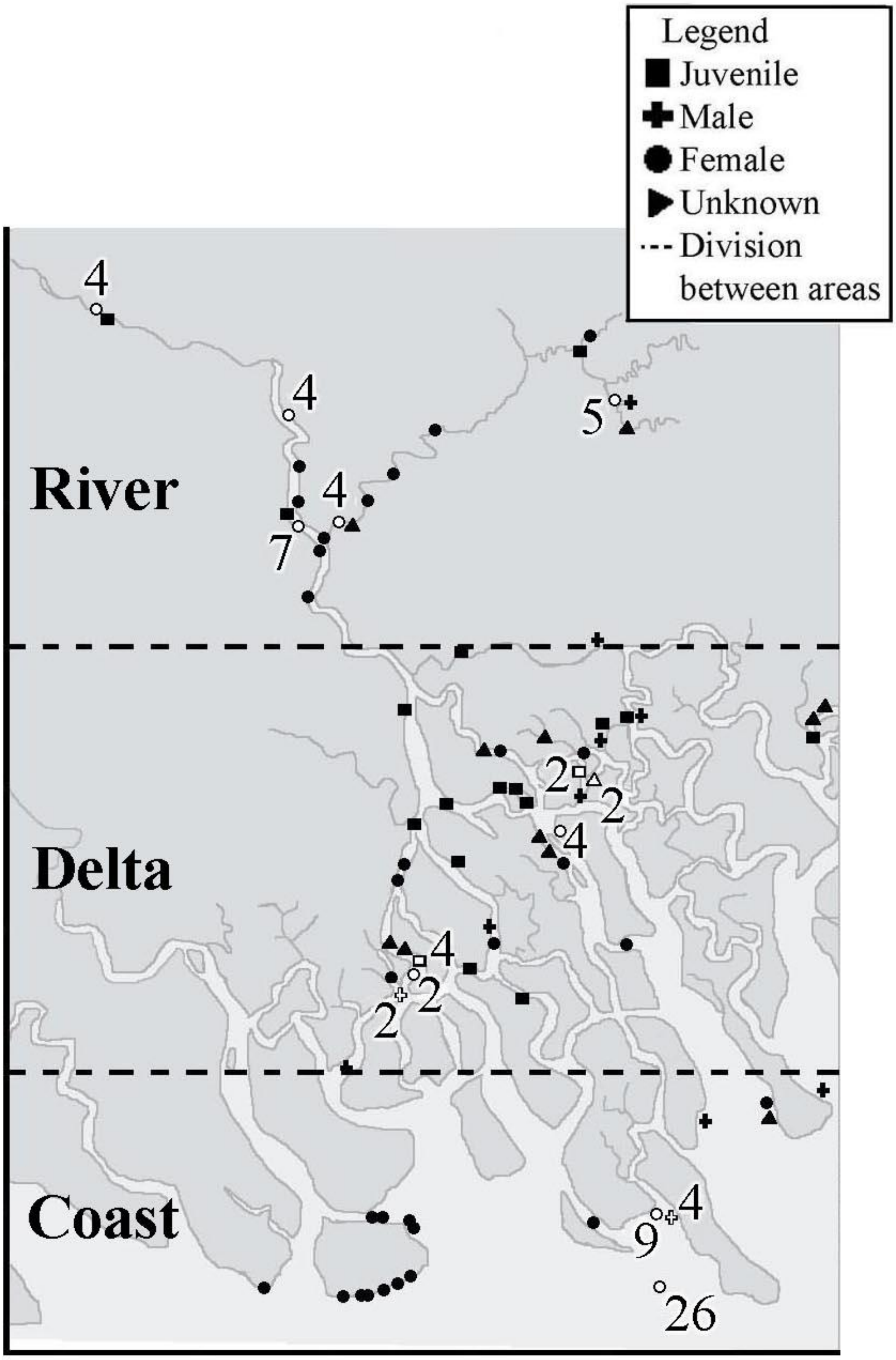


Figure 5.3 Locations of capture for females, males and juveniles of *Carettochelys insculpta* harvested in the Kikori region during the 2007-08 and 2008-09 nesting seasons (n = 129). The proportion of females, males and juveniles captures differ significantly among areas (X = 14.41; df = 4; $p < 0.01$). Areas where more than one female/male/juvenile were captured are presented in white with the absolute number adjacent.

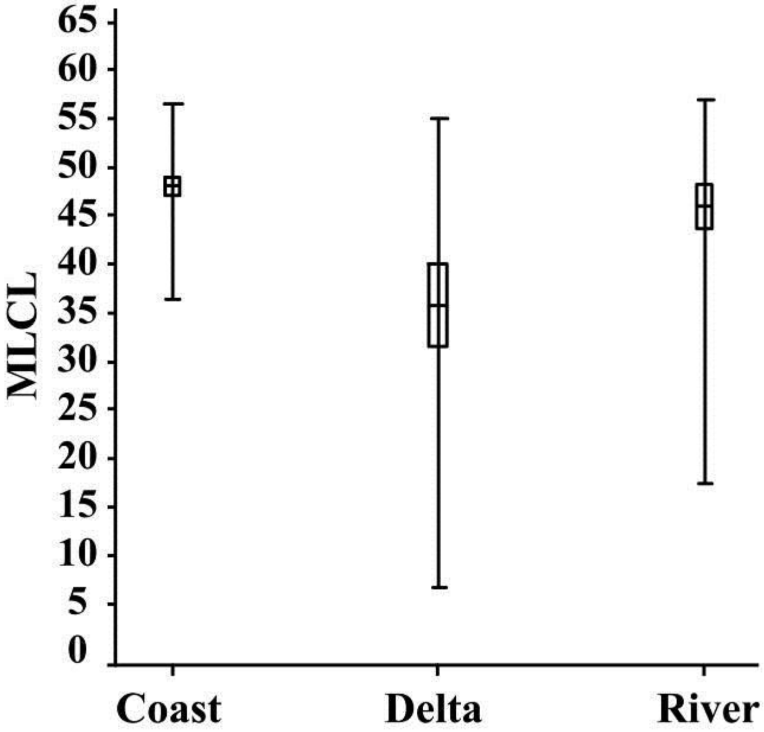


Figure 5.4 Variation in body size of *Carettochelys insculpta* across regions of the Kikori area. MLCL, total linear carapace length. Means are given with 95% confidence limits (boxes) and ranges (vertical bars). Turtles from the delta were significantly smaller than those from the river and coast (F = 26.02; df = 2,141; $p < 0.0001$).

In the delta, the sex ratio of 33.3% males (n = 9) recorded in 1980-82 was not significantly different from the 37.5% (n = 8) recorded in 2007-09 ($X^2 = 0.12$; df = 1; p = 0.73). Likewise, the sex ratio in the river of 40.0% males (n = 20) in 1981-82 was not significantly different from 11.1% (n = 9) in 2007-09 ($X^2 = 1.64$; df = 1; p = 20), although sample sizes were small.

The numbers of *C insculpta* sold at market differed between the two periods of study and among language-group aggregations ($X^2 = 24.69$; df = 2; $p < 0.00001$; Figure 5.5). The proportion of *C. insculpta* sold by Kerewo-Urama in 2007-09 (n = 82) was 39.7% less than in 1980-82 (n = 32). On the other hand, Rumu-Kasere sold 36.3% (n = 80) of their catch in 1980-82, but this increased to 40.0% (n = 35) in 2007-09. The Porome-Kibiri sold none of their catch (n = 5) in 1980-82, but sold 5.9% (n = 17) in 2007-09. There was no difference in the proportion of language-group aggregations responsible for selling *C. insculpta* in the market in the two periods ($X^2 = 2.13$; df = 2; p = 0.35). In both 1980-82 (n = 46) and 2007-09 (n = 26) Rumus sold the greatest proportion of *C. insculpta* at market (63.04% and 53.85% respectively), followed by Kerewos (37.0% and 42.3% respectively), with the Poromes responsible for only 3.9% of the market in 2007-09. There were no data available for means of transport used by hunters while capturing *C. insculpta* in 1980-82. In 2007-09, 10.7% (n = 9) of the *C. insculpta* were captured by hunters using a boat with a motor up to 50 hp, 79.8% (n = 67) by hunters paddling a canoe and 9.5% (n = 8) by walking.

Discussion

The interactions between humans and turtles differ across the different ethnic groups that inhabit specific sections of the rivers. I found major differences in the use and methods of capture of *C. insculpta* among language-groups of the Kikori region, which was correlated with the area these groups occupy. Capture of nesting females from sandbanks is considered by the local people to be the easiest way to harvest turtles. However this is not the main harvest method employed in the delta, owing to the lack of nesting sandbanks in this area. The area frequented by a specific group, while villagers undertake subsistence activities, dictates the main harvest method. Rumu and Kasere tribes live and hunt primarily on the riverine areas and rely mainly on the capture of nesting females. Delta groups, Porome and Kibiri, have no sandbanks with nesting females or eggs within their hunting and activity range and depend more on fishing lines and nets to capture turtles.

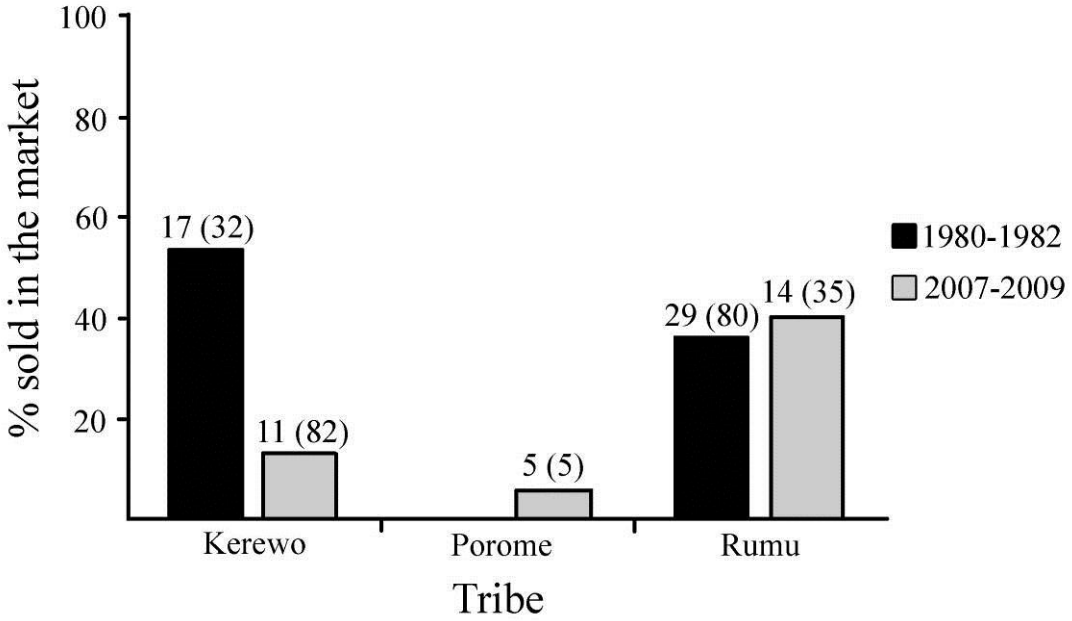


Figure 5.5 Percentage of *Carettochelys insculpta* sold in the Kikori and Sirebi markets of the Kikori lowlands in the nesting seasons of 1980-81, 1981-82, 2007-08 and 2008-09. The difference in the trade between 1980-82 and 2007-09 was significant ($X^2 = 24.69$; df = 2; $p < 0.00001$). Number above the bars are number *C. insculpta* sold and total season catch (in parentheses).

Urama and Kerewo villages are distributed in both delta and coastal areas and together are responsible for 54% of *C. insculpta* harvest. Their presence in both locations make them skilled in all hunting methods. I did not find evidence of the basket traps in Kikori, a technique used to capture pig-nosed turtles in other regions of New Guinea (Schultze-Westrum 1963).

Locals from both Kikori and Purari Rivers claim that, although *C. insculpta* adults occur from the coast to up to 100 km upstream, juveniles congregate mainly in the lower delta (Georges et al. 2008b). Until this study, no data have been available to support these anecdotal reports. In this study, delta villages were responsible for most of the juvenile captures. All villages used net and fishing line, the main methods of capture of *C. insculpta* juveniles, in their daily fishing activities. If juveniles were present in the riverine or at the coastal areas, I would expect fishermen in these areas to capture juveniles occasionally. My data show that small juveniles are found exclusively in the delta. The presence of juveniles predominantly in the delta strongly suggests that hatchlings migrate from nesting sites in the river and at coast to the delta. This presents them with a formidable challenge, particularly those emerging from nests on the coast.

Typically, small immature freshwater turtles do not migrate long distances, probably owing to the high risk of predation and lack of energy reserves (Bodie & Semlitsch 2000; Butler & Graham 1995; Moll & Legler 1971). On the other hand, there are substantial evolutionary incentives for hatchlings and juveniles to grow rapidly since mortality is higher for individuals of smaller size (Iverson 1991b). For this reason, migration to an area with more food resources, promoting faster growth, would be highly advantageous (Bodie & Semlitsch 2000). Mangrove plants, such as *Sonneratia ssp* and *Nypa fructicans*, are found mostly in the delta and compose the main part of the *C. insculpta* diet in the Kikori region (Georges et al. 2008b). The reduced water clarity of the lower delta, compared with coastal regions and upstream areas, may also be an important factor for hatchlings since it is likely to decrease the predator risk (Georges et al. 2008b). Few species of freshwater turtles are able to nest on the coast (Dunson & Moll 1980; Dunson & Seidel 1986; Moll 1994) and usually their hatchlings can tolerate short-term exposure to high salinities (Davenport & Wong 1986). However, small animals will face osmoregulatory problems if they experience long-term exposure to sea water (Dunson & Seidel 1986). Consequently, migration to the delta by hatchlings emerging on coastal beaches is probably mandatory for survival. How they navigate is an area that warrants further examination.

In PNG, modern technologies have improved access to areas distant from the villages. A most notable change in Kikori was the introduction and increase of western fishing technology in the form of nets and fishing lines. In the PNG Western Province and Australia's Northern Territory traditional methods of *C. insculpta* capture have also shifted to include modern fishing technologies (Cann 1972; Georges 1987; Georges et al. 2006). The introduction of outboard motors and modern fishing gear has previously been associated with increased rates of *C. insculpta* capture in the Kikori (Georges et al. 2006; Georges et al. 2008b; Rose et al. 1982). However, in this study I observed that 90% of the harvest happened without the help of outboard motors. It seems that hunting in distant areas is still greatly moderated by the scarcity and cost of fuel and the lack of fundamental infrastructure to facilitate travel and transport of goods. Despite this, it is likely that new fishing technology has an important impact on pig-nosed turtle capture rates. The use of fishing lines and nets are probably leading to an increase in the harvest of juvenile and male pig-nosed turtles that would be rarely harvested using traditional methods.

However, 43% of harvested turtles in 2007-09 were nesting females. The preferential harvest of a particular age group and sex has its own consequences. Selective harvest can alter different aspects of the population, including genetics, behaviour, life history and demography over a short ecological time scale (Close & Seigel 1997; Fordham et al. 2007; Gamble & Simons 2004; Wallace & Saba 2009). The observed sex ratios in populations of different species of *Podocnemis* in the Amazon, which were skewed towards males, are usually attributed to preferential harvest of nesting females (Fachín-Terán et al. 2003; Fachín-Terán & Vogt 2004; Ramo 1982). Although I have recorded significant reduction in the body size of female *C. insculpta* in the last 30 years (Chapter 4), I have found no evidence of significant change in the sex ratio. Likewise, Gamble and Simons (2004) did not find significant differences in the proportions of *Chrysemys picta* males, females and juveniles among lakes with different harvest status. However, higher female mortality has been show to lead to a male-biased sex ratio in older age classes of a *Gopherus berlandieri* population (Hellgren et al. 2000). On the other hand, other variables, such as incubation temperature (for species with temperature-dependent sex determination), mortality rates and age of maturity, could also affect the freshwater turtle population sex ratio (Godfrey et al. 1997; Lovich & Gibbons 1990;

Vogt & Flores-Villela 1992) and potentially mask the effects preferential harvest of adult female.

Growth in human populations is another factor that increases pressure on harvested wildlife populations which can be expected to shift the balance between village consumption and sales (Milner-Gulland & Bennett 2003). However, each language-group aggregation has responded differently to population size change. Language-groups close to Kikori town and markets have significantly increased the proportion of *C. insculpta* sold at the market relative to that consumed in the village while the Kerewo/Urama, the most isolated aggregation, have in contrast sold a reduced proportion of their catch. Their isolated location makes access to jobs created in the town more complicated and consequently they have less access to cash, motors, fuel and fishing technologies.

A similar trend was observed in the temporal changes of hunting methods in coastal areas, which are more isolated from the market than delta and river areas. In these areas, no significantly different changes in harvest methods were recorded from 1980-82 to 2007-09. Aswani (2002) compared two villages representing different sea tenure arrangements within the Roviana Lagoon, Solomon Islands and observed distinct responses in the way communities managed environmental changes resulting from growth in population. Sea-tenure is a situation in which a group of inhabitants have the right to use and access resources of areas near the coast. Access to the resource may be prohibited for nonmembers and resource-use limitations on participants are possibly enforced. These rights vary among systems and can change over time. (McCay & Acheson 1987). Sea-tenure regimes were more vulnerable in socioculturally heterogeneous communities because these communities were less efficient at reducing transaction costs, such as those arising from negotiation, monitoring and enforcement. Likewise, it is very important to recognise the different responses to the introduction of new technology and population grow among groups if a conservation program is implemented in the Kikori. Similar management tactics in villages with different harvest approaches may lead to very different outcomes.

Increased harvest is a likely cause of the demonstrated decline in the abundance of *C. insculpta* in the Kikori region in the last 30 years (Chapter 4). The optimal scenario, in which pig-nosed turtle harvest is completely forbidden, is highly unlikely to be achieved. When total prohibition of hunting is not viable, different management scenarios need to be considered. It is necessary to take into account local perspectives in order to understand what is realistically achievable (Campbell 2002; Mascia et al. 2003). The economic advantages, stemming from the creation of jobs and the legal sale of Olive Ridley (*Lepidochelys olivacea*) eggs, in Ostional, Costa Rica, have resulted in a long-term sustainable conservation program for this species (Campbell 1998). If *C. insculpta* eggs became a valuable commodity and the need to protect sandbank and no-take areas leads to the creation of job opportunities, the safety of females could become a community priority and conservation programs may be seen as an investment. A similar approach could protect juveniles in delta communities. Here the employment of a minimum size for capture could be applied, as it is commonly used in fisheries (Boxrucker 2002; Colvin 1991; Ricker 1945). Juveniles do not provide a substantial amount of meat and the same animal could instead be captured in the future when it represents a more substantial meal. Such actions could also been seen locally as an investment in the future. However, studies on recruitment, growth, mortality and structure of the pig-nosed population in Kikori are needed before an optimum minimum harvestable size is established (Brousseau & Armstrong 1987).

Conservation can only be achieved if an acceptable source of protein is provided to substitute the pig-nosed turtle meat and eggs. Historically, indigenous wild animal species were replaced by exotic domestic livestock. Oppositely, more recent initiatives had demonstrated that the use of an appropriate combination of domestic and wild animals, with different feeding requirements, might be more beneficial both ecologically and economically (Child 1991). However, many nutritional and social problems can rise in an indigenous group during the shift from consumption of local animals and plants to alternative sources of food (Kuhnlein & Receveur 1996). As they start to rely more on limited kinds of market food, there is usually a decrease of food diversity (Barrett 1995; Pelto & Vargas 1992).

For example, among the !Kung San, Kalahari Bushmen, there was an increase in anemia rates during the transition from the balanced diet obtained by hunting and gathering in the late sixties to a settlement life in the early eighties, when food started to be purchased from local stores or provided by government agencies (Fernandes-Costa et al. 1984). A shift away from traditional food in the Artic Dene/Metis communities, Canada, also brought negative health consequences, since their market food was characterized mostly by carbohydrate (particularly sucrose), fat and saturated fat (Receveur et al. 1997). The increasing use of imported food (e.g. tin fish and meat, rice) was already observed in in many areas of PNG (Aswani 2002). In these areas it was detected a general improvement in nutritional status and a positive effect in children growth and mortality, although there was a great variation among areas (Heywood 1983).

Many hunting and ranching crocodilians programs are good examples of how conservation of a long lived species of reptile could be effectively obtained through sustainable-use (Thorbjarnarson 1999). The recovery of populations from overhunting and the success of programs in United States, Zimbabwe and Papua New Guinea in the mid-sixties and early seventies demonstrated that crocodilians could be managed on a sustainable basis (Child 1987; Joanen et al. 1997; Hollands 1987). These previous experiences showed that, simultaneously with leather production, other options should be consider, such as ecotourism and meat production for the local market, since they buffer the program against the vagaries of the cyclical exotic reptile leather market (Thorbjarnarson 1999). Nowadays, decisions about the use and management of crocodiles' wild populations take into consideration studies about their biology and population monitoring is generally given a high priority (Ross 1997).

Monitoring was also very important to access the sustainability of traditional dugong harvest in Torres Strait and Cape York Australia. Similar to turtles, Dugongs have slow development and populations do not sustain a high number of adults harvest (Johannes & MacFarlane 1991; Marsh et al. 1997). However, its harvest is also culturally important to indigenous populations, who hunt them for meat and oil (Johannes & MacFarlane, 1991). Analogously to the Kikori region, there is a potential for a conflict between indigenous people concerned with their future access to an important component of their culture and conservationists concerned with a potential over-exploitation and consequent local extinction (Marsh et al. 2004). Recent studies indicated that it is likely that the present indigenous dugong harvest is an order of magnitude too high to be sustainable and urgeded for a reduction of harvesting to a maximum of 100 dugongs per annum (Heinsohn et al. 2004; Marsh et al. 2004). Under this scenario, the traditional culture of Torres Straits Islanders' relies on the reduction of dugong hunting since their culture cannot be preserved if dugongs become locally extinct (Marsh et al. 2004).

In the Kikori region, harvest of long lived animals, such as marine turtles, dugongs and crocodiles, are incidental to other hunting activities and do not face the same high harvest pressure as the pig-nosed turtle. I did not find crocodile farming enterprises in Kikori, although in the early eighties, crocodile farming was considered a promising activity in Gulf Province due to its high success rate in areas where the tidal water could bring naturally invertebrate food to the crocodiles (Bolton & Laufa 1982).

In order to operate in the middle of the conservation spectrum, where harvest may still be sustainably practised, each group in the Kikori region will need to give up at least part of their current pig-nosed turtle harvest. I propose a scenario, in which jobs created for the protection of the pig-nosed turtle will help to persuade the community to manage the pig-nosed turtle. Nevertheless, all six language-groups in the Kikori region have to benefit from this conservation project. If any one group is not included in this project it could lead to resentment and resurgence of old land disputes within the region (Warner 2000). It is also necessary to consider the specific hunting characteristics of each group. Riverine and coastal villages would have to stop harvest of nesting females but would benefit from sandbank protection. Meanwhile, delta villages would not be able to harvest juveniles but would benefit from jobs related to no-take areas. In non-take areas animals can increase in abundance, live longer and produce more offspring (Gell & Roberts 2003). This approach, in which females and juveniles are protected, covers 56% of all *C. insculpta* harvest events recorded during this research. The pig-nosed turtle harvest would likely be reduced by around 50%, without completely preventing any group from hunting.

CHAPTER 6

Synopsis

Illustration by Lorence Kimiri Ivae

Winner of the 2008 “Piku drawing competition” in the Kopi primary School

“Before all, the turtle used to talk to each other. They used to come out of the water and crawled up on the ground to look for foods in the bush. All the time they used to crawl up on the ground to look for food in the bushes. All the time they used to make like that: Came! Came! Old people died, turtle went in to the water and now it stays there forever and forever.“

(Taurari Aburo; Waira Village; Recorder: Elma John)

CHAPTER 6

Synopsis

This thesis (a) provides fundamental information on nesting ecology of *C. insculpta* in the Kikori region of Papua New Guinea and helps to better understand the evolution of its life history traits. It also (b) grapples with the complex issues of establishing decline of a species in the context of human harvest and changing patterns in a subsistence economy, (c) establishes that the populations have indeed declined as suspected in anecdotal reports (Georges et al. 2008a; Georges et al. 2008b; Groombridge & Wright 1982; Pauza 2003), (d) characterizes *C. insculpta* harvest patterns and trends, (e) suggests future research activities and (f) identifies possible conservation and management initiatives to ensure the persistence of substantial populations of *C. insculpta* in the Kikori region.

Nesting ecology and ecological responses to environmental conditions

In comparing my data with those from the wet-dry tropics of northern Australia and the wet tropics of southern New Guinea in the context of climatic differences I attempt to explain the differences in nesting patterns in *C. insculpta*, differences in body size and differences in other life history attributes between Australia and New Guinea. I believe my work has provided the greatest insights in three areas in particular, as elaborated in Chapters 2 and 3.

The first is in explaining the differences in spatial and temporal nesting patterns between New Guinea and Australia. In both regions, nesting coincides with the driest months of the year. The dry season differ between regions and the nesting phenology differs accordingly. However, in New Guinea, the rainfall in the driest months is still sufficient to reduce salinities in coastal areas to 10.1 psu, opening the possibility of nesting in both coastal and upstream reaches of the Kikori region. This option is not available in the wet-dry tropics of Australia and they do not nest on the coast there. In Chapter 2 I have argued that this has had consequences for life history parameters, particularly body size and attendant attributes of egg size and clutch sizes. In Chapter 2, I also took a broader taxonomic view to demonstrate a correlation between body size and propensity to enter estuarine or coastal areas, which reinforced my interpretations.

The discovery that *C. insculpta* in Australia lays two clutches per year every second year (Doody et al. 2003a) has been a perplexing problem, as discussed in more detail in Chapter 2.

Such life history attributes are traditionally explained by high establishment costs for reproduction. Species that migrate long distances to nesting grounds may be adapted to do this every other year, or at greater intervals (e.g. marine turtles) (Brotherick et al. 2003), but skipping a year only to nest twice in the non-migratory Australian *C. insculpta* is enigmatic. I provide an explanation. In New Guinea, *C. insculpta* does incur a substantial cost in initiating reproduction – populations reside principally in the delta regions and must migrate substantial distances upstream or to the coast in order to nest. The costs of this are exacerbated by difficulties in locating suitable nesting areas in the context of a continually reshaped riverine and coastal landscape and by the costs of exposure to saline environments.

In New Guinea, nesting twice every second year is a plausible evolutionary response to these constraints. In Chapter 2, I have argued that in Australia, this trait may have been maintained, but not evolved, in response to resource limitations. This is a subtle but important distinction between the explanations provided by Doody et al. (2003a). In New Guinea, the trade-offs between nesting upstream and on the coast have been explored in Chapter 3. In this chapter, I have proposed that coastal nesting is probably a response to highly stochastic environments and opportunity (reduced salinity in the coast). Coastal nesting areas complement the highly unpredictable riverine areas. The use of both areas for nesting provides less variable environments, predator free areas and doubles the nesting season period. The questions arising from this dichotomy have yet to be fully resolved, because I was unable to determine whether the turtles were nesting first on the coast, then migrating upstream, or if particular turtles were "specializing" on one or the other regions, either in any one year or as a life trait. This is an important area for future investigation.

A third area where I believe my study makes a contribution to our understanding of the evolution of the life history attributes of *C. insculpta* is in embryonic diapause. Fully developed embryos of *C. insculpta* delay hatching until anoxic conditions prevail, either when the nest soil is saturated by torrential rain or when nests are flooded (Georges 1992; Webb et al. 1986). Anoxia caused by rain events and river level rise presumably signals the beginning of the wet season and facilitates turtle hatchling emergence and dispersal in the Daly River (Doody et al. 2001). In Chapter 2, I have argued that in the Kikori riverine areas, where rain and flooding are unpredictable even in the dryer months of the breeding season, embryonic diapauses terminated by heavy rainfall or flooding is not likely to afford great advantage. In contrast, on the Kikori coast, nests are laid high on the beaches and emergence following inundation by the highest tides would afford considerable advantage. Beach migration may be a major source of hatchling turtle mortality due to predation and high sand temperatures on the surface (Mrosovsky 1968; Witherington et al. 1990).

It may again be a case of a trait evolving in one ecological context (coastal beaches) and being maintained because of different advantage from those that drove its evolution in other parts of its range (wet-dry tropics of Australia). Of course the reverse could be true, but my study provides an example of the caution required when placing evolutionary interpretations on life history traits whose manifestation is studied only within a restricted portion of a species range.

These three outcomes of my study provide insights on the evolution of life history traits of a single species across disparate parts of its range. It also shows the limitations of matching current traits with current environmental conditions, or interpreting adaptive advantage from a small fraction of the distribution of a species. Under this scenario, it is important to recognise these limitations while the data are interpreted and selective advantage is inferred. On perhaps an even more sobering note, phenotypic plasticity can mask the full repertoire of life history responses of a species to environmental conditions beyond even those that manifest over all parts of a species range at a particular point in time. I believe that I have exercised sufficient caution in my interpretations of life history parameters reflecting the spatial and temporal scope of my studies.

Establishing Decline

In chapter 4, I provide, for the first time, concrete evidence that the *C. insculpta* population in the Kikori River has declined substantially in the last 30 years. One line of evidence was a decline in market sales of turtle eggs and meat. To use these data as evidence of decline, I needed to eliminate alternative plausible explanations for the reduction in market sales, among them the possibility of a shift in the balance between home consumption and local trade. I did this through matched village surveys between the 1980s and the present.

A second confounding factor was a shift in the local economy from subsistence to a cash economy brought about by oil and other industries that now provide employment opportunities for the locals. This may have reduced interest in the turtles as a resource and driven decline in both market and village estimates. I eliminated this possibility by demonstrating that the intensity of harvest remains extraordinarily high and that there is no evidence yet of changed intensity as a result of a shift in the character of the local economy.

Evidence of decline was also evident in a reduction in the size of turtles caught in the 1980’s compared to the present. When a population comes under harvest pressure, one of the first indicators of stress is the reduction in body size (Bhupathy & Saravanan 2006; Daza & Páez 2007; Múnera et al. 2004). This is because the larger individuals are more likely to be targeted and because of reduction in life expectancy, which in a species with indeterminate growth translates to a lower average body size in the population. As such, I believe that I have both provided robust evidence of decline (approximately 57.2% over 30 years) and demonstrated through this case study the complexities of demonstrating decline in a species that is driven in large part by harvest by indigenous communities.

Internationally, *C. insculpta* is listed in the IUCN Red List as Vulnerable (IUCN 2009) because of suspected dramatic declines over most of its range. My results give substance to those concerns and should result in a re-evaluation of the status of the species in New Guinea and globally from Vulnerable to Endangered. In addition, the decline in wildlife meat affects the livelihood of local people from rural and poor communities as a reduction in available animal product has both negative affects on the health and financial stability of people who depend on it for consumption and trade (Milner-Gulland & Bennett 2003; Robinson & Bennett 2002).

The global and local perspectives of the pig-nosed turtle are dramatically different. From the point of view of the local community, the pig-nosed turtle remains as an important and traditional source of food, particularly protein. From one side, local villages consider it a fishery to be managed sustainably. From the other side, the global community will see the pig-nosed turtle as an important relict species to be preserved. Both perspectives are similar in their common desire to see populations of the species persist into perpetuity. However, they differ in their response to declines in abundance and in the perception of what level of population decline is acceptable. This diversity in perspective is an important consideration while creating conservation plans for the pig-nosed turtle in PNG. I discuss the possibilities of community-led actions towards the pig-nosed turtle conservation in further details in the last section of the synopsis.

Harvest Patterns and Trends

Carettochleys insculpta have been traditionally harvested in the Kikori River for thousands of years. Highly prized as food, it is the most exploited turtle in New Guinea (van Dijk 2009). Both turtle and eggs are collected for trade or consumption by local villagers (Georges et al. 2008a). Overexploitation of wildlife is often a consequence of the introduction of modern hunting technologies, removal of the natural limits to consumption associated with traditional hunting techniques, increase in human populations, commercialization and greater access to biological resources (Bennett & Robinson 2000). The impact of a cash economy is a double-edged sword. One cannot assume that economic development will reduce demand for wild meat, indeed the opposite could easily happen in the short-term (Milner-Gulland & Bennett 2003).

My results in Chapter 5 demonstrate a visible temporal change in Kikori *C. insculpta* harvest methods with the introduction and increase of western fishing technology, in the form of nets and fishing lines. Yet, I observed that the vast majority of the harvest happened without the help of outboard motors. It seems that hunting in distant areas is still greatly moderated by the scarcity and cost of fuel and the lack of fundamental infrastructure to facilitate travel and transport of goods. This lack of availability of fuel and access to transport networks and infrastructure represents a latent threat to *C. insculpta* in the Kikori. In a sense, the impact of changes to Kikori communities through introduction of modern technologies is dampened by the limitations the community faces in putting those technologies to effective use.

Outboard motors have been purchased and are in use, but their deployment in activities likely to increase harvest of eggs and adults of *C. insculpta* is limited by fuel costs. This may rapidly change as affluence in a cash sense replaces affluence in a subsistence sense as the oil and gas and forestry industries expand. Networks for the regional and international trade in *C. insculpta* exist in Papua New Guinea (Georges et al., 2008b), but the Kikori community does not have access to these networks because of poor transport infrastructure. There is no road access to the Kikori lowlands. This too will soon change and bring an influx of people with new and relatively more cosmopolitan perspectives to trade and knowledge and access to trade networks. Again, rapid change in opportunity and practice may follow quickly on the heals of road access, with unpredictable consequences for *C. insculpta*. I have already demonstrated decline in this species over the last 30 years. I consider a monitoring on future developments and future trends in population numbers of *C. insculpta* to be a critical element in its future management.

Environmental education activities

Scientists working in traditional communities should make substantial effort to return the data to the communities of origin and provide capacity-building to help them manage their own information (Mauro & Hardison 2000). Decisions towards pig-nosed turtle conservation will be largely a matter for Kikori communities. Papua New Guinea (PNG) is unique among tropical centres of biodiversity because 97% of the land is privately owned (Lynch & Marat 1993). The land is held by kinship groups or individuals according to the customary system of each tribe (Foley 1986). Any resource planning and control will be mainly dependent on community participation. Locals from Kikori region need to decide how important the pig-nosed turtle is to them, how crucial is its maintenance for future generations and whether they wish to respond to the concerns of the global community. These decisions need to be made on an informed basis.

I have attempted to meet this challenge not only by gathering strategic scientific data, but also by developing specific environmental education tools that help to transmit this information to the Kikori people. I developed activities to bring awareness of the pig-nosed turtle decline and conservation from the beginning of the project in Aug-2007 until its end in Oct-2009. Together with the local schools I developed an interactive book called “The Adventures of Piggy on the Kikori River”. Five thousand copies of this book were distributed to all schools and villages of the region. The book tells the story of Piggy, a pig-nosed turtle and included information and games about its life history and conservation (Appendix I).

Another successful project was developed in a partnership with the local radio station Kikori CDI-FM (Community Development Initiative). A radio program, called “Piku-on-radio” was developed to bring awareness about conservation issues in the Kikori region. This program consisted of radio plays, where students would narrate the voices of animals being interviewed about the problems they faced in the Kikori region such as harvest and pollution (Appendix II). The balance between the time spent on educational and research activities was highly positive. Educational projects helped to not only bring awareness about the pig-nosed turtle decline, but also increased local collaboration (i.e. increase on the quality of the data collected, decreased the number of devices stolen).

Future conservation and research activities

The ultimate best scenario for the species, where *C. insculpta* harvest is completely banished, is highly unlikely. The moderate extent of the conservation spectrum, where harvest is still sustainably practiced, will be only possible if each group in the Kikori region reduces at least part of their current *C. insculpta* harvest. Under this scenario, it is extremely important to engage the six language groups of Kikori equally and recognize their specific cultural differences. I propose to establish a protected nesting beach zone in the Kikori riverine and coastal areas and non-take zones in delta areas. This project would draw upon community members and committed land owners, to alleviate pressure on the pig-nosed turtle population, especially nesting females and their nests in critical breeding areas. In so doing, it will provide new employment opportunities for local people and build capacity for the local community to take control over the sustainability of their natural resources. This will yield a sustained program to redress the decline in the species. It will also instigate a long-term monitoring program of eggs and meat through the Kikori markets and villages.

Monitoring is an essential component of determining future trends in the species and to assess the efficacy of any remedial conservation measures (Low et al. 2009; Marcovaldi & Marcovaldi 1999; Townsend et al. 2005). The value of monitoring cannot be overestimated and it would be an opportunity to engage the community and local schools in a long term program to monitor egg consumption in the villages and markets surveyed also in 1980-81 and 2007-09. Constant environmental education activities should be maintained through the local radio station and schools. These activities will inform the communities about conservation issues related to the area and the progress of the project activities.

Carettochelys insculpta population dynamics are still poorly understood in the Kikori region. This impedes the ability to predict the efficacy of management efforts and the design of new management interventions. Until an appropriate conservation program is implemented in this area, successful mark/recapture studies are highly unlikely. Once a turtle is captured, locals are reluctant to release the animal as it is a waste of protein. These dichotomous needs could create conflicts between researchers and local landowners. Genetic and satellite/radio tracking studies have better chances to succeed and can improve the understanding of the population dynamics and nesting patterns in the Kikori region. Genetic studies can also confirm if *C. insculpta* in this region is in fact a single population, which is essential for an effective management plan. Ethnobiological, socioeconomic and political studies are also needed to better understand pig-nosed turtle exploitation and its role in the traditional communities of the Kikori region.

A robust management plan will only be possible when the major social and environmental aspects influencing the pig-nosed turtle population are identified. Both “umbrella” and “flagship” species were useful tools in the past to raise concern about conservation. They result in a global network of conservation projects with profound implications in community empowerment, international relations and governance (Frazier 2005). A rapid increase in the Kikori pig-nosed turtle population is not realistic and conservation actions must be vigorously upheld and remain in place for several decades to achieve significant signs of recovery (Musick 1999). Long-term conservation projects are absent in the Kikori region. The use of the pig-nosed turtle as a “flagship” and “umbrella” species may hopefully act as a trigger for many other wildlife conservation and management projects in this area and other regions of PNG.

References

Ackerman, R. A. 1981. Growth and gas exchange of embryonic sea turtles (Chelonia, *Caretta*). Copeia **1981**:757-765.

Ades, G. W. J. 2002. Turtle trade monitoring in South China and summary of turtle rescue operation in Hong Kong. Technical workshop on conservation of and trade in freshwater turtles and tortoises in Asia, 25-28 March 2002, Kunning, Yunnan Province, People's Republic of China.

Alacs, E., and A. Georges. 2008. Wildlife across our borders: a review of the illegal trade in Australia. Australian Journal of Forensic Sciences **40**:147-160.

Alho, C. J. R., and L. F. M. Pádua. 1982. Reproductive parameters and nesting behavior of the Amazon turtle *Podocnemis expansa* (Testudinata: Pelomedusidae) in Brazil. Canadian Journal of Zoology **60**:97-103.

Andelman, S. J., and W. F. Fagan. 2000. Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences of the United States of America **97**:5954-5959.

Aswani, S. 2002. Assessing the effects of changing demographic and consumption patterns on sea tenure regimes in the Roviana Lagoon, Solomon Islands. AMBIO: A Journal of the Human Environment **31**:272–284.

Auliya, M. 2003. Hot trade in cool creatures: a review of the live reptile trade in the European Union in the 1990s with a focus on Germany. TRAFFIC, Brussels, Belgium.

Ballinger, R. E. 1979. Intraspecific variation in demography and life history of the lizard, *Sceloporus jarrovi*, along an altitudinal gradient in southeastern Arizona. Ecology **60**:901-909.

Ballinger, R. E., and J. D. Congdon. 1980. Food resource limitation of body growth rates in *Sceloporus scalaris* (Sauria: Iguanidae). Copeia **1980**:921-923.

Barrett B. 1995. Commentary: Plants, pesticides and production in Guatemala; nutrition, health and nontraditional agriculture. Ecology of Food and Nutrition **33**:293-309.

Bennett, E. L., and J. G. Robinson. 2000. Hunting of wildlife in tropical forests: implications for biodiversity and forest peoples. Environment Department papers, Biodiversity series–Impact studies, The World Bank Institute, Washington DC, USA.

Bernardo, J. 1996. Maternal effects in animal ecology. American Zoologist **36**:83-105.

Bhupathy, S., and S. Saravanan. 2006. Status of marine turtles in the Gulf of Mannar, India. Chelonian Conservation and Biology **5**:139-141.

Bilinski, J. J., R. D. Reina, J. R. Spotila, and F. V. Paladino. 2001. The effects of nest environment on calcium mobilization by leatherback turtle embryos (*Dermochelys coriacea*) during development. Comparative Biochemistry and Physiology – Part A: Molecular & Integrative Physiology **130**:151-162.

Bilton, D. T., J. Paula, and J. D. D. Bishop. 2002. Dispersal, genetic differentiation and speciation in estuarine organisms. Estuarine, Coastal and Shelf Science **55**:937-952.

Bjorndal, K. A. 1985. Nutritional ecology of sea turtles. Copeia **1985**:736-751.

Blanckenhorn, W. U. 2000. The evolution of body size: What keeps organisms small? The Quarterly Review of Biology **75**:385-407.

Blomberg, S. P., and T. Garland. 2002. Tempo and mode in evolution: phylogenetic inertia, adaptation and comparative methods. Journal of Evolutionary Biology **15**:899-912.

Blundell, D. 2006. Digital Language Atlas of the Pacific Area. 6th edition. Berkeley, USA. Available from www.ecai.org/austronesiaweb/PacificMaps.htm (accessed August 2010)

Bobyn, M. L., and R. J. Brooks. 1994. Interclutch and interpopulation variation in the effects of incubation conditions on sex, survival and growth of hatchling turtles (*Chelydra serpentina*). Journal of Zoology **233**:233-257.

Bodie, J. R. 2001. Stream and riparian management for freshwater turtles. Journal of Environmental Management **62**:443-455.

Bodie, J. R., and R. D. Semlitsch. 2000. Spatial and temporal use of floodplain habitats by lentic and lotic species of aquatic turtles. Oecologia **122**:138-146.

Bolton, M., and M. Laufa. 1982. The crocodile project in Papua New Guinea. Biological Conservation **22**:169-179.

Bonin, F., B. Devaux, and A. Dupré 2006. Turtles of the world. Johns Hopkins University Press, Maryland, USA.

Booth, D. T. 1998. Effects of incubation temperature on the energetics of embryonic development and hatchling morphology in the Brisbane river turtle *Emydura signata*. Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology **168**:399-404.

Booth, D. T. 2000. The effect of hypoxia on oxygen consumption of embryonic estuarine crocodiles (*Crocodylus porosus*). Journal of Herpetology **34**:478-481.

Booth, D. T. 2002a. The breaking of diapause in embryonic broad-shell river turtles (*Chelodina expansa*). Journal of Herpetology **36**:304-307.

Booth, D. T. 2002b. Incubation of rigid-shelled turtle eggs: do hydric conditions matter? Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology **172**:627-633.

Booth, D. T. 2006. Influence of incubation temperature on hatchling phenotype in reptiles. Physiological and Biochemical Zoology **79**:274-281.

Bosque, C., and M. T. Bosque. 1995. Nest predation as a selective factor in the evolution of developmental rates in altricial birds. The American Naturalist **145**:234-260.

Bowen, K. D., R.-J. Spencer, and F. J. Janzen. 2005. A comparative study of environmental factors that affect nesting in Australian and North American freshwater turtles. Journal of Zoology **267**:397-404.

Boxrucker, J. 2002. Rescinding a 254-mm minimum length limit on white crappies at Ft. supply reservoir, Oklahoma: The influence of variable recruitment, compensatory mortality, and angler dissatisfaction. North American Journal of Fisheries Management **22**:1340-1348.

Bradshaw, C. J. A., Y. Fukuda, M. Letnic, and B. W. Brook. 2006. Incorporating known sources of uncertainty to determine precautionary harvests of saltwater crocodiles. Ecological Applications **16**:1436-1448.

Bragg, W. K., J. D. Fawcett, T. B. Bragg, and B. E. Viets. 2000. Nest-site selection in two eublepharid gecko species with temperature-dependent sex determination and one with genotypic sex determination. Biological Journal of the Linnean Society **69**:319–332.

Broderick, A. C., F. Glen, B. J. Godley, and G. C. Hays. 2003. Variation in reproductive output of marine turtles. Journal of Experimental Marine Biology and Ecology **288**:95-109.

Broin, F. 2000. The oldest pré-podocnemidid turtle (Chelonii, Pleurodira), from the Early Cretaceous, Ceará State, Brasil, and its environment. Treballs del Museu de Geologia de Barcelona **9**:43-95.

Brousseau, C. S., and E. R. Armstrong. 1987. The role of size limits in walleye management. Fisheries **12**:2-5.

Brown, J. H., P. A. Marquet, and M. L. Taper. 1993. Evolution of body size: Consequences of an energetic definition of fitness. The American Naturalist **142**:573-584.

Brown, L., and D. W. Macdonald. 1995. Predation on green turtle *Chelonia mydas* nests by wild canids at Akyatan beach, Turkey. Biological Conservation **71**:55-60.

Browne, C. L., and S. J. Hecnar. 2007. Species loss and shifting population structure of freshwater turtles despite habitat protection. Biological Conservation **138**:421–429.

Burbidge, A. A., and N. L. McKenzie. 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biological Conservation **50**:143-198.

Burger, J. 1976. Temperature relationships in nests of the northern diamondback terrapin, *Malaclemys terrapin terrapin*. Herpetologica **32**:412-418.

Burger, J., and W. A. Montevecchi. 1975. Nest site selection in the terrapin *Malaclemys terrapin*. Copeia **1975**:113-119.

Burger, R., and M. Lynch. 1995. Evolution and extinction in a changing environment: A quantitative-genetic analysis. Evolution **49**:151-163.

Burke, V. J., J. W. Gibbons, and J. L. Greene. 1994. Prolonged Nesting Forays by Common Mud Turtles (*Kinosternon subrubrum*). American Midland Naturalist **131**:190-195.

Burke, V. J., S. L. Rathbun, J. R. Bodie, and J. W. Gibbons. 1998. Effect of density on predation rate for turtle nests in a complex landscape. Oikos **83**:3-11.

Busse, M., S. Turner, and N. Araho 1993. The people of Lake Kutubu and Kikori: Changing meanings of daily life. Papua New Guinea National Museum, Port Moresby, Papua New Guinea.

Bustard, H. R., and P. Greenham. 1968. Physical and chemical ractors affecting hatching in the green sea turtle, *Chelonia Mydas* (L.). Ecology **49**:269-276.

Butler, B. O., and T. E. Graham. 1995. Early post-emergent behavior and habitat selection in hatchling Blanding's turtles, *Emydoidea blandingii*. Chelonian Conservation and Biology **1**:187-196.

Campbell, L. M. 1998. Use them or lose them? Conservation and the consumptive use of marine turtle eggs at Ostional, Costa Rica. Environmental Conservation **25**:305-319.

Campbell, L. M. 2002. Science and sustainable use: views of marine turtle conservation experts. Ecological Applications **12**:1229-1246.

Cann, J. 1972. Notes on some tortoises collected in northern Australia. Victorian Naturalist **89**:165-168.

Cann, J. 1978. Tortoises of Australia. Angus and Robertson Sydney, Australia.

Cann, J. 1998. Australian freshwater turtles. Beaumont Publishing, Singapore.

Caro, T. M., and K. M. Laurenson. 1994. Ecological and genetic factors in conservation: a cautionary tale. Science **263**:485-486.

Carr, T., and N. Carr. 1985. *Trionyx triunguis*: habitat. Herpetological Review **16**:30.

Caut, S., E. Guirlet, and M. Girondot. 2010. Effect of tidal overwash on the embryonic development of leatherback turtles in French Guiana. Marine Environmental Research **69**:254-226.

Census, P. N. G. 2000. Provincial Report. National Statistical Office of Papua New Guinea, Port Moresby, Papua New Guinea.

Child, G. 1987. The management of crocodiles in Zimbabwe. Pages 49-62 in G. J. W. Webb, S. C. Manolis, and P. Whiitehead, editors. Wildlife management: crocodiles and alligators. Surrey Beatty and Sons, Chipping Norton, Australia**.**

Child, G. S. 1991. People's participation in wildlife utilization in Africa. Landscape and Urban Planning **20**:159-162.

Christian, K. A., and C. R. Tracy. 1981. The effect of the thermal environment on the ability of hatchling Galapagos land iguanas to avoid predation during dispersal. Oecologia **49**:218-223.

Cinner, J. E., and T. R. McClanahan. 2006. Socioeconomic factors that lead to overfishing in small-scale coral reef fisheries of Papua New Guinea. Environmental Conservation **33**:73-80.

Cinner, J., M. J. Marnane, T. R. McClanahan, and G. R. Almany. 2006. Periodic closures as adaptive coral reef management in the Indo-Pacific. Ecology and Society **11**:31.

Cinner, J. E., and S. Aswani. 2007. Integrating customary management into marine conservation. Biological Conservation **140**:201-216.

Cinner, J. E., M. J. Marnane, and T. I. M. R. McClanahan. 2005. Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea. Conservation Biology **19**:1714-1723.

Close, L. M., and R. A. Seigel. 1997. Differences in body size among populations of red-eared sliders (*Trachemys scripta elegans*) subjected to different levels of harvesting. Chelonian Conservation and Biology **2**:563-566.

Cogger, H. G., and H. Heatwole. 1981. The Australian reptiles: origins, biogeography, distribution patterns and island evolution. Ecological biogeography of Australia **2**:343-360.

Colvin, M. A. 1991. Evaluation of minimum-size limits and reduced daily limits on the crappie populations and fisheries in five large Missouri reservoirs. North American Journal of Fisheries Management **11**:585-597.

Congdon, J. D., A. E. Dunham, and R. C. V. L. Sels. 1993. Delayed sexual maturity and demographics of blanding's turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology **7**:826-833.

Congdon, J. D., and J. W. Gibbons. 1990. Turtle eggs: their ecology and evolution. Pages 109-123 in J. W. Gibbons, and H. W. Avery, editors. Life history and ecology of the slider turtle. Smithsonian Institution Press Washington, DC, USA.

Connell, J. 1997. Papua New Guinea: the struggle for development. Routledge, New York, USA.

Cox, W. A., and K. R. Marion. 1978. Observations on the remale reproductive cycle and associated phenomena in spring-dwelling populations of *Sternotherus minor* in North Florida (Reptilia: Testudines). Herpetologica **34**:20-33.

Crouse, D. T., L. B. Crowder, and H. Caswell. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. Ecology **68**:1412-1423.

Darimont, C. T., S. M. Carlson, M. T. Kinnison, P. C. Paquet, T. E. Reimchen, and C. C. Wilmers. 2009. Human predators outpace other agents of trait change in the wild. Proceedings of the National Academy of Sciences **106**:952-954.

Daszak, P., A. Strieby, A. A. Cunningham, J. E. Longcore, C. C. Brown, and D. Porter. 2004. Experimental evidence that the bullfrog (*Rana catesbeiana*) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetological Journal **14**:201-208.

Davenport, J. 1997. Temperature and the life-history strategies of sea turtles. Journal of Thermal Biology **22**:479-488.

Davenport, J., and E. A. Macedo. 1990. Behavioural osmotic control in the euryhaline diamondback terrapin *Malaclemys terrapin*: responses to low salinity and rainfall. Journal of Zoology **220**:487-496.

Davenport, J., and T. M. Wong. 1986. Observations on the water economy of the estuarine turtles *Batagur baska* (gray) and *Callagur borneoensis* (Schlegel and Muller). Comparative Biochemistry and Physiology Part A: Physiology **84**:703-707.

Davenport, J., T. M. Wong, and J. East. 1992. Feeding and digestion in the omnivorous estuarine turtle *Batagur baska* (Gray). Herpetological Journal **2**:133-139.

David, B. 2008. Rethinking cultural chronologies and past landscape engagement in the Kopi region, Gulf Province, Papua New Guinea. The Holocene **18**:463-479.

Davies, C. L. 2005. Thermoregulation, activity, and energetics of the pig-nosed turtle (*Carettochelys insculpta*) in the Daly River, NT. Honours Thesis, Institute for Applied Ecology, University of Canberra, Canberra, Australia.

Daza, J. M., and V. P. Páez. 2007. Morphometric variation and its effect on reproductive potential in female Colombian slider turtles (*Trachemys callirostris callirostris*). Herpetologica **63**:25-134.

Deeming, D. C. 2004. Post-hatching phenotypic effects of incubation in reptiles in D. C. Deeming, editor. Reptilian Incubation Environment, Evolution and Behaviour. Nottingham University Press, Nottingham, UK.

Delfino, M., U. Fritz, and M. Sánchez-Villagra. 2010. Evolutionary and developmental aspects of phalangeal formula variation in pig-nosed and soft-shelled turtles (Carettochelyidae and Trionychidae). Organisms Diversity & Evolution **10**:69-79.

Doak, D., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the western Mojave Desert. Ecological Applications **4**:446-460.

Donlan, E. M. 2004. Predation of *Caretta caretta* (Testudines: Cheloniidae) eggs by larvae of *Lanelater sallei* (Coleoptera: Elateridae) on Key Biscayne, Florida. Caribbean Journal of Science **40**:415-420.

Doody, J. S., and A. Georges. 2002. A novel technique for gathering emergence and testing phenology data in turtles. Herpetological Review **40**:220-222.

Doody, J. S., A. Georges, and J. E. Young. 2003a. Twice every second year: reproduction in the pig-nosed turtle, *Carettochelys insculpta*, in the wet-dry tropics of Australia. Journal of Zoology **259**:179-188.

Doody, J. S., A. Georges, and J. E. Young. 2004. Determinants of reproductive success and offspring sex in a turtle with environmental sex determination. Biological Journal of the Linnean Society **81**:1-16.

Doody, J. S., A. Georges, J. E. Young, M. D. Pauza, A. L. Pepper, R. L. Alderman, and M. A. Welsh. 2001. Embryonic aestivation and emergence behaviour in the pig-nosed turtle, *Carettochelys insculpta*. Canadian Journal of Zoology **79**:1062-1072.

Doody, J. S., R. A. Sims, and A. Georges. 2003b. Gregarious behavior of nesting turtles (*Carettochelys insculpta*) does not reduce nest predation risk. Copeia **2003**:894-898.

Doody, J. S., P. West, and A. Georges. 2003c. Beach selection in nesting pig-nosed turtles, *Carettochelys insculpta*. Journal of Herpetology **37**:178–182.

Doody, J. S., J. E. Young, and A. Georges. 2002. Sex differences in activity and movements in the pig-nosed turtle, *Carettochelys insculpta*, in the wet-dry tropics of Australia. Copeia **2002**:93-103.

Downes, S. J., and R. Shine. 1999. Do incubation-induced changes in a lizard's phenotype influence its vulnerability to predators? Oecologia **120**:9-18.

Dudgeon, D., A. H. Arthington, M. O. Gessner, Z.-I. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, A.-H. Prieur-Richard, D. Soto, M. L. J. Stiassny, and C. A. Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews of the Cambridge Philosophical Society **81**:163-182.

Dunham, A. E., B. W. Grant, and K. L. Overall. 1989. Interfaces between biophysical and physiological ecology and the population ecology of terrestrial vertebrate ectotherms. Physiological Zoology **62**:335-355.

Dunham, A. E., D. B. Miles, and D. N. Reznick. 1988. Life history patterns in squamate reptiles. Pages 441-522 in C. Gans, and R. Huey, editors. Biology of the Reptilia. Alan R. Liss, Inc., New York, USA.

Dunson, W. A. 1976. Salt glands in reptiles. Pages 413-445 in C. Gans, editor. Biology of the Reptilia. Academic Press, London, UK.

Dunson, W. A. 1979. Salinity tolerance and osmoregulation of the key mud turtle, *Kinosternon B. baurii*. Copeia **1979**:548-552.

Dunson, W. A. 1986. Estuarine populations of the snapping Turtle (*Chelydra*) as a model for the evolution of marine adaptations in reptiles. Copeia **1986**:741-756.

Dunson, W. A., and F. J. Mazzotti. 1989. Salinity as a limiting factor in the distribution of reptiles in Florida Bay: A theory for the estuarine origin of marine snakes and turtles. Bulletin of Marine Science **44**:229-244.

Dunson, W. A., and E. O. Moll. 1980. Osmoregulation in sea water of hatchling emydid turtles, *Callagur borneoensis*, from a Malaysian sea beach. Journal of Herpetology **14**:31-36.

Dunson, W. A., and M. E. Seidel. 1986. Salinity tolerance of estuarine and insular emydid turtles (*Pseudemys nelsoni* and *Trachemys decussata*). Journal of Herpetology **20**:237-245.

Ehrenfeld, D. W. 1979. Behavior associated with nesting. Pages 417-434 in M. Harless, and H. Morlock, editors. Turtles: perspectives and research. John Wiley and Sons, New York, USA.

Eldredge, N. 2001. The Sixth extinction. Actionbioscience.org, http://www.actionbioscience.org/newfrontiers/eldredge2.html#educator (accessed August 2010).

Enesar. 2005. Environmental impact statement. PNG Gas Project. Report CR 790-20-Rev4. Volume 1. Esso Highlands, Port Moresby, Papua New Guinea.

Erwin, D. H. 2001. Lessons from the past: Biotic recoveries from mass extinctions. Proceedings of the National Academy of Sciences of the United States of America **98**:5399 -5403.

Escalona, T., and J. E. Fa. 1998. Survival of nests of the Terecay turtle (*Podocnemis Unifilis*) in the Nichare-Tawadu Rivers, Venezuela. Journal of Zoology **244**:303-312.

Fachín-Terán, A., and R. C. Vogt. 2004. Estrutura populacional, tamanho e razão sexual de *Podocnemis unifilis* (Testudines, Podocnemididae) no rio Guaporé (RO), norte do Brasil. Phyllomedusa **3**:29-42.

Fachín-Terán, A., R. C. Vogt, and J. B. Thorbjarnarson. 2003. Estrutura populacional, razão sexual e abundância de *Podocnemis sextuberculata* (Testudines, Podocnemididae) na Reserva de Desenvolvimento Sustentável Mamirauá, Amazonas. Phyllomedusa **2**:43-63.

Fachín-Terán, A., R. C. Vogt, and J. B. Thorbjarnarson. 2006. Seasonal movements of *Podocnemis sextuberculata* (Testudines: Podocnemididae) in the Mamirauá sustainable development reserve, Amazonas, Brazil. Chelonian Conservation and Biology **5**:18-24.

Fenberg, P. B., and K. Roy. 2008. Ecological and evolutionary consequences of size-selective harvesting: how much do we know? Molecular Ecology **17**:209-220.

Fernandes-Costa, F. J., J. Marshall, C. Ritchie, S. V. van Tonder, D. S. Dunn, T. Jenkins, and J. Metz. 1984. Transition from a hunter-gatherer to a settled lifestyle in the !Kung San: effect on iron, folate, and vitamin B12 nutrition. The American Journal of Clinical Nutrition **40**:1295-1303.

Finkler, M. S., D. L. Knickerbocker, and D. L. Claussen. 2000. Influence of hydric conditions during incubation and population on overland movement of neonatal snapping turtles. Journal of Herpetology **34**:452-455.

Fitch, H. S., and A. V. Fitch. 1967. Preliminary experiments on physical tolerances of eggs of lizards and snakes. Ecology **48**:160-165.

Foley, A. M., S. A. Peck, and G. R. Harman. 2006. Effects of sand characteristics and inundation on the hatching success of loggerhead sea turtle (*Caretta caretta*) clutches on low-relief mangrove islands in southwest Florida. Chelonian Conservation and Biology **5**:32-41.

Foley, W. A. 1986. The Papuan languages of New Guinea. Cambridge University Press, Cambridge, UK.

Fordham, D. A., A. Georges, and B. W. Brook. 2007. Demographic response of snake-necked turtles correlates with indigenous harvest and feral pig predation in tropical northern Australia. Journal of Animal Ecology **76**:1231-1243.

Fowler, L. E. 1979. Hatching success and nest predation in the green sea turtle, *Chelonia Mydas*, at Tortuguero, Costa Rica. Ecology **60**:946-955.

Frazer, N. B. 1992. Sea turtle conservation and halfway technology. Conservation Biology **6**:179-184.

Frazier, J. 2005. Marine turtles: the role of flagship species in interactions between people and the sea. Maritime Studies **3**:5-39.

Fund, T. C. 2002. A global action plan for conservation of tortoises and freshwater turtles: strategy and funding prospectus 2002-2007. Pages 12-15. Conservation International and Chelonian Research Foundation, Washington D.C. USA.

Gadgil, M., and W. H. Bossert. 1970. Life historical consequences of natural selection. The American Naturalist **104**:1-24.

Gaffney, E. S., and M. R. Sánchez-Villagra. 1996. Relationships of the Shweboemys group of side necked turtles. Journal of Vertebrate Paleontology **16**:36A.

Gaffney, E. S., and R. C. Wood. 2002. *Bairdemys*, a new side-necked turtle (Pelomedusoides: Podocnemididae) from the Miocene of the Caribbean. American Museum Novitates **3359**:1-28.

Gamble, T., and A. M. Simons. 2004. Comparison of harvested and nonharvested painted turtle populations. Wildlife Society Bulletin **32**:1269-1277.

Garcia, A., G. Ceballos, and R. Adaya. 2003. Intensive beach management as an improved sea turtle conservation strategy in Mexico. Biological Conservation **111**:253-261.

Garcon, J. S., A. Grech, J. Moloney, and M. Hamann. 2009. Relative exposure index: an important factor in sea turtle nesting distribution. Aquatic Conservation: Marine and Freshwater Ecosystems **20**:140-149.

Gell, F. R., and C. M. Roberts. 2003. Benefits beyond boundaries: the fishery effects of marine reserves. Trends in Ecology & Evolution **18**:448-455.

Georges, A. 1983. Reproduction of the Australian Freshwater Tortoise, *Emydura krefftii* (Chelonia: Chelidae). Journal of Zoology **201**:331-350.

Georges, A. 1987. The pig-nosed turtle Warradjan. Australian Natural History **22**:230-234.

Georges, A. 1989. Female turtles from hot nests: is it duration of incubation or proportion of development at high temperatures that matters? Oecologia **81**:323-328.

Georges, A. 1992. Thermal characterstics and sex determination in field nests of the pig-nosed turlte, *Carettochelys insculpta* (Chelonia: Carettochelydidae), from northern Australia. Australian Journal of Zoology **30**:511-521.

Georges, A., E. Alacs, M. Pauza, F. Kinginapi, A. Ona, and C. Eisemberg. 2008a. Freshwater turtles of the Kikori Drainage, Papua New Guinea, with special reference to the pig-nosed turtle, *Carettochelys insculpta*. Wildlife Research **35**:700-711.

Georges, A., D. Choquenot, A. J. Coventry, and P. Wellings. 1989. A note on *Carettochelys insculpta* (Testudinata : Carettochelydidae) from northern Australia. Northern Territory Naturalist **11**.

Georges, A., S. Doody, C. Eisemberg, and E. Alacs. 2008b. *Carettochelys insculpta* Ramsay 1886 – Pig-Nosed Turtle, Fly River Turtle. Chelonian Research Monographs:1-17.

Georges, A., F. Guarino, and B. Bito. 2006. Freshwater turtles of the TransFly region of Papua New Guinea: notes on diversity, distribution, reproduction, harvest and trade. Wildlife Research **33**:373-384.

Georges, A., and R. Kennett. 1989. Dry-season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, Northern Australia. Australian Wildlife Research **16**:323-335.

Georges, A., C. Limpus, and R. Stoutjesdijk. 1994. Hatchling sex in the marine turtle *Caretta caretta* is determined by proportion of development at a temperature, not daily duration of exposure. Journal of Experimental Zoology **270**:432-444.

Georges, A., I. Webster, E. Guarino, M. Thoms, P. Jolley, and J. S. Doody. 2002. National River Health Program: modelling dry season flows and predicting the impact of water extraction on a flagship species. Page 73pp. Department of Lands, Planning and Environment, NT, Canberra, Australia.

Georges, A., and J. C. Wombey. 1993. Family Carettochelyidae. Pages 153-156 in J. Godsell, editor. Fauna of Australia. Australian Biological Resources Study, DASEET, Canberra, Australia.

Gibbons, J. W. 1990. The slider turtle. Pages 3-18 in J. W. Gibbons, editor. Life History and Ecology of the Slider Turtle. Smithsonian Institution Press, Washington, DC.

Gibson, J., and S. Rozelle. 2003. Poverty and Access to Roads in Papua New Guinea. Economic Development and Cultural Change **52**:159-185.

Godfrey, M. H., R. Barreto, and N. Mrosovsky. 1997. Estimating past and present sex ratios of turtles in Suriname. Canadian Journal of Zoology **74**:267-276.

Goh, T. Y., and R. M. O'Riordan. 2007. Are tortoises and freshwater turtles still traded illegally as pets in Singapore? Oryx **41**:97-100.

Gordon, R. G., and B. F. Grimes 2005. Ethnologue: Languages of the world. SIL International Dallas, USA.

Gould, S. J., and E. S. Vrba. 1982. Exaptation – A missing term in the science of form. Paleobiology **8**:4-15.

Grether, G. F. 2005. Environmental change, phenotypic plasticity, and genetic compensation. The American Naturalist **166**:E115-E123.

Groombridge, B., and L. Wright 1982. The IUCN Amphibia-Reptilia red data book. Part 1, Testudines, Crocodylia, Rhynchocephalia. IUCN, London, UK.

Haas, G. 1978. A new turtle of the genus *Podocnemis* from the lower Cenomanian of 'Em Yabrud. Israel Journal of Zoology, **27**:169-175.

Hairston, N. G., S. P. Ellner, M. A. Geber, T. Yoshida, and J. A. Fox. 2005. Rapid evolution and the convergence of ecological and evolutionary time. Ecology Letters **8**:1114-1127.

Hatase, H., M. Kinoshita, T. Bando, N. Kamezaki, K. Sato, Y. Matsuzawa, K. Goto, K. Omuta, Y. Nakashima, H. Takeshita, and others. 2002. Population structure of loggerhead turtles, *Caretta caretta*, nesting in Japan: bottlenecks on the Pacific population. Marine Biology **141**:299-305.

Hays, G. C., A. Mackay, C. R. Adams, J. A. Mortimer, J. R. Speakman, and M. Boerema. 1995. Nest site selection by sea turtles. Journal of the Marine Biological Association of the UK **75**:667-674.

Heaphy, J. L. 1990. The ecology of the pig-nosed turtle, *Carettochelys insculpta*, in northern Australia. Univeristy of New South Wales, Sydney, Australia.

Heger, N. A., and S. F. Fox. 1992. Viability of lizard (*Sceloporus undulatus*) eggs exposed to simulated flood conditions. Journal of Herpetology **26**:338-341.

Hellgren, E. C., R. T. Kazmaier, D. C. R. Iii, and D. R. Synatzske. 2000. Variation in tortoise life history: demography of *Gopherus berlandieri*. Ecology **81**:1297-1310.

Heinsohn, R., R. C. Lacy, D. B Lindenmayer, H. Marsh, D. Kwan, and I. R Lawler. 2004. Unsustainable harvest of dugongs in Torres Strait and Cape York (Australia) waters: two case studies using population viability analysis. Animal Conservation **7**:417-425.

Hendrickson, J. R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings of the Zoological Society of London **130**:455-535.

Hendrickson, J. R. 1980. The ecological strategies of sea turtles. American Zoologist **20**:597-608.

Hendry, A. P., T. J. Farrugia, and M. T. Kinnison. 2008. Human influences on rates of phenotypic change in wild animal populations. Molecular Ecology **17**:20-29.

Hendry, A. P., and M. T. Kinnison. 1999. Perspective: The pace of modern life: Measuring rates of contemporary microevolution. Evolution **53**:1637-1653.

Heppell, S. S. 1998. Application of life-history theory and population model analysis to turtle conservation. Copeia **1998**:367-375.

Heppell, S. S., L. B. Crowder, and D. T. Crouse. 1996. Models to evaluate headstarting as a management tool for long-lived turtles. Ecological Applications **6**:556-565.

Hewavisenthi, S., and C. J. Parmenter. 2002. Incubation environment and nest success of the Flatback Turtle (*Natator depressus*) from a natural besting beach. Copeia **2002**:302-312.

Heywood, P. F. 1983. Growth and nutrition in Papua New Guinea. Journal of Human Evolution **12**:133-143.

Hollands, M. 1987. The management of crocodiles in Papua New Guinea. Pages 73-89 in G. J. W. Webb, S. C. Manolis, and P. Whitehead, editors. Wildlife management: crocodiles and alligators. Surrey Beatty and Sons, Darwin, Australia.

Hughes, J. B., G. C. Daily, and P. R. Ehrlich. 1997. Population diversity: Its extent and extinction. Science **278**:689-692.

IUCN. 2009. IUCN Red List of Threatened Species. Version 2009.2. IUCN, Available from www.iucnredlist.org (accessed August 2010).

Iverson, J. B. 1991a. Life history and demography of the yellow mud turtle, *Kinosternon flavescens*. Herpetologica **47**:373-395.

Iverson, J. B. 1991b. Patterns of survivorship in turtles (Order Testudines). Canadian Journal of Zoology **69**:385-391.

Iverson, J. B., and G. R. Smith. 1993. Reproductive ecology of the painted turtle (*Chrysemys picta*) in the Nebraska Sandhills and across its range. Copeia **1993**:1-21.

Jackson, J. B. C. 2008. Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences **105**:11458-11465.

Janzen, F. J. 1994. Vegetational cover predicts the sex ratio of hatchling turtles in natural nests. Ecology **75**:1593-1599.

Janzen, F. J. 1995. Experimental evidence for the evolutionary significance of temperature dependent sex determination. Evolution **49**:864-873.

Janzen, F. J., and C. L. Morjan. 2001. Repeatability of microenvironment-specific nesting behaviour in a turtle with environmental sex determination. Animal Behaviour **62**:73-82.

Joanen, T., L. McNease, R. M. Elsy, and M. A. Staton. 1997. The commercial consumptive use of the American alligator (*Alligator mississippiensis*) in Louisiana: its effect on conservation. Pages 465-506 in C. H. Freese, editor. Harvesting wild species. The Johns Hopkins University Press, Baltimore, USA.

Johannes, R. E., and J. W MacFarlane. 1991. Traditional fishing in the Torres Strait islands. CSIRO Division of Fisheries, Marine Laboratories, Hobart, Australia.

Johnson, M. T. J., and J. R. Stinchcombe. 2007. An emerging synthesis between community ecology and evolutionary biology. Trends in Ecology & Evolution **22**:250-257.

Jones, S. M., R. E. Ballinger, and W. P. Porter. 1987. Physiological and environmental sources of variation in reproduction: Prairie lizards in a food rich environment. Oikos **48**:325-335.

Kam, Y.-C. 1994. Effects of simulated flooding on metabolism and water balance of turtle eggs and embryos. Journal of Herpetology **28**:173-178.

Kinneary, J. J. 1992. The effect of water salinity on growth and oxygen consumption of snapping turtle (*Chelydra serpentina*) hatchlings from an estuarine habitat. Journal of Herpetology **26**:461-467.

Kinneary, J. J. 1993. Salinity relations of *Chelydra serpentina* in a Long Island estuary. Journal of Herpetology **27**:441-446.

Kinneary, J. J. 1996. The origin of marine turtles: a pluralistic view of evolution. Chelonian Conservation and Biology **2**:73-77.

Kinnison, M. T., and N. G. Hairston. 2007. Eco-evolutionary conservation biology: contemporary evolution and the dynamics of persistence. Functional Ecology **21**:444-454.

Kinnison, M. T., and A. P. Hendry. 2001. The pace of modern life II: from rates of contemporary microevolution to pattern and process. Genetica **112**:145-164.

Klemens, M. W., and J. B. Thorbjarnarson. 1995. Reptiles as a food resource. Biodiversity and Conservation **4**:281-298.

Koczberski, G., G. N Curry, and J. Connell. 2001. Full circle or spiralling out of control? State violence and the control of urbanisation in Papua New Guinea. Urban Studies **38**:2017-2036.

Kolbe, J. J., and F. J. Janzen. 2001. The influence of propagule size and maternal nest-site selection on survival and behaviour of neonate turtles. Functional Ecology **15**:772-781.

Kolbe, J. J., and F. J. Janzen. 2002. Spatial and temporal dynamics of turtle nest predation: edge effects. Oikos **99**:538-544.

Kuchling, G. 1993. Possible biennial ovarian cycle of the freshwater turtle *Erymnochelys madagascariensis*. Journal of Herpetology **27**:470-472.

Kuchling, G. 1999. Reproductive biology of the chelonia. Springer, Berlin, Germany.

Kuchling, G., and S. D. Bradshaw.1993. Ovarian cycle and egg production of the Western Swamp Tortoise *Pseudemydura umbrina* (Testudines: Chelidae) in the wild and in captivity. Journal of Zoology **229**: 405-419.

Kudo, G., and A. S. Hirao. 2005. Habitat-specific responses in the flowering phenology and seed set of alpine plants to climate variation: implications for global-change impacts. Population Ecology **48**:49-58.

Kuhnlein H. V., and O. Receveur. 1996. Dietary change and traditional food systems of indigenous peoples. Annual Review of Nutrition **16**:417–442.

Lahanas, P. N., M. M. Miyamoto, K. A. Bjorndal, and A. B. Bolten. 1994. Molecular evolution and population genetics of Greater Caribbean green turtles (*Chelonia mydas*) as inferred from mitochondrial DNA control region sequences. Genetica **94**:57-66.

Lapparent de Broin, F., and C. Werner. 1998. New late Cretaceous turtles from the western desert, Egypt. Annales de Paléontologie, **84**:131-214.

Laurance, W. F., M. A. Cochrane, S. Bergen, P. M. Fearnside, P. Delamônica, C. Barber, S. D'Angelo, and T. Fernandes. 2001. Environment. The future of the Brazilian Amazon. Science **291**:438-439.

Laurén, D. J. 1985. The effect of chronic saline exposure on the electrolyte balance, nitrogen metabolism, and corticosterone titer in the american alligator, *Alligator mississippiensis*. Comparative Biochemistry and Physiology Part A: Physiology **81**:217-223.

Lehman, D. 2002. Demography and Causes of Death among the Huli in the Tari Basin. Papua New Guinea Medical Journal **45**:51-62.

Löffler, E. 1977. Geomorphology of Papua New Guinea. Australian National University Press, Canberra, Australia.

Lovich, J. E., and J. W. Gibbons. 1990. Age at maturity influences adult sex ratio in the turtle *Malaclemys terrapin*. Oikos **59**:126-134.

Low, B., S. R. Sundaresan, I. R. Fischhoff, and D. I. Rubenstein. 2009. Partnering with local communities to identify conservation priorities for endangered Grevy's zebra. Biological Conservation **142**:1548-1555.

Ludwig, D. 1993. Environmental sustainability: magic, science, and religion in natural resource management. Ecological Applications **3**:555-558.

Lunney, D., A. L. Curtin, D. Ayers, H. G. Cogger, and C. R. Dickman. 1996. An ecological approach to identifying the endangered fauna of New South Wales. Pacific Conservation Biology **2**:212-223.

Lynch, O., and A. Marat. 1993. A review and analysis of national laws and policies concerning customary owners' rights and the conservation and sustainable development of forests and other biological resources. Pages 7-29 in B. M. P. Beehler, and J. F. Swartzendruber, editors. Papua New Guinea Conservation Needs Assessment Report. Biodiversity Support Program, Washington D.C., USA.

Magnusson, W. E. 1982. Mortality of eggs of the crocodile *Crocodylus porosus* in Northern Australia. Journal of Herpetology **16**:121-130.

Magun, W. 2006. STRP launches first community marine reserve in Papua New Guinea. Sea Turtle Restoration Project, http://www.seaturtles.org/article.php?id=1278 (accessed January 2009).

Marchand, M. N., J. A. Litvaitis, T. J. Maier, and R. M. DeGraaf. 2002. Use of artificial nests to investigate predation on freshwater turtle nests. Wildlife Society Bulletin **30**:1092-1098.

Marcovaldi, M. Â., and G. G. Marcovaldi. 1999. Marine turtles of Brazil: the history and structure of Projeto TAMAR-IBAMA. Biological Conservation **91**:35-41.

Marsh, H., A. N. M. Harris, and I. R Lawler. 1997. The sustainability of the indigenous dugong fishery in Torres Strait, Australia/Papua New Guinea. Conservation Biology **11**:1375-1386.

Marsh, H., I. R. Lawler, D. Kwan, S. Delean, K. Pollock, and M. Alldredge. 2004. Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. Animal Conservation **7**:435-443.

Martin, T. E. 1993. Nest predation among vegetation layers and habitat types: Revising the dogmas. The American Naturalist **141**:897-913.

Mascia, M. B., J. P. Brosius, T. A. Dobson, B. C. Forbes, L. Horowitz, M. A. McKean, and N. J. Turner. 2003. Editorial: conservation and the social sciences. Conservation Biology **17**:649-650.

Maturbongs, J. A. 1999. Trade monitoring of pig-nose turtle (*Carettochelys insculpta*) from Vriendschap River, District of Suator, Merauke Regency, Irian Jaya. Pages 21–27 in M. Noerdjito, and I. Maryanto, editors. Jenis-jenis Hayati yang Dilindungi Perundangundangan Indonesia. Lembaga Ilmu Pengetahuan Indonesia (LIPI) and The Nature Conservancy, Cibinong, Indonesia.

Maurer, B. A., J. H. Brown, and R. D. Rusler. 1992. The micro and macro in body size evolution. Evolution **46**:939-953.

Mauro, F., and P. D. Hardison. 2000. Traditional knowledge of indigenous and local communities: International debate and policy initiatives. Ecological Applications **10**:1263-1269.

McCay, B. J., and J. M. Acheson. 1987. Human ecology of the commons. Pages 1-34 in B. J. McCay, and J. M. Acheson, editors. The Question of the Commons: The Culture and Ecology of Communal Resources. University of Arizona Press, Tucson, USA.

McClanahan, T. R., H. Glaesel, J. Rubens, and R. Kiambo. 2002. The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. Environmental Conservation **24**:105-120.

Miller, K. 1993. The improved performance of snapping turtles (*Chelydra serpentina*) hatched from eggs incubated on a wet substrate persists through the neonatal period. Journal of Herpetology **27**:228-233.

Milner-Gulland, E. J., and E. L. Bennett. 2003. Wild meat: the bigger picture. Trends in Ecology & Evolution **18**:351-357.

Mittermeier, R. A., J. L. Carr, I. R. Swingland, T. B. Werner, and R. B. Mast. 1992. Conservation of amphibians and reptiles. Pages 59-80 in K. Adler, editor. Herpetology. Current Research on the Biology of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Oxford, USA.

Mittermeier, R. A., C. G. Mittermeier, and P. R. Gil 1997. Megadiversity: Earth's biologically wealthiest nations. CEMEX, Monterrey, Mexico.

Moll, D. 1994. The ecology of sea beach nesting in slider turtles (*Trachemys scripta venusta*) from Caribbean Costa Rica. Chelonian Conservation and Biology. **1**:107-116.

Moll, D., and E. O. Moll. 1990. The slider turtle in the neotropics: adaptation of a temperate species to a tropical environment. Pages 152-161 in J. W. Gibbons, editor. Life History and Ecology of the Slider Turtle. Smithsonian Institution Press, Washington D.C., USA.

Moll, D., and E. O. Moll 2004. The ecology, exploitation, and conservation of river turtles. Oxford University Press, Oxford, USA.

Moll, E. O., and J. M. Legler 1971. The life history of a neotropical slider turtle, *Pseudemys scripta* (Schoepff), in Panama. Los Angeles County Museum of Natural History, Los Angeles, USA.

Monitoring, H. C. L., and C. Network. 2006. Status of the leatherback turtle in Papua New Guinea. Pages 102-107 in M. Hamann, C. Limpus, G. Hughes, J. Mortimer, and N. Pilche, editors. Assessment of the conservation status of the leatherback turtle in the Indian Ocean and South East Asia. IOSEA Marine Turtle MoU, Bangkok, Thailand.

Mortimer, J. A. 1990. The influence of beach sand characteristics on the nesting behavior and clutch survival of green turtles (*Chelonia mydas*). Copeia **1990**:802-817.

Mousseau, T. A., and C. W. Fox 1998. Maternal effects as adaptations. Oxford University Press Oxford, USA.

Mrosovsky, N. 1968. Nocturnal emergence of hatchling sea turtles: control by thermal inhibition of activity. Nature **220**:1338-1339.

Mrosovsky, N. 1983. Ecology and nest-site selection of leatherback turtles *Dermochelys coriacea*. Biological Conservation **26**:47-56.

Múnera, M. B., J. M. Daza, and V. P. Páez. 2004. Ecología reproductiva y cacería de la tortuga *Trachemys scripta* (Testudinata: Emydidae), en el área de la Depresión Momposina, norte de Colombia. Revista de Biología Tropical **52**:229-238.

Musick, J. A. 1999. Ecology and conservation of long-lived marine animals. American Fisheries Society Symposium **23**:1-10.

Myers, N. 1983. A priority-ranking strategy for threatened species? The Environmentalist **3**:97-120.

Nazarea, V., R. Rhoades, E. Bontoyan, and G. Flora. 1998. Defining indicators which make sense to local people: Intra-cultural variation in perceptions of natural resources. Human Organization **57**:159-170.

Nieuwolt-Dacanay, P. M. 1997. Reproduction in the western box turtle, *Terrapene ornata luteola*. Copeia **1997**:819-826.

NTPC. 2005. Draft territory parks and conservation master plan. Page 1. Northern Territory Parks & Conservation Masterplan.

O'Connor, C., M. Marvier, and P. Kareiva. 2003. Biological vs. social, economic and political priority-setting in conservation. Ecology Letters **6**:706-711.

Obbard, M. E., and R. J. Brooks. 1980. Nesting migrations of the Snapping Turtle (*Chelydra serpentina*). Herpetologica **36**:158-162.

Obbard, M. E., and R. J. Brooks. 1987. Prediction of the onset of the annual nesting season of the common snapping turtle, *Chelydra serpentina*. Herpetologica **43**:324-328.

Olsson, M., and R. Shine. 1997. The seasonal timing of oviposition in sand lizards (*Lacerta agilis*): why early clutches are better. Journal of Evolutionary Biology **10**:369-381.

Özdemir, A., O. Türkozan, and Ö. Güçlü. 2008. Embryonic mortality in loggerhead turtle (*Caretta caretta*) nests: a comparative study on Fethiye and Göksu delta beaches. Turkish Journal of Zoology **32**:287-292.

Packard, G. C. 1999. Water relations of chelonian eggs and embryos: Is wetter better? American Zoologist **39**:289-303.

Packard, G. C., K. Miller, M. J. Packard, and G. F. Birchard. 1999. Environmentally induced variation in body size and condition in hatchling snapping turtles (*Chelydra serpentina*). Canadian Journal of Zoology **77**:278-289.

Packard, G. C., and M. J. Packard. 1988. The physiological ecology of reptilian eggs and embryos. Pages 523-605 in C. Gans, and R. B. Huey, editors. Biology of Reptilia, Ecology B, Defense and Life History. Alan R. Liss, New York, USA.

Paladino, F. V., M. P. O'Connor, and J. R. Spotila. 1990. Metabolism of leatherback turtles, gigantothermy, and thermoregulation of dinosaurs. Nature **344**:858-860.

Palumbi, S. R. 2002. The evolution explosion: how humans cause rapid evolutionary change. WW Norton & Company, New York, USA.

Parker, F. 1981. Collecting, export, import, research and filming involving wildlife in Papua New Guinea. Wildlife Papua New Guinea Wildlife Publications **81**:1–58.

Patino-Martinez, J., A. Marco, L. Quiñones, and B. Godley. 2008. Globally significant nesting of the leatherback turtle (*Dermochelys coriacea*) on the Caribbean coast of Colombia and Panama. Biological Conservation **141**:1982-1988.

Pauza, M. 2003. The pig-nosed turtle project. Report to the World Wide Fund for Nature Boroko, Papua New Guinea.

Pelto G. H., and L. A. Vargas. 1992. Introduction: Dietary change and nutrition. Ecology of Food and Nutrition **27**:159-161.

Pernetta, J. C., and S. Burgin. 1980. Census of crocodile populations and their exploitation in the Purari area (with an annotated checklist of the herpetofauna). Purari River (Wabo) Hydroelectric Scheme Environmental Study **14**:1–44.

Pigliucci, M., and C. J. Murren. 2003. Perspective: genetic assimilation and a possible evolutionary paradox: Can macroevolution sometimes be so fast as to pass us by? Evolution **57**:1455-1464.

Pimbert, M. P., and J. N. Pretty. 1998. Diversity and sustainability in community based conservation. Pages 58-77 in A. Kothari, N. Pathak, R. V. Anuradha, and B. Taneja, editors. Communities and conservation: natural resource management in South and Central Asia. Sage Publications, New Delhi, India.

Pimm, S. L. 1991. The balance of nature?: ecological issues in the conservation of species and communities. The University of Chicago Press, Chicago, USA.

Pimm, S. L., G. J. Russell, J. L. Gittleman, and T. M. Brooks. 1995. The future of biodiversity. Science **269**:347-350.

Plummer, M. V. 1976. Some aspects of nesting success in the turtle, *Trionyx muticus*. Herpetologica **32**:353-359.

Plummer, M. V., C. E. Shadrix, and R. C. Cox. 1994. Thermal limits of incubation in embryos of softshell turtles (*Apalone mutica*). Chelonian Conservation and Biology **1**:141-144.

Portal, R. L., V. L. Luz, and J. E. L. Medonça. 2005. Avaliação do processo de nidificação das espécies do gênero *Podocnemis – P. expansa* Schweigger, 1812; *P. unifilis* Troschel, 1848 (Testudines, Podocnemididae) na região estuarina do Amapá e Pará – Brasil. Série Quelônios **1**:5-30.

Powles, H., M. J. Bradford, R. G. Bradford, W. G. Doubleday, S. Innes, and C. D. Levings. 2000. Assessing and protecting endangered marine species. ICES Journal of Marine Science **57**:669-676.

Pritchard, P. C. H. 2001. Observations on body size, sympatry, and niche divergence in softshell turtles (Trionychidae). Chelonian Conservation and Biology **4**:5-27.

Pritchard, P. C. H., and P. Trebbau 1984. The turtles of Venezuela. Society for the Study of Amphibians and Reptiles, Caracas, Venezuela.

Ramo, C. 1982. Biología del Galápago (*Podocnemis vogli* Muller, 1935) en el hato" El Frío", Llanos de Apure, Venezuela. Doñana Acta Vertebrata **9**:1-161.

Receveur, O., M. Boulay, and H. V. Kuhnlein. 1997. Decreasing traditional food use affects diet quality for adult Dene/Metis in 16 communities of the Canadian Northwest Territories. The Journal of Nutrition **127**:2179-2186.

Restrepo, V. R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31, Washington D.C., USA.

Reznick, D. N., and C. K. Ghalambor. 2001. The population ecology of contemporary adaptations: what empirical studies reveal about the conditions that promote adaptive evolution. Genetica **112**:183-198.

Rhen, T., and J. W. Lang. 1998. Among-family variation for environmental sex determination in reptiles. Evolution **52**:1514-1520.

Rhen, T., and J. W. Lang. 1999. Temperature during embryonic and juvenile development influences growth in hatchling snapping turtles, *Chelydra serpentina*. Journal of Thermal Biology **24**:33-41.

Rhodin, A. G. J., and V. R. Genorupa. 2000. Conservation status of freshwater turtles in Papua New Guinea. Chelonian Research Monographs **2**:129-136.

Rhodin, A. G. J., P. C. H. Pritchard, P. P. van Dijk, R. A. Saumure, K. A. Buhlmann, J. B. Iverson, and R. A. Mittermeier. 2009. Turtles of the world: Annotated checklist of taxonomy and synonymy, 2009 update, with conservation status summary. Chelonian Research Monographs:39-84.

Rhodin, A. G. J., and S. D. Rhodin. 1977. Iakttagelser fran en herpetologisk samlingsresa till Papua New Guinea. Snoken-National Swedish Herpetological Association **7**:65-72.

Ricciardi, A., and J. B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. Conservation Biology **13**:1220-1222.

Ricker, W. E. 1945. A Method of estimating minimum size limits for obtaining maximum yield. Copeia **1945**:84-94.

Roberge, J. M., and P. Angelstam. 2004. Usefulness of the umbrella species concept as a conservation tool. Conservation Biology **18**:76-85.

Robinson, J. G., and E. L. Bennett 2000. Hunting for sustainability in tropical forests. Columbia University Press, New York, USA.

Robinson, J. G., and E. L. Bennett. 2002. Will alleviating poverty solve the bushmeat crisis? Oryx **36**:332-332.

Roe, J. H., and A. Georges. 2007. Heterogeneous wetland complexes, buffer zones, and travel corridors: landscape management for freshwater reptiles. Biological Conservation **135**:67-76.

Roemer, G. W., C. J. Donlan, and F. Courchamp. 2002. Golden eagles, feral pigs, and insular carnivores: How exotic species turn native predators into prey. Proceedings of the National Academy of Sciences of the United States of America **99**:791 -796.

Roosenburg, W. M. 1996. Maternal condition and nest site choice: An alternative for the maintenance of environmental sex determination? American Zoologist **36**:157-168.

Roosenberg, W. M., and A. E. Dunham. 1997. Allocation of reproductive output: egg- and clutch-size variation in the diamondback terrapin. Copeia **1997**:290-297.

Rose, M., F. Parker, and A. G. J. Rhodin. 1982. New Guinea plateless turtle or pitted shell turtle (Fly River or pig-nosed turtle), *Carettochelys insculpta* Ramsay 1886. Pages 243–

246 in B. Groombridge, and L. Wright, editors. The IUCN Amphibia-Reptilia Red Data Book. Part 1, Testudines Crocodylia and Rhynchocephalia. IUCN, London, UK.

Ross, P. 1997. Biological basis and application of sustainable use for the conservation of crocodilians. Pages 182-187 in Memorias de la 4ta. Reunion Regional del Grupo de Especialistas de Cocodrilos de America Latina y el Caribe. Centro Regional de Inovacion Agroindustrial, S.C. Villahermosa, Tabasco, Mexico.

Rosser, A. M., and S. A. Mainka. 2002. Overexploitation and species extinctions. Conservation Biology **16**:584-586.

Rossiter, M. 1996. Incidence and consequences of inherited environmental effects. Annual Review of Ecology and Systematics **27**:451-476.

Rowe, J. W., K. A. Coval, and K. C. Campbell. 2003. Reproductive characteristics of female midland painted turtles (*Chrysemys picta marginata*) from a population on Beaver Island, Michigan. Copeia **2003**:326-336.

Samedi, A. R., and D. T. Iskandar. 2002. Utilization and trade in freshwater turtles and tortoises in Indonesia. Pages 25-28. Technical Workshop on Conservation of and Trade in Freshwater Turtles and Tortortoises in Asia Kunming, Peoples Republic of China.

Samedi, M. L., and D. T. Iskandar. 2000. Freshwater turtle and tortoise conservation and utilization in Indonesia. Chelonian Research Monographs **2**:106-111.

Sánchez-Villagra, M. R., R. J. Burham, D. C. Campbell, R, M. Feldmann, E, S. Gaffney, R. F. Kay, R. Lozsán, R. Purdy, and J. G. M. Thewissen. 2000. A near-shore marine fauna and flora from the early Neogene of northwestern Venezuela. Journal of Paleontology **74**:957-968.

Satake, A., A. Sasaki, and Y. Iwasa. 2001. Variable timing of reproduction in unpredictable environments: adaption of flood plain plants. Theoretical Population Biology **60**:1-15.

Saunders, D. L., J. J. Meeuwig, and A. C. J. Vincent. 2002. Freshwater protected areas: strategies for conservation. Conservation Biology **16**:30-41.

Schwarzkopf, L., and R. J. Brooks. 1985. Sex determination in northern painted turtles: effect of incubation at constant and fluctuating temperatures. Canadian Journal of Zoology **63**:2543-2547.

Schultze-Westrum, T. 1963. Die Papuaschildkröte aus Neuguinea. Natur und Museum, Frankfurt **93**:119-127.

Shaffer, H. B. 2009. Turtles (Testudines). Pages 398-401 in S. B. Hedges, and S. Kumar, editors. The time tree of life. Oxford University Press, Oxford, UK.

Shepherd, C. R., and V. Nijman. 2007. An overview of the regulation of the freshwater turtle and tortoise pet trade in Jakarta, Indonesia. TRAFFIC Southeast Asia, Kuala Lumpur, Malaysia.

Shine, R. 1983. Reptilian viviparity in cold climates: testing the assumptions of an evolutionary hypothesis. Oecologia **57**:397-405.

Shine, R. 1987. Intraspecific variation in thermoregulation, movements and habitat use by Australian blacksnakes, *Pseudechis porphyriacus* (Elapidae). Journal of Herpetology **21**:165-177.

Short, J. 1998. The extinction of rat-kangaroos (Marsupialia: Potoroidae) in New South Wales, Australia. Biological Conservation **46**:365-377.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological conservation **83**:247-257.

Simon, C. A. 1975. The influence of food abundance on territory size in the iguanid lizard *Sceloporus jarrovi*. Ecology **56**:993-998.

Sminkey, T. R., and J. A. Musick. 1996. Demographic analysis of the sandbar shark, *Carcharhinus plumbeus*, in the western North Atlantic. Fishery Bulletin **94**:341-347.

Smith, N. J. H. 1979. Aquatic turtles of Amazonia: an endangered resource. Biological Conservation **16**:165-179.

Sodhi, N. S., L. P. Koh, B. W. Brook, and P. K. L. Ng. 2004. Southeast Asian biodiversity: an impending disaster. Trends in Ecology & Evolution **19**:654-660.

Sokal, R. R., and F. J. Rohlf 1981. Biometry. The principles and practice of statistics in biological research, 859 pp. WH Freeman, New York, USA.

Souza, F. L., and A. S. Abe. 2000. Feeding ecology, density and biomass of the freshwater turtle, *Phrynops geoffroanus*, inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology **252**:437-446.

Spencer, R.-J. 2002. Experimentally testing nest site selection: fitness trade-offs and predation risk in turtles. Ecology **83**:2136-2144.

Spencer, R.-J., and M. B. Thompson. 2003. The significance of predation in nest site selection of turtles: an experimental consideration of macro- and microhabitat preferences. Oikos **102**:592-600.

Stamps, J., and S. Tanaka. 1981. The influence of food and water on growth rates in a tropical lizard (*Anolis Aeneus*). Ecology **62**:33-40.

Stearns, S. C. 1976. Life-history tactics: a review of the ideas. The Quarterly Review of Biology **51**:3-47.

Stockwell, C. A., A. P. Hendry, and M. T. Kinnison. 2003. Contemporary evolution meets conservation biology. Trends in Ecology & Evolution **18**:94-101.

Stoneburner, D. L., and J. I. Richardson. 1981. Observations on the role of temperature in loggerhead turtle nest site selection. Copeia **1981**:238-241.

Story, R., R. W. Galloway, J. R. McAlpine, J. M. Aldrick, and M. A. J. Williams. 1976. Lands of the Alligator River Area, Northern Territory [Australia; land systems, climate and water balance, geology, geomorphology, soils, vegetation, erosion, land use]. Land Research Series-Commonwealth Scientific and Industrial Research Organization (Australia).

Story, R., M. A. J. Williams, A. D. L. Hooper, R. E. O'Ferrall, and M. J. R. 1969. Lands of the Adelaide-Alligator area, Northern Territory. Land Research Series Number 25. CSIRO (Commonwealth Scientific and Industrial Research Organization), Melbourne, Australia.

Stubbs, D. 1989. Tortoises and freshwater turtles: an action plan for their conservation. IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Canterbury, UK.

Swingland, I. R., and M. Coe. 1978. The natural regulation of giant tortoise populations on Aldabra Atoll. Reproduction. Journal of Zoology **186**:285-309.

Taylor, J. A., and D. O. N. Tulloch. 1985. Rainfall in the wet-dry tropics: extreme events at Darwin and similarities between years during the period 1870–1983 inclusive. Austral Ecology **10**:281-295.

Thom, B. G., and L. D. Wright. 1983. Geomorphology of the Purari Delta. Pages 47-65 in T. Petr, editor. The Purari – Tropical environment of a high rainfall river basin. Dr W. Junk Publishers, The Hague, Netherlands.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. Townsend Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature **427**:145-148.

Thompson, M. B. 1983. Populations of the Murray River tortoise, *Emydura* (Chelodina): the effect of egg predation by the red fox, *Vulpes vulpes*. Wildlife Research **10**:363-371.

Thompson, M. B. 1988. Nest temperatures in the pleurodiran turtle, *Emydura macquarii*. Copeia **1988**:996-1000.

Thorbjarnarson, J. B., N. Perez, and T. Escalona. 1993. Nesting of *Podocnemis unifilis* in the Capanaparo River, Venezuela. Journal of Herpetology **27**:344-347.

Thorbjarnarson, J. 1999. Crocodile tears and skins: international trade, economic constraints, and limits to the sustainable use of crocodilians. Conservation Biology **13**:465-470.

Tomillo, P. S., V. S. Saba, R. Piedra, F. V. Paladino, and J. R. Spotila. 2008. Effects of illegal harvest of eggs on the population decline of leatherback turtles in Las Baulas Marine National Park, Costa Rica. Conservation Biology **22**:1216-1224.

Townsend, W. R., A. Randall Borman, E. Yiyoguaje, and L. Mendua. 2005. Cofán Indians' monitoring of freshwater turtles in Zábalo, Ecuador. Biodiversity and Conservation **14**:2743-2755.

TSSC. 2005. Pig-nosed turtle (*Carettochelys insculpta*) advice to the Minister for the environment and heritage on amendments to the list of threatened species under the environment protection and biodiversity conservation act 1999. Department of the Environment, Water, Heritage and the Arts, http://www.environment.gov.au /biodiversity/threatened/species/pig-nosed-turtle.html (accessed February 2010).

Tucker, J. K., F. J. Janzen, and G. L. Paukstis. 1997. Response of embryos of the red-eared turtle (*Trachemys scripta elegans*) to experimental exposure to water-saturated substrates. Chelonian Conservation and Biology **2**:345-351.

Tucker, J. K., and D. Moll. 1997. Growth, reproduction, and survivorship in the red-eared turtle, *Trachemys scripta elegans*. Chelonian Conservation and Biology **2**:352-357.

Turner, F. B., P. A. Medica, and C. L. Lyons. 1984. Reproduction and survival in the desert tortoise (*Scaptochelys agassizii*) in Ivanpah Valley. Copeia **1984**:811-820.

USFWS. 2003. Singapore man sentenced to over three years in jail for illegally smuggling wildlife. U. S. Fish and Wildlife Service – Green Environment Place, http://www.fws.gov/southeast/news/2003/r03-140.html (acessed August 2010),

Valenzuela, N. 2001. Maternal effects on life-history traits in the amazonian giant river turtle *Podocnemis expansa*. Journal of Herpetology **35**:368-378.

Valenzuela, N. 2005. Temperature-dependent sex determination. Pages 229-252 in D. C. Deeming, editor. Reptilian incubation environment, evolution and behaviour. Nottingham University Press, Nottingham. UK.

Valenzuela, N., and F. J. Janzen. 2001. Nest-site philopatry and the evolution of temperature-dependent sex determination. Evolutionary Ecology Research **3**:779-794.

Valenzuela, N., and V. A. Lance 2005. Temperature-dependent sex determination in vertebrates. Smithsonian Institution, Washington, DC, USA.

van Dijk, P. P. 2009. Red list – *Carettochelys insculpta* – draft. IUCN, Washington D. C., USA.

van Dijk, P. P., D. T. Iskandar, and T. Palasuwan. 2000. Turtle trade in southeast asia: regional summary (Indonesia, Malaysia, Papua New Guinea, and Thailand). Chelonian Research Monographs **2**:145-147.

Vié, J.-C., C. Hilton-Taylor, and S. N. Stuart 2009. Wildlife in a Changing World: An Analysis of the 2008 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of earth's ecosystems. Science **277**:494-499.

Vitt, L. J., and J. D. Congdon. 1978. Body shape, reproductive effort, and relative clutch mass in lizards: Resolution of a paradox. The American Naturalist **112**:595-608.

Vogt, R. C., and J. J. Bull. 1984. Ecology of hatchling sex ratio in map turtles. Ecology **65**:582-587.

Vogt, R. C., and O. Flores-Villela. 1992. Effects of incubation temperature on sex determination in a community of neotropical freshwater turtles in southern Mexico. Herpetologica **48**:265-270.

Wake, D. B., and V. T. Vredenburg. 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences **105**:11466-11473

Walker, W. E. 1973. The locomotor apparatus of Testudines in C. Gans, and T. S. Parsons, editors. Biology of the Reptilia. Academic Press New York, New York, USA.

Wallace, B. P., and V. S. Saba. 2009. Environmental and anthropogenic impacts on intra-specific variation in leatherback turtles: opportunities for targeted research and conservation. Endangered Species Research **7**:11-21.

Wardlow, H. 2007. Men’s Extramarital Sexuality in Rural Papua New Guinea. American Journal of Public Health **97**:1006-1014.

Warner, M. 2000. Conflict management in community-based natural resource projects: experiences from Fiji and Papua New Guinea. Working Paper 135. Overseas Development Institute (ODI), London, UK.

Webb, G. J. W., D. Choquenot, and P. J. Whitehead. 1986. Nests, eggs, and embryonic development of *Carettochelys insculpta* (Chelonia: Carettochelidae [Carettochelydidae]) from northern Australia. Journal of Zoology, London 1B **1**:521-550.

Webb, G. J. W., H. Messel, and W. Magnusson. 1977. The Nesting of *Crocodylus porosus* in Arnhem Land, Northern Australia. Copeia **1977**:238-249.

Welsh, M. 1999. Resource partitioning among the freshwater turtles of the Daly River, Northern Territory. Honours thesis, University of Canberra., Canberra, Australia.

Western, D. 1987. Africa's elephants and rhinos: flagships in crisis. Trends in Ecology & Evolution **2**:343-346.

Whiting, A. U., A. Thomson, M. Chaloupka, and C. J. Limpus. 2008. Seasonality, abundance and breeding biology of one of the largest populations of nesting flatback turtles, *Natator depressus*: Cape Domett, Western Australia. Australian Journal of Zoology **56**:297-303.

Whitmore, C. P., and P. H. Dutton. 1985. Infertility, embryonic mortality and nest-site selection in leatherback and green sea turtles in Suriname. Biological Conservation **34**:251-272.

Wibbels, T., J. Cowan, and R. LeBoeuf. 1998. Temperature-dependent sex determination in the red-eared slider turtle, *Trachemys scripta*. Journal of Experimental Zoology Part A: Comparative Experimental Biology **281**:409-416.

Wilcox, B. A. 1984. In situ conservation of genetic resources: determinants of minimum area requirements. Pages 639-647 in J. A. McNeely, and K. R. Miller, editors. National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Smithsonian Institution Press, Washington D.C., USA.

Wilson, D. S. 1998. Nest-site selection: Microhabitat variation and its effect on the survival of turtle embryos. Ecology **79**:1884-1892.

Wilson, D. S., H. R. Mushinsky, and E. D. McCoy. 1999. Nesting behavior of the striped mud turtle, *Kinosternon baurii* (Testudines: Kinosternidae). Copeia **1999**:958-968.

Winemiller, K. O., and M. A. Leslie. 1992. Fish assemblages across a complex, tropical freshwater/marine ecotone. Environmental Biology of Fishes **34**:29-50.

Winkler, J. D, and M. R Sánchez-Villagra. 2006. A nesting site and egg morphology of a Miocene turtle from Urumaco, Venezuela: evidence of marine adaptations in pelomedusoides. Palaeontology **4**: 641-646.

Witherington, B. E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica **48**:31-39.

Witherington, B. E., K. Bjorndal, and C. M. McCabe. 1990. Temporal patterns of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copeia **1990**:1165-1168.

Wolak, M. E., G. W. Gilchrist, V. A. Ruzicka, D. M. Nally, and R. M. Chambers. 2010. A contemporary, sex-limited change in body size of an estuarine turtle in response to commercial fishing. Conservation Biology:(Article online in advance of print).

Wolanski, E., D. Williams, S. Spagnol, and H. Chanson. 2004. Undular tidal bore dynamics in the Daly Estuary, Northern Australia. Estuarine, Coastal and Shelf Science **60**:629-636.

Wood, D. W., and K. A. Bjorndal. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. Copeia **2000**:119-128.

Wright, L. D. 1989. Dispersal and deposition of river sediments in coastal seas: Models from Asia and the tropics. Netherlands Journal of Sea Research **23**:493-500.

Wurm, S. A., and S. Hattori 1981. Language Atlas of the Pacific Area. Australian Academy of the Humanities and the Japanese Academy, Canberra, Australia.

Yerli, S., A. F. Canbolat, L. J. Brown, and D. W. Macdonald. 1997. Mesh grids protect loggerhead turtle *Caretta caretta* nests from red fox *Vulpes vulpes* predation. Biological Conservation **82**:109-111.

Young, B. A., B. Walker, A. E. Dixon, and V. A. Walker. 1989. Physiological adaptation to the environment. Journal of Animal Science **67**:2426-2432.

Young, J. E., A. Georges, J. S. Doody, P. B. West, and R. L. Alderman. 2004. Pivotal range and thermosensitive period of the pig-nosed turtle, *Carettochelys insculpta* (Testudines: Carettochelydidae), from northern Australia. Canadian Journal of Zoology **82**:1251-1257.

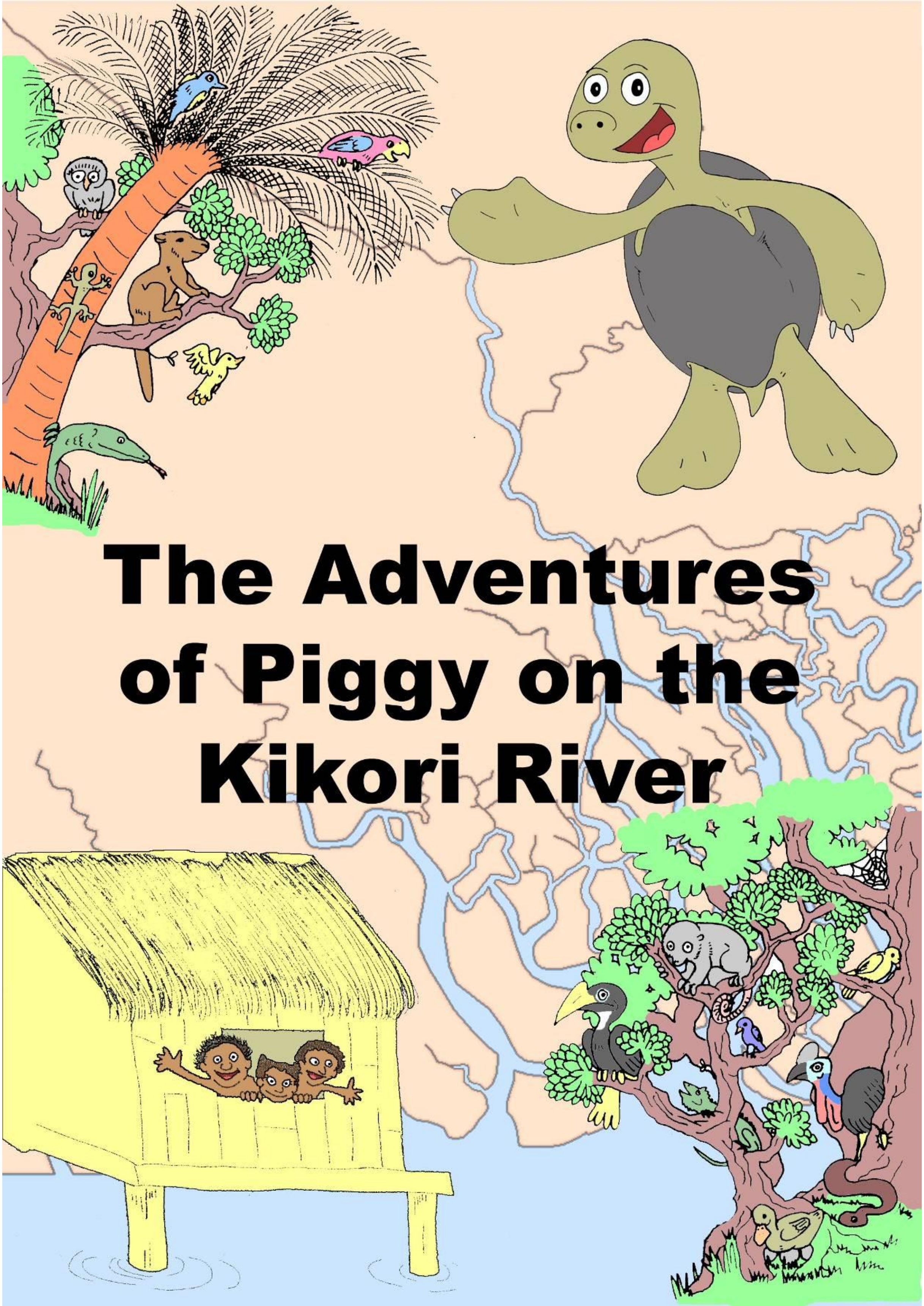
Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall Inc, Englewood Clifffs, USA.

Appendix I

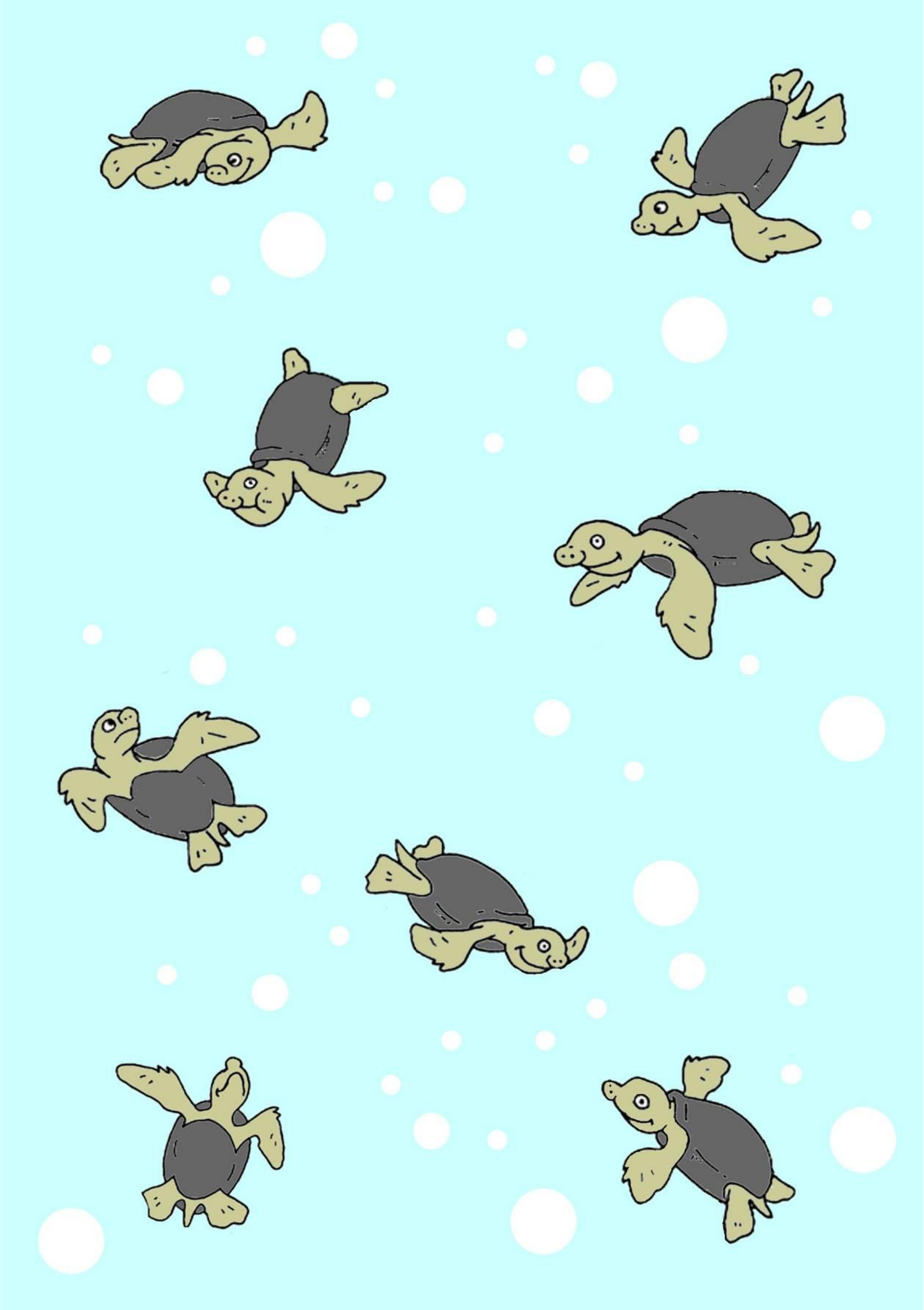
Eisemberg, C. C., Perini, F. A. & Georges, A. 2008. The Adventures of Piggy on the Kikori River. Institute for Applied Ecology, Canberra, Australia. (ISBN 978 0 646 50191 8)

Child from Babaguna (Kerewo tribe), paddling home after receiving his copy of the book "The Adventures of Piggy on the Kikori River"

Photo by Ricardo França Silva



The Adventures of Piggy on the Kikori River



Citation details:
Eisemberg, C. C., Perini, F. A. and Georges, A. (2008). The adventures of Piggy on the Kikori River. Book prepared by the Institute for Applied Ecology. Canberra, ACT, Australia. ISBN 978 0 646 50191 8.

Address for correspondence:
Carla C. Eisemberg, MsC.
Institute for Applied Ecology,
University of Canberra ACT 2601 Australia
Phone +61 2 62012937 (Mobile 0448348754)
Email: eisemberg@aerg.canberra.edu.au

Sponsored by:

U C

OIL SEARCH LIMITED

WWF

Materials development team:

Authors: Carla Camilo Eisemberg
Fernando Araújo Perini
Arthur Georges

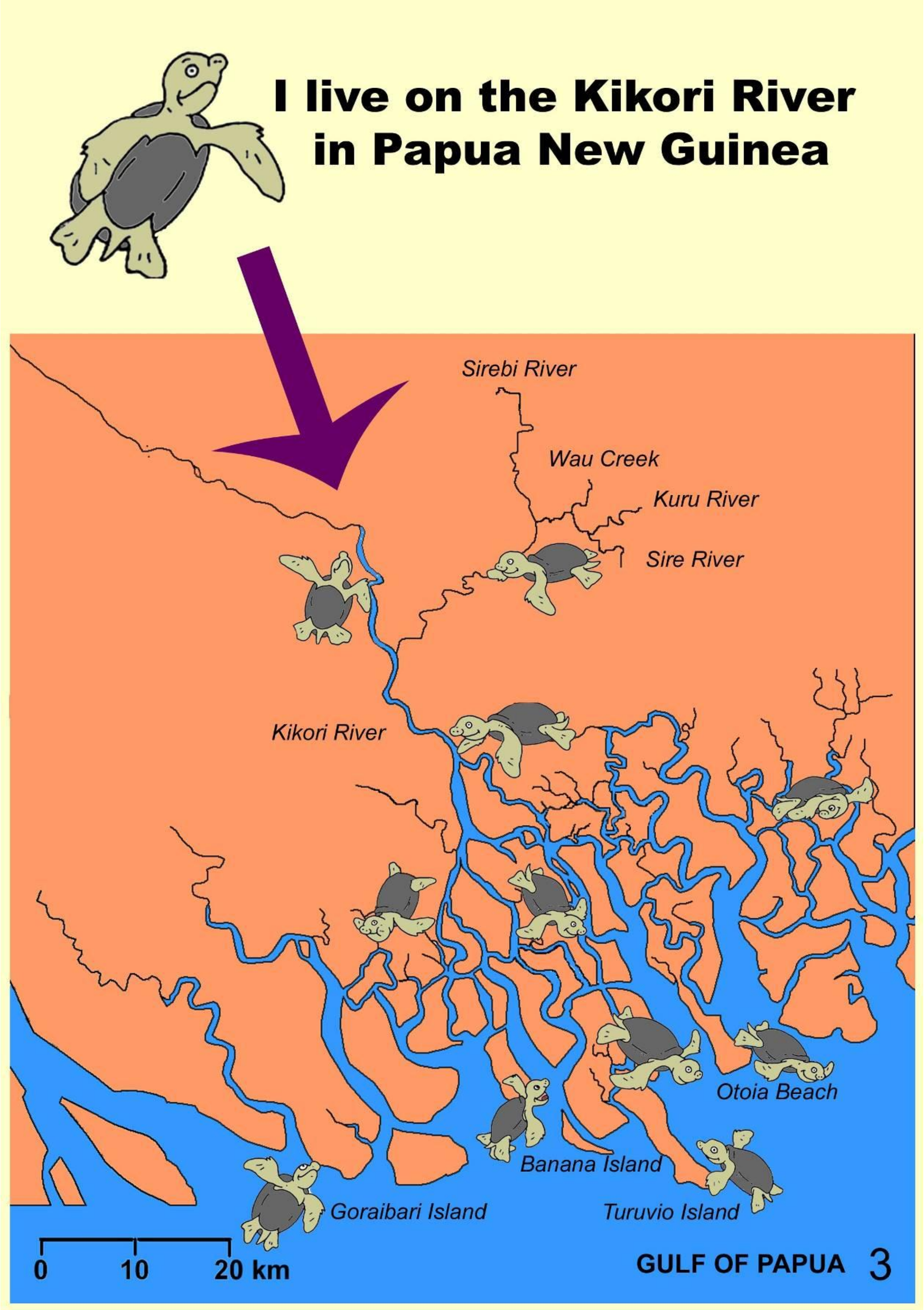
Illustrator: Fernando Araújo Perini

Printed by: CPP Instant Print, 28 Pirie Street, Fyshwick, 2609, Canberra, ACT.

ISBN 978 0 646 50191 8

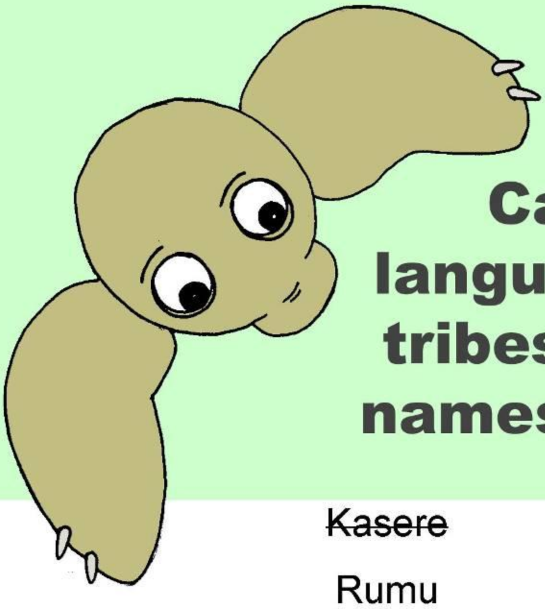
Hi! My name is Piggy

2


I live on the Kikori River
in Papua New Guinea
Sirebi River
Wau Creek
Kuru River
Sire River
Kikori River
Otoia Beach
Banana Island
Goraibari Island
Turuvio Island
0
10
20 km
GULF OF PAPUA
3

Each tribe that lives on the Kikori River gives me a different name:

Tribe		Piggy’s name
Kasere	→	*Kaso-Uwo*
Rumu	→	*Piku*
Kibiri	→	*Watemui*
Porome	→	*Watemu*
Kerewo	→	*Uwo*
Urama	→	*Waema*



Can you find the languages of the Kikori tribes and my different names in the box below?

~~Kasere~~

Rumu

Kibiri

Porome

Kerewo

Urama

Kaso-Uwo

Piku

Watemui

Watemu

Uwo

Waema

K	P	N	W	C	A	W	T	K	A	S	O	U	W	O	A
A	M	E	N	E	E	A	M	W	T	M	P	Z	B	F	G
S	K	W	D	Q	Y	T	I	O	K	N	G	P	E	R	E
E	T	Y	L	Q	K	E	A	H	E	R	C	R	P	A	O
R	B	B	R	O	P	M	M	G	R	M	S	U	C	T	R
E	C	D	M	Z	A	U	G	K	E	T	G	M	E	J	S
L	A	L	S	W	M	I	I	U	W	P	A	U	L	G	W
Y	E	M	L	H	E	V	N	Y	O	W	X	R	A	O	L
X	U	E	W	R	V	U	E	T	I	A	E	S	U		P
P	W	Q	M	F	M	Q	B	Y	M	W	A	T	E	M	U
V	O	O	X	P	K	I	B	I	R	I	U	R	S	G	P
K	O	R	N	A	S	T	M	V	L	D	R	A	F	W	A
S	M	O	U	R	A	M	A	U	P	A	C	K	M	A	C
F	G	M	N	V	V	Z	P	M	I	R	A	I	G	E	C
A	W	Z	M	P	C	L	I	O	K	T	J	A	Z	M	E
P	O	R	O	M	E	K	U	X	U	M	I	W	Y	A	A

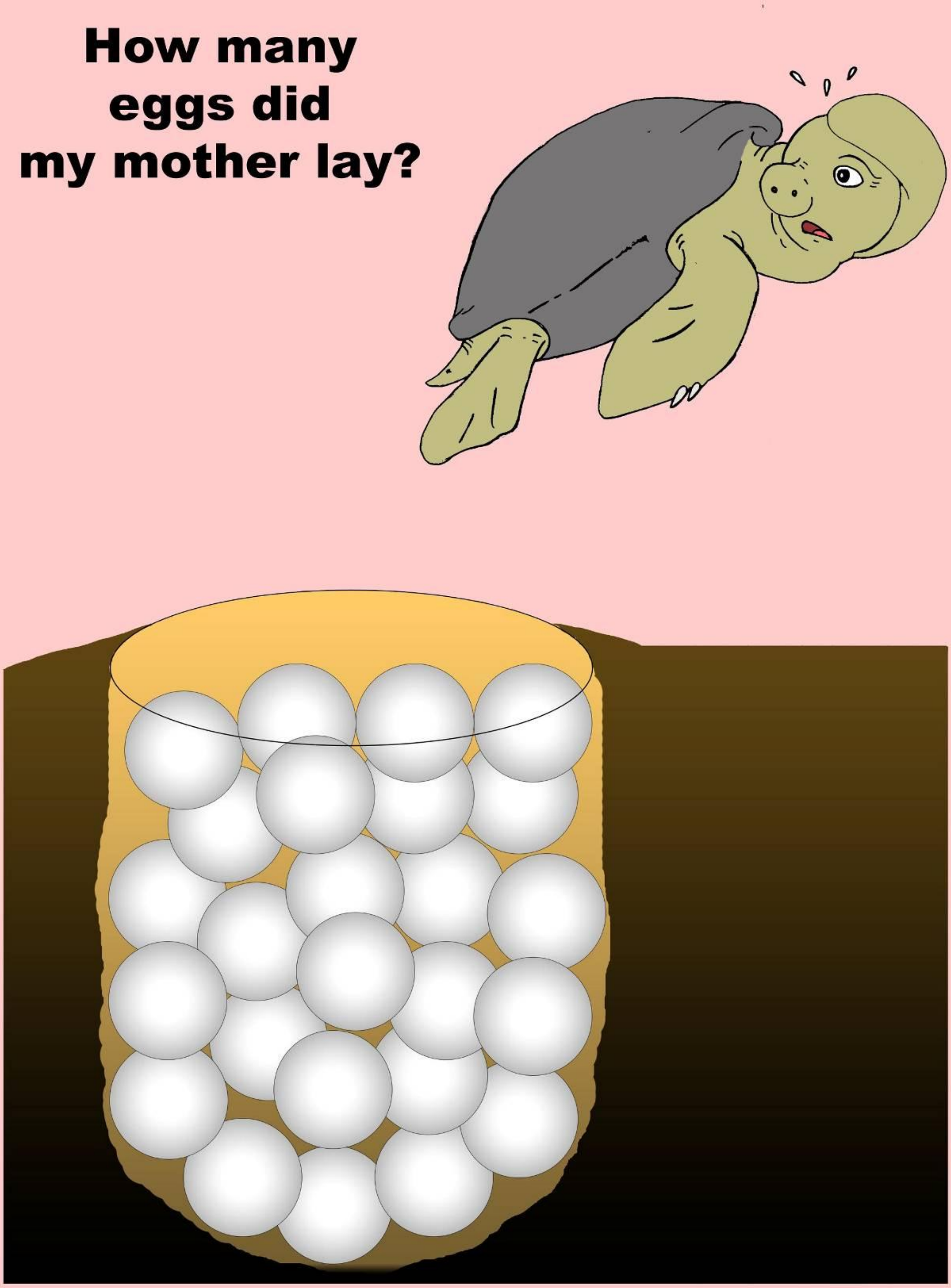
5

I hatched some years ago on a sand bank near the sea

But this is not the only place where turtles of my species lay their eggs

We can lay our nests on riverine or coastal sand banks

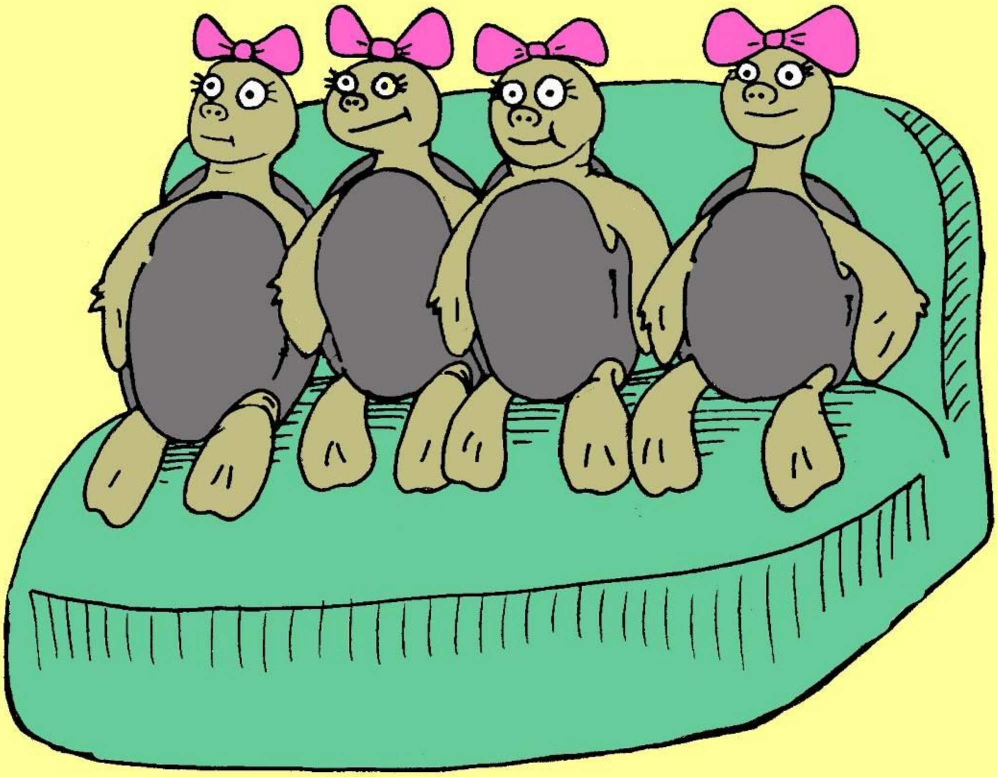
How many
eggs did
my mother lay?



7

My mother laid her eggs on a beach without trees and with hot sand

That is why I have only sisters



If my mother had made her nest on a beach with many trees and cold sand, we would all be boys

☾✎↯☾☺〰 🌨♥↯☺♫ 📚⚐🚹〰

💧↯⚐🚹 ✈⚐☾ ☼〰🐕📚✈〰♫

🐕🖃✋ ☾✎↯☾☺〰 ☼⚐🕒♫

💧↯⚐🚹 📚⚐☺✋ ☼〰🐕📚✈〰♫

Find out what secret my sisters are talking about:

A = 🐕

B = ☼

C = 📚

D = ✋

E = 〰

F = 💧

G = 🌨

H = ✈

I = ♥

L = ☺

M = 🚹

N = 🖃

O = ⚐

R = ↯

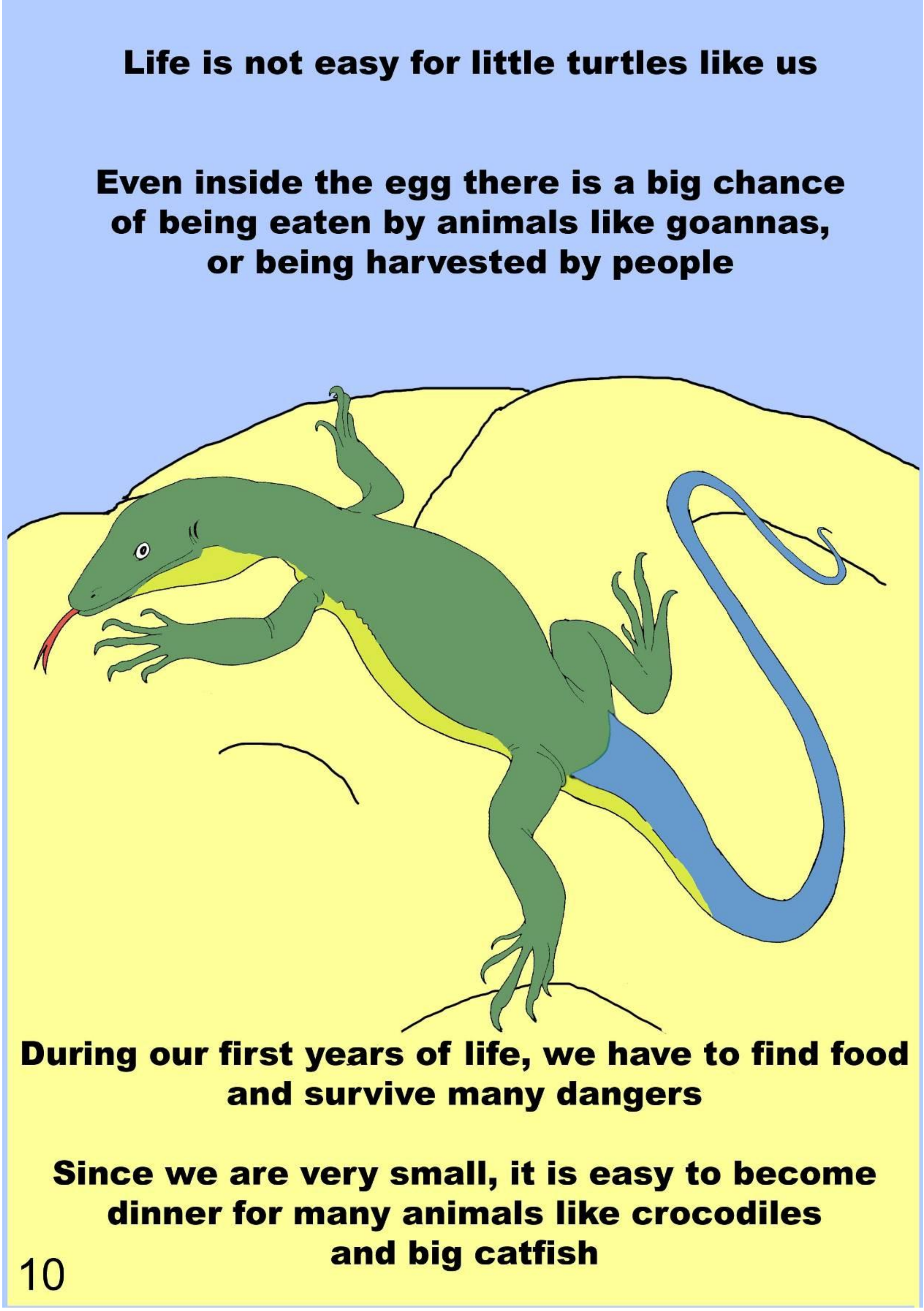
S = ♫

T = ☾

U = ✎

Y = 🕒

9



Life is not easy for little turtles like us

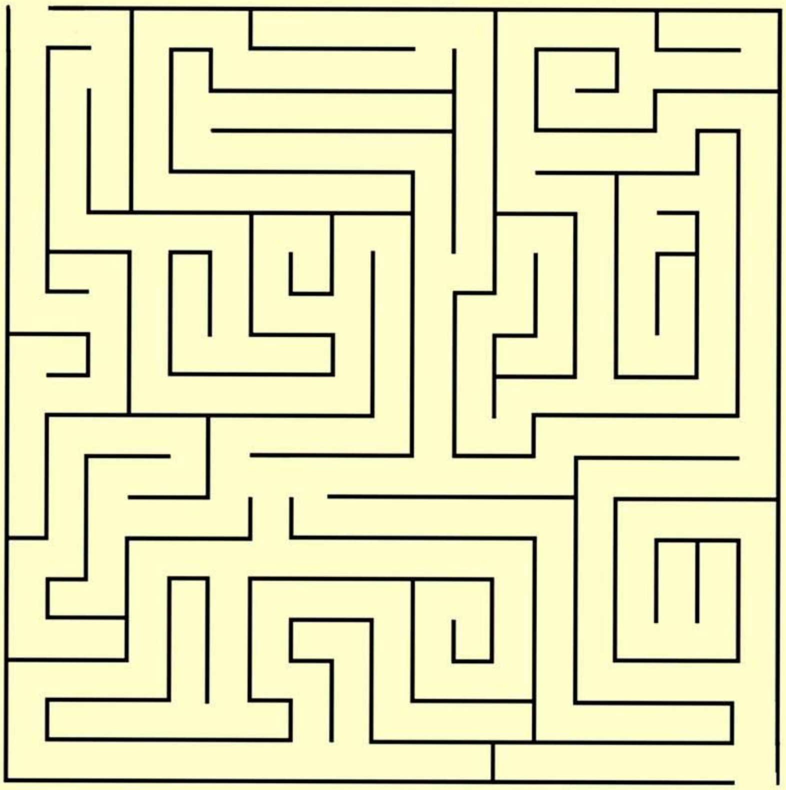
Even inside the egg there is a big chance
of being eaten by animals like goannas,
or being harvested by people

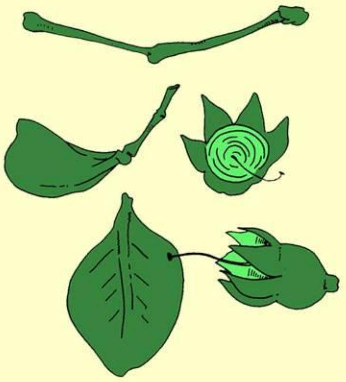
During our first years of life, we have to find food
and survive many dangers

Since we are very small, it is easy to become
dinner for many animals like crocodiles
and big catfish

10

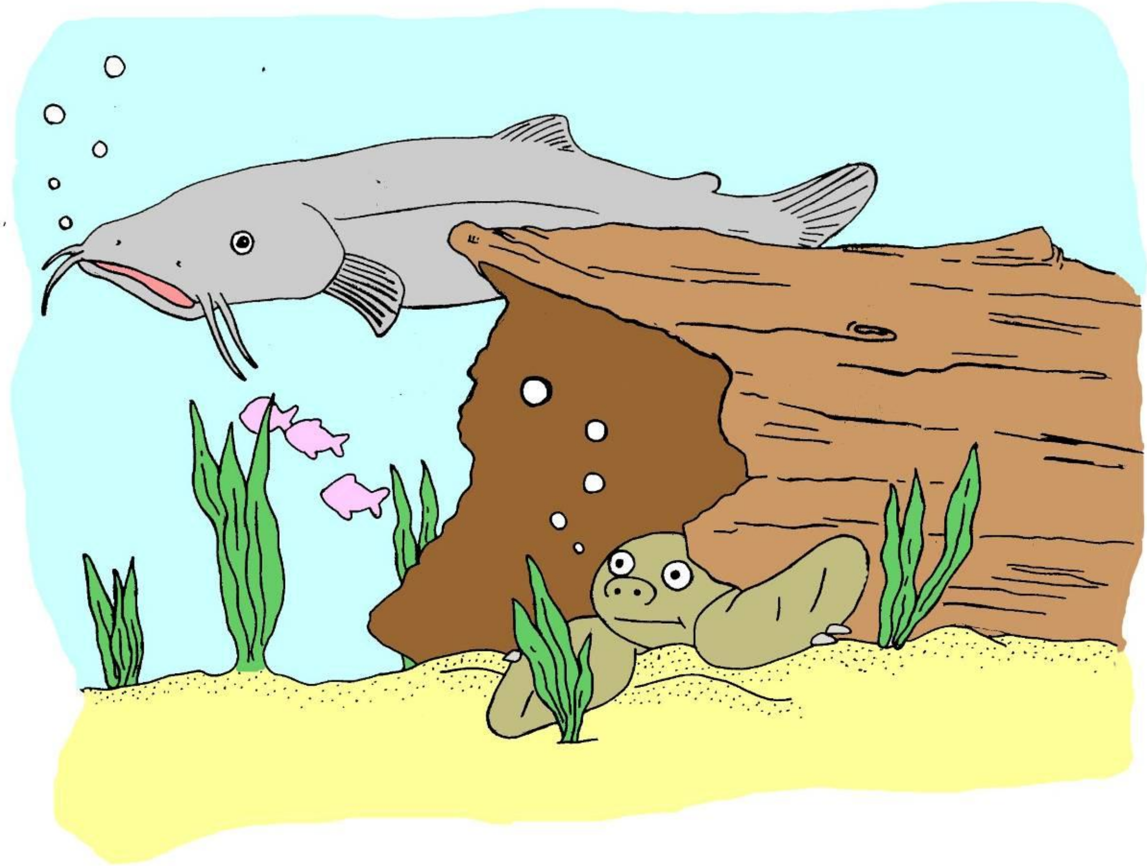
Help Piggy and her sisters to reach their food





11

Since I am very smart, I found a safe place with food to help me grow

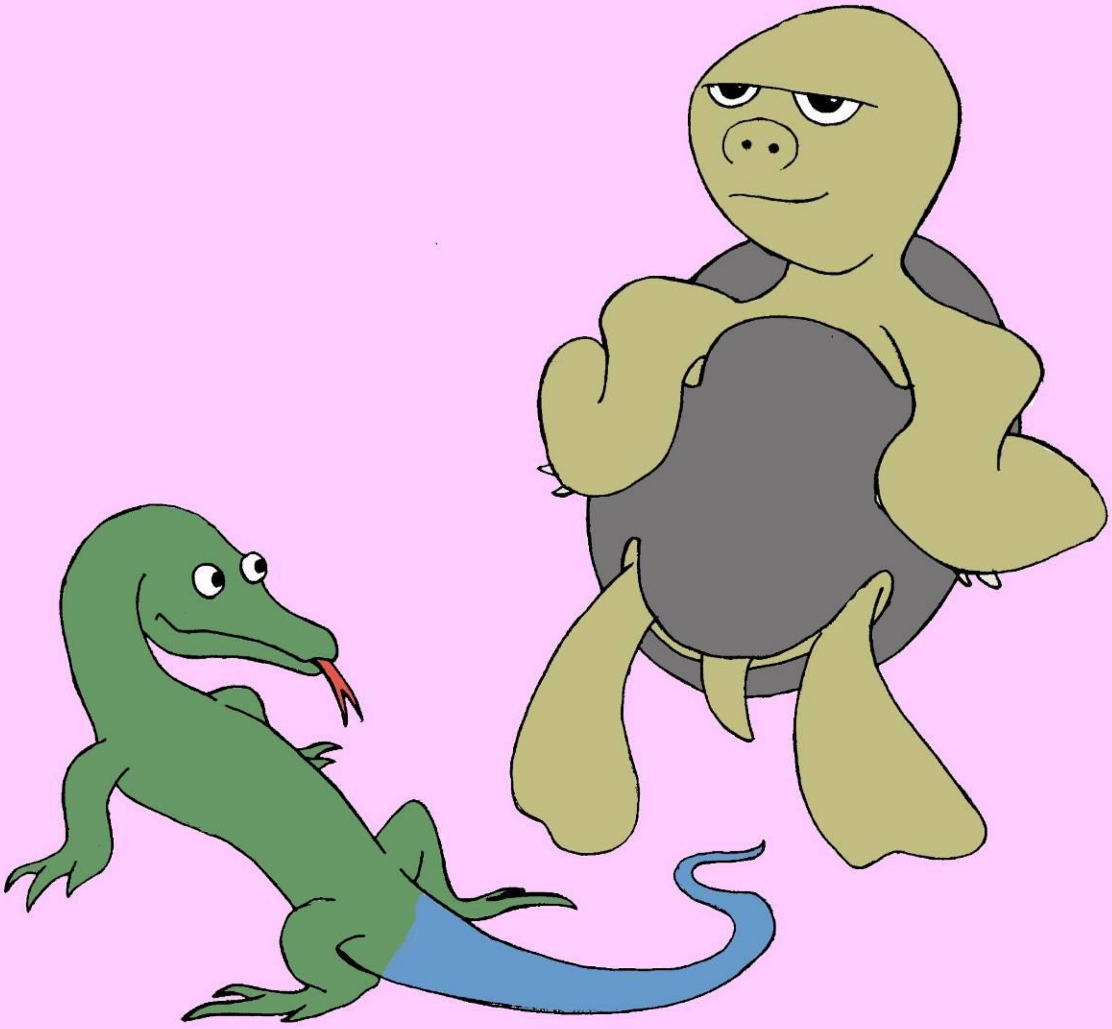


Unfortunately, most hatchlings do not have the same luck

12

Can you find Piggy and her sisters hidden here?

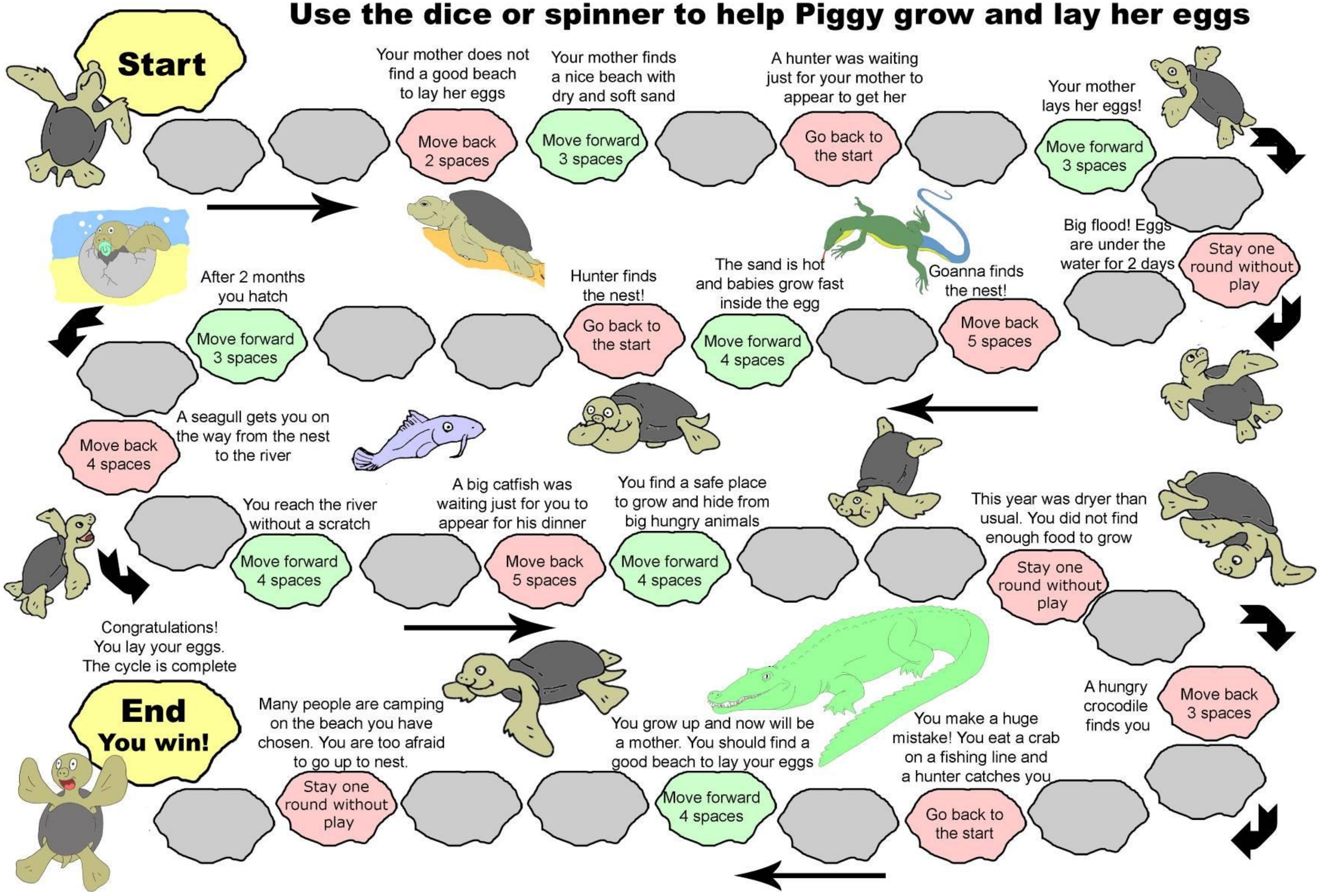
When I grow up, the risks decrease



Few animals are big and strong enough to break my hard shell

14

Welcome to Piggy's life!
Use the dice or spinner to help Piggy grow and lay her eggs



Your mother does not find a good beach to lay her eggs

Move back 2 spaces

Your mother finds a nice beach with dry and soft sand

Move forward 3 spaces

A hunter was waiting just for your mother to appear to get her

Go back to the start

Your mother lays her eggs!

Move forward 3 spaces

Big flood! Eggs are under the water for 2 days

Stay one round without play

Goanna finds the nest!

Move back 5 spaces

The sand is hot and babies grow fast inside the egg

Move forward 4 spaces

Hunter finds the nest!

Go back to the start

After 2 months you hatch

Move forward 3 spaces

A seagull gets you on the way from the nest to the river

Move back 4 spaces

You reach the river without a scratch

Move forward 4 spaces

A big catfish was waiting just for you to appear for his dinner

Move back 5 spaces

You find a safe place to grow and hide from big hungry animals

Move forward 4 spaces

This year was dryer than usual. You did not find enough food to grow

Stay one round without play

A hungry crocodile finds you

Move back 3 spaces

You make a huge mistake! You eat a crab on a fishing line and a hunter catches you

Go back to the start

You grow up and now will be a mother. You should find a good beach to lay your eggs

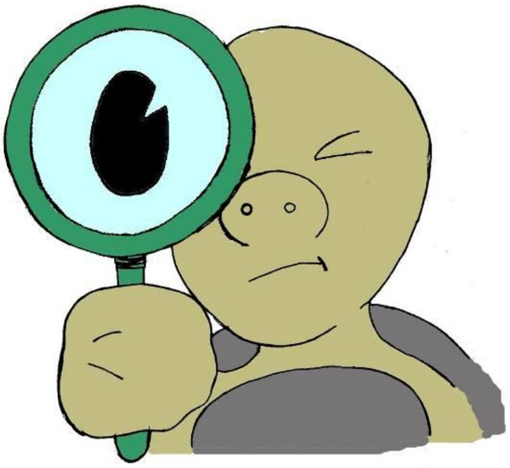
Move forward 4 spaces

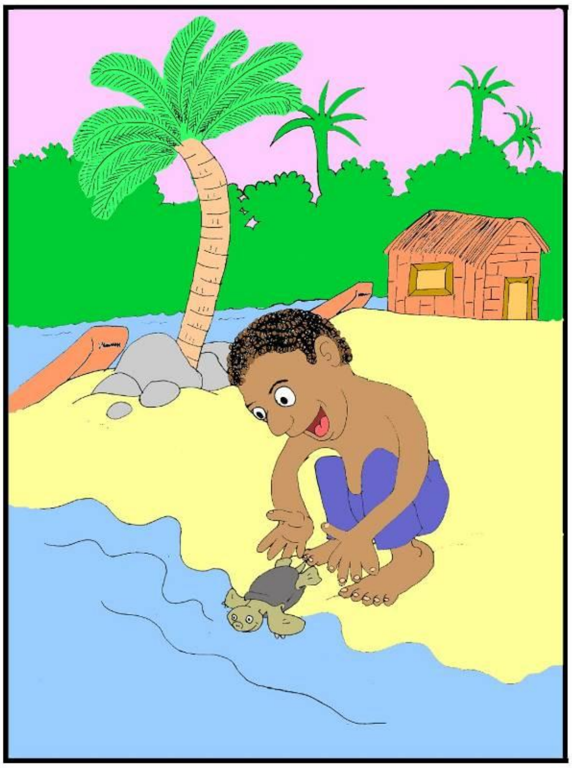
Many people are camping on the beach you have chosen. You are too afraid to go up to nest.

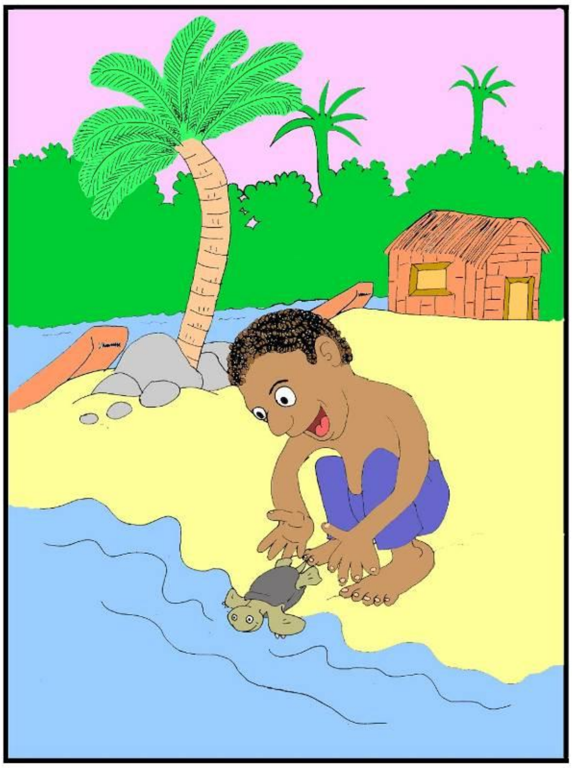
Stay one round without play

Congratulations! You lay your eggs. The cycle is complete

Can you find the 7 differences in these two drawings?







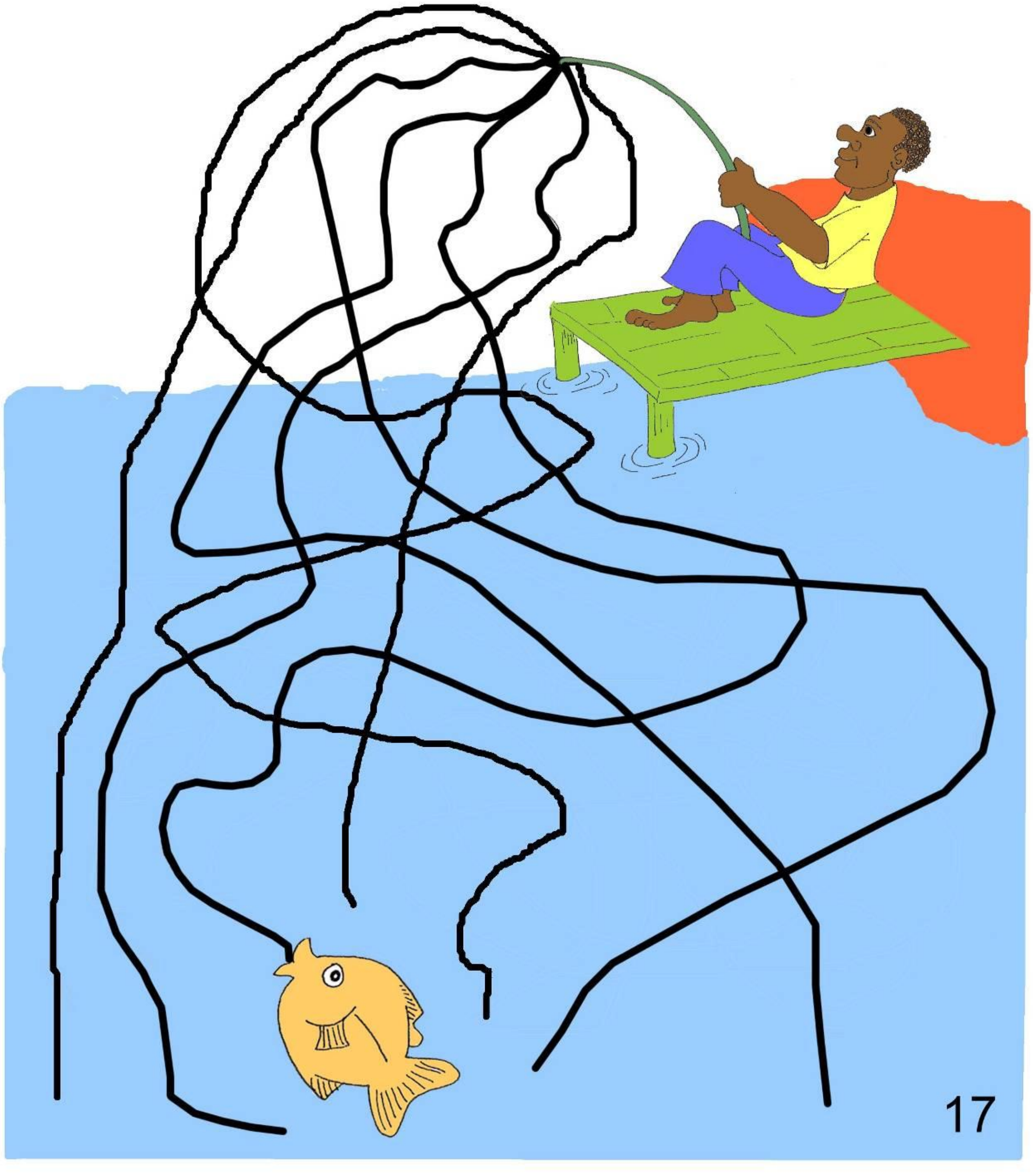
15

But this does not mean
that I can relax

I need to be always alert
to other threats

If I do not pay attention, I can
get caught by a hunter's
fishing line or net

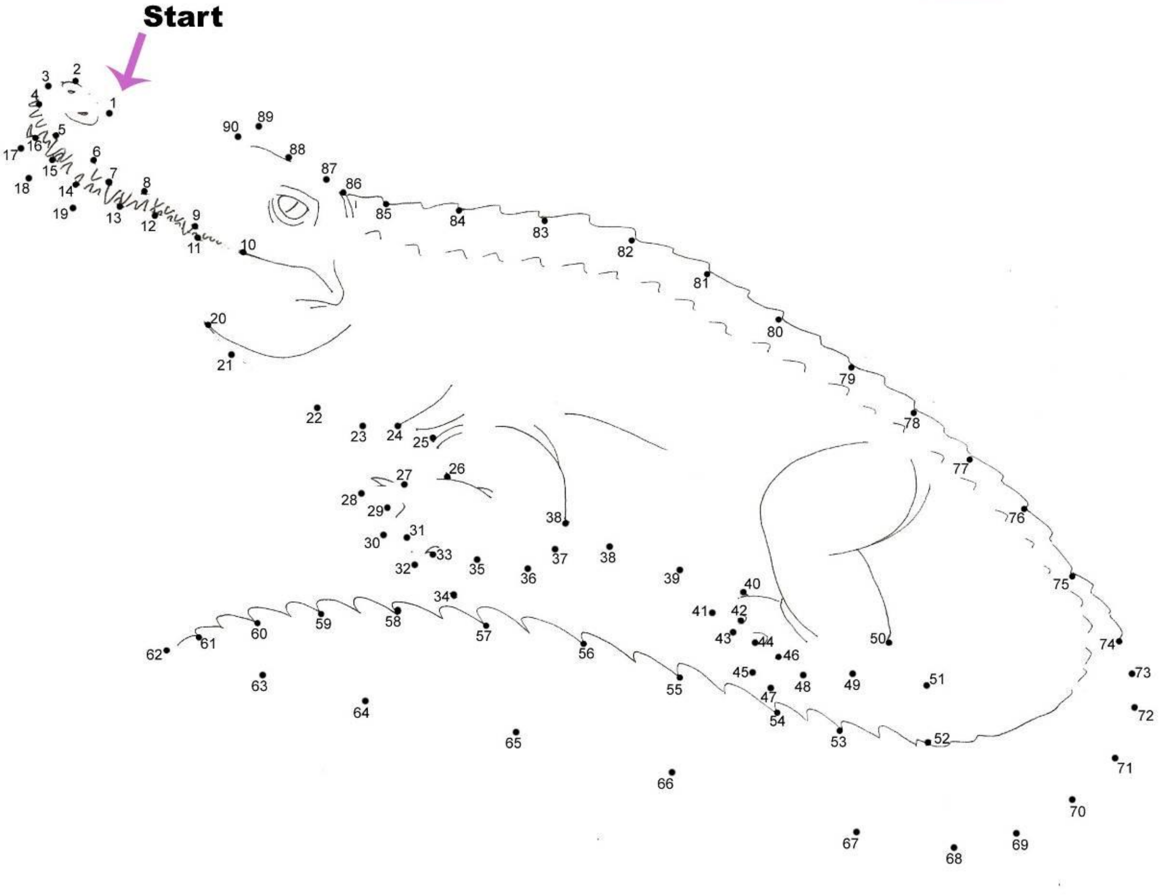
Help the fisherman to find which fishing line caught the fish



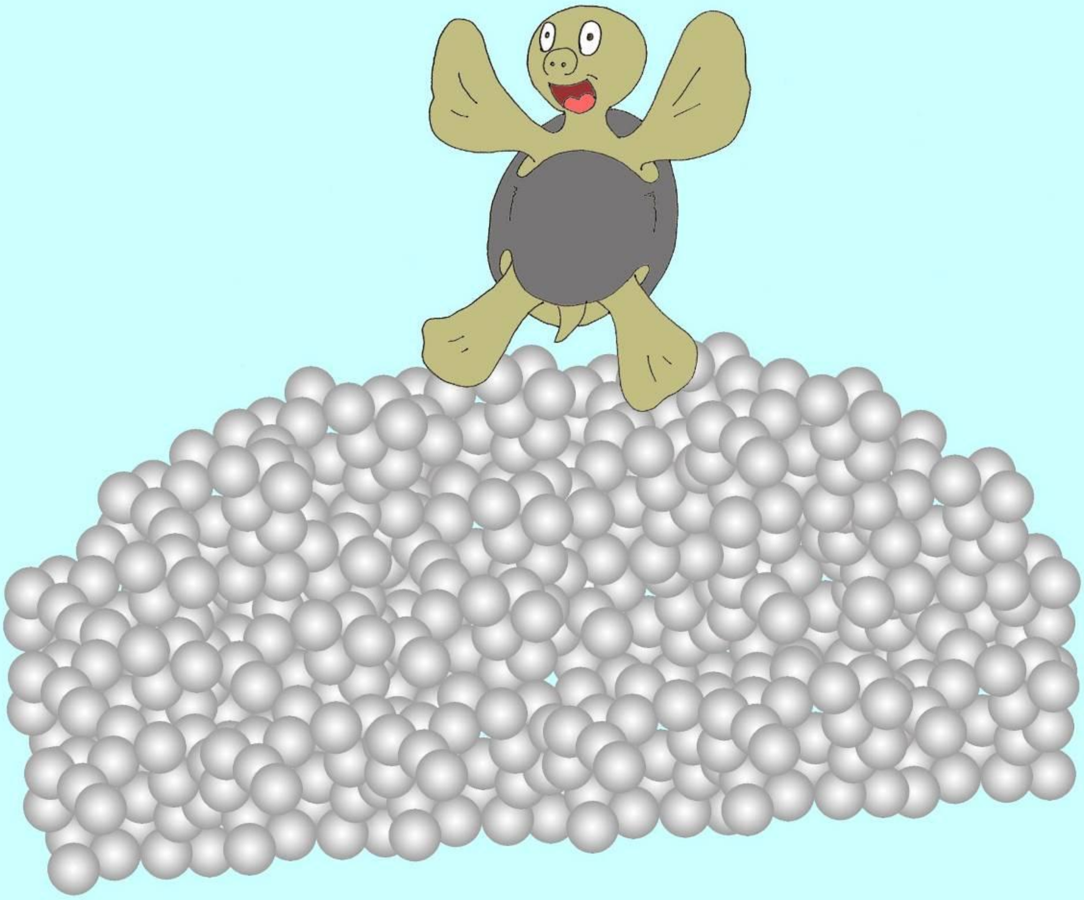
In the future, when I grow up,
I will find a nice sand
bank and lay many eggs like
my mother did

I will climb up taking care to not
be caught by animals or hunters
that want me and my eggs

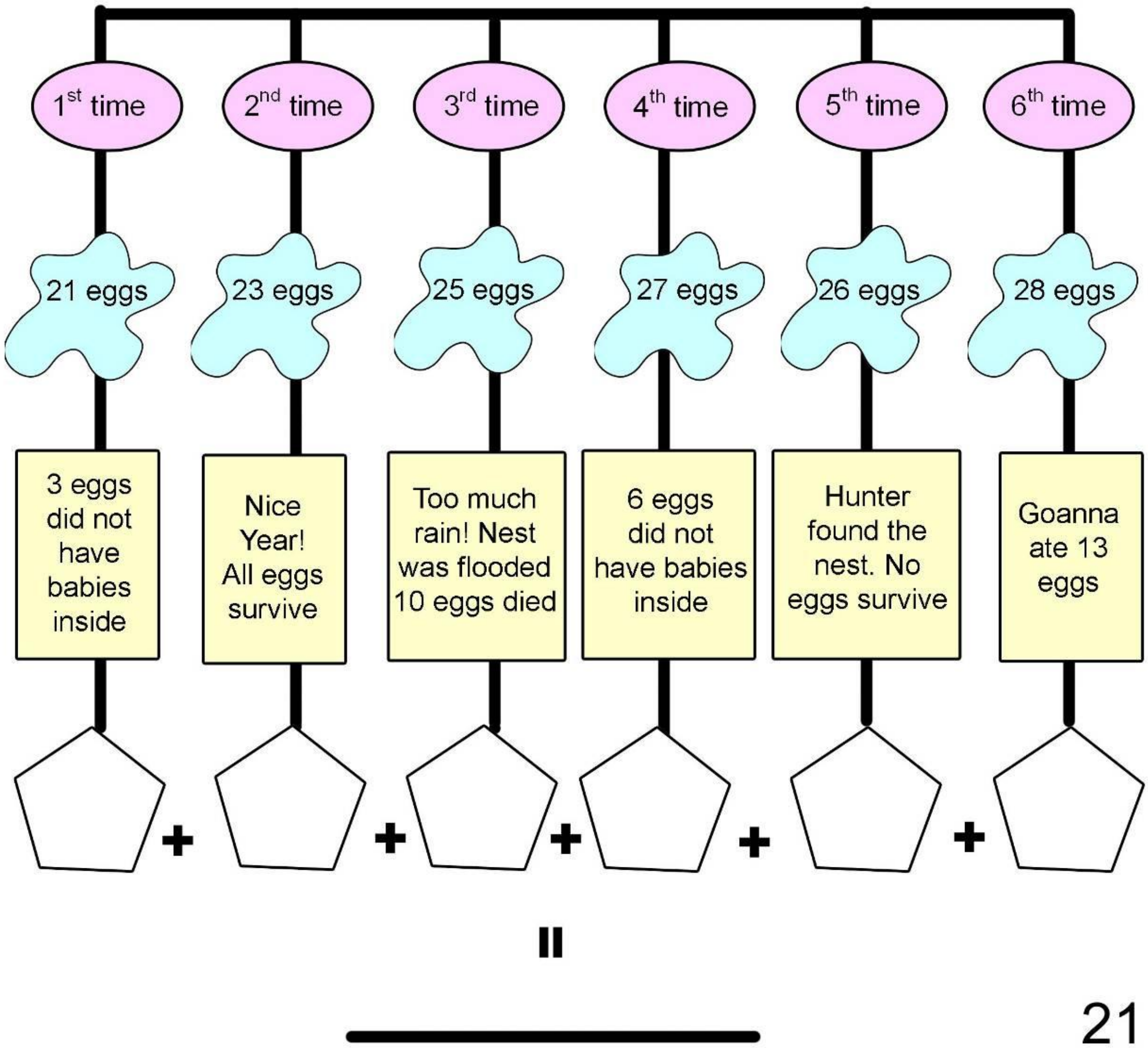
Connect the points in the correct order to find out which animal loves a turtle for its breakfast



**If everything goes alright,
and I do not get caught,
I can keep laying eggs
for more than 30 years**

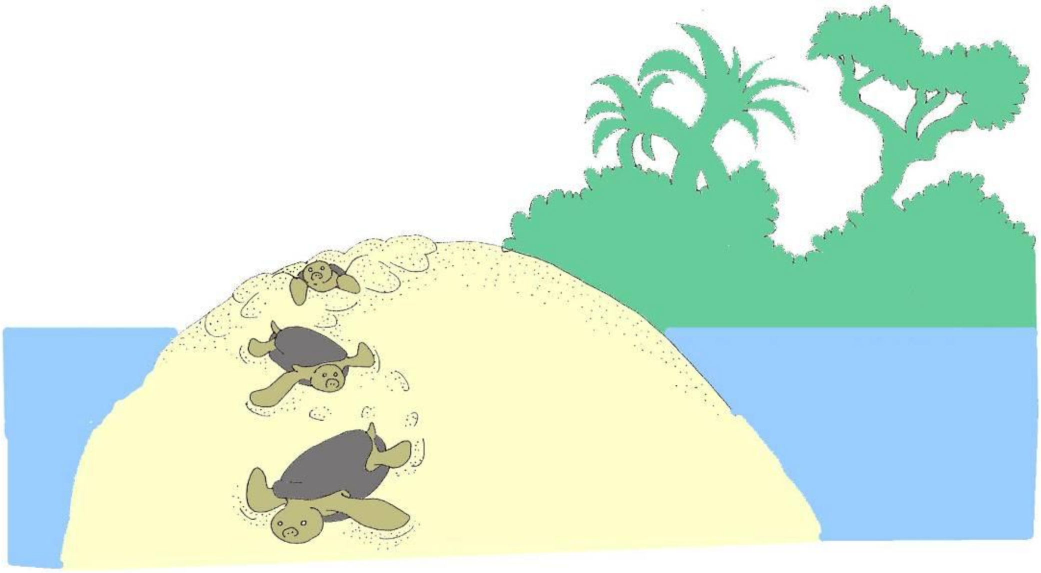


Find out how many babies Piggy will have in her first 6 clutches if she does not get caught



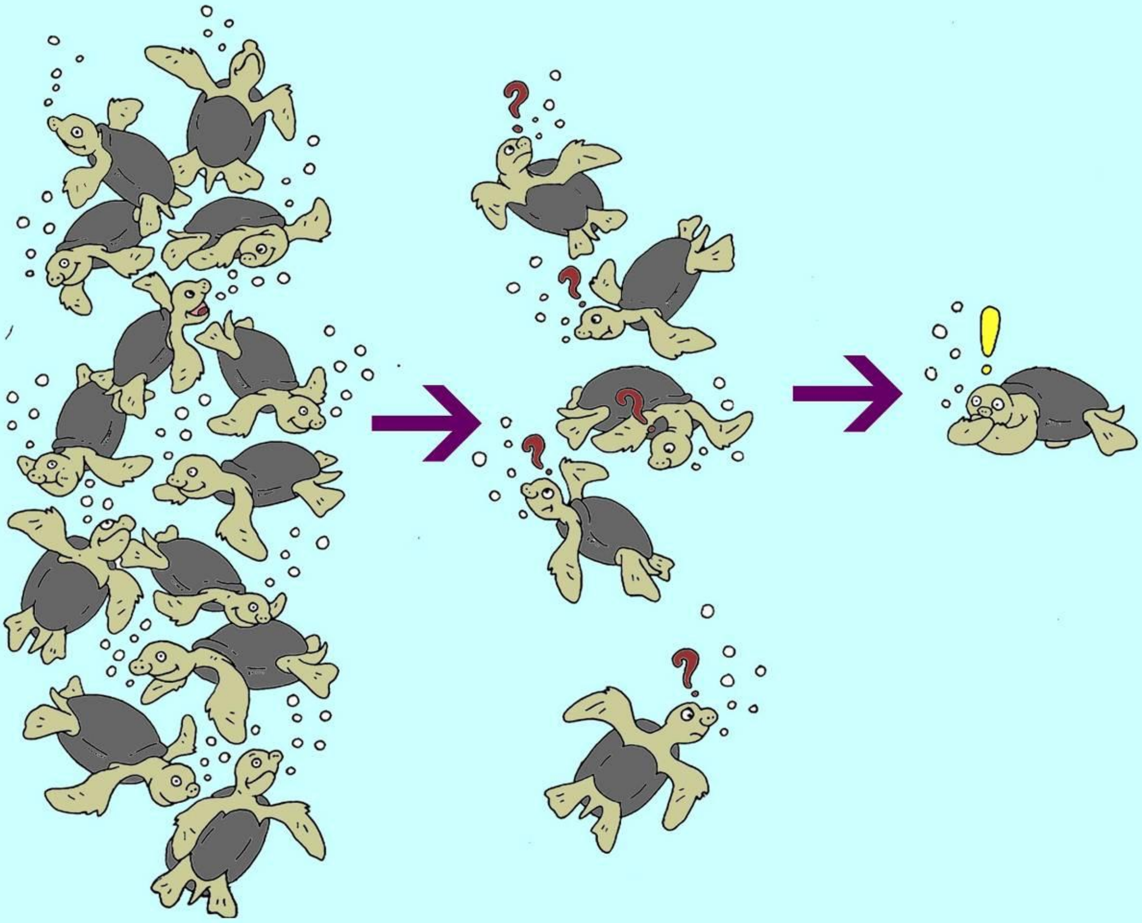
1st time	2nd time	3rd time	4th time	5th time	6th time
21 eggs	23 eggs	25 eggs	27 eggs	26 eggs	28 eggs
3 eggs did not have babies inside	Nice Year! All eggs survive	Too much rain! Nest was flooded 10 eggs died	6 eggs did not have babies inside	Hunter found the nest. No eggs survive	Goanna ate 13 eggs

A mother turtle lays many eggs for many years



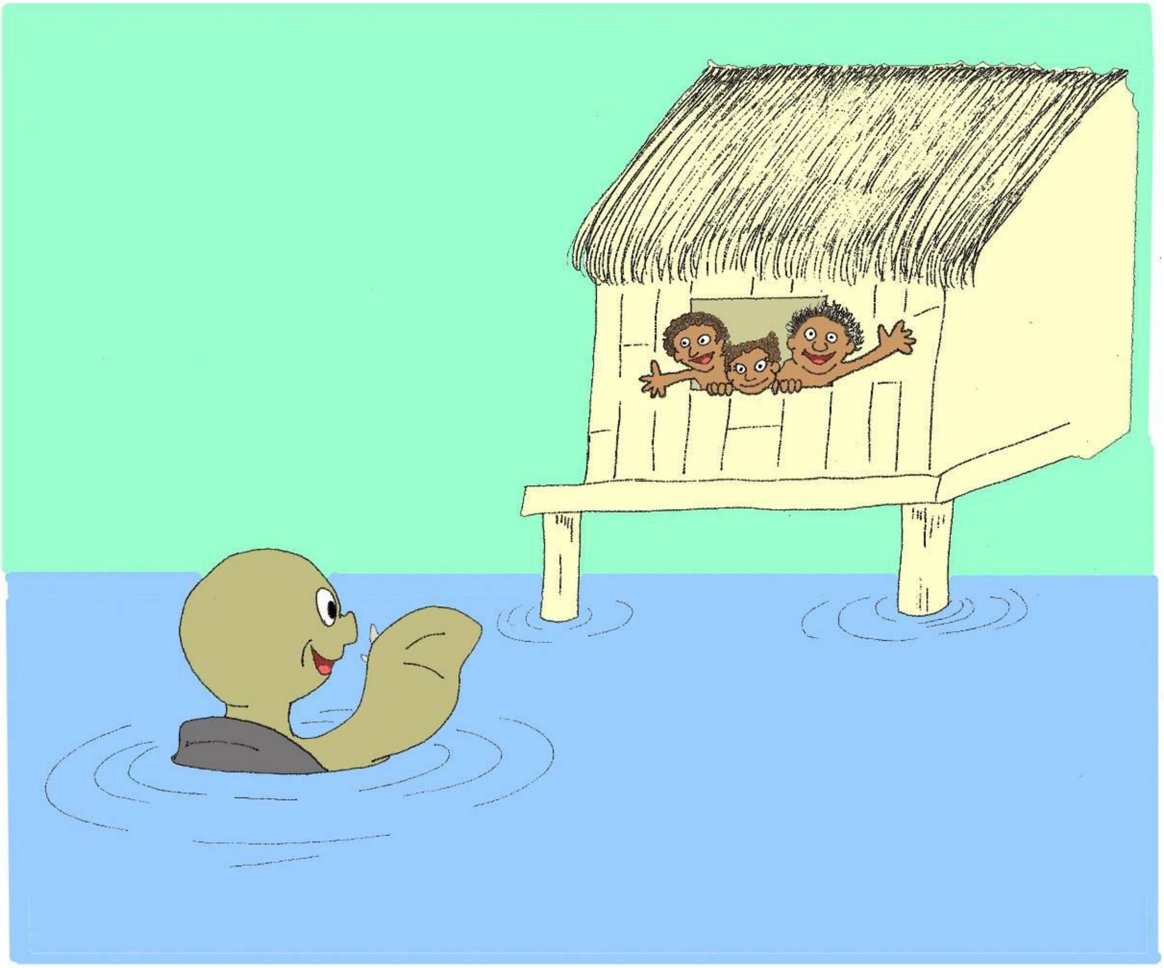
It is not a problem if some nests are harvested or eaten by animals

But, we need to be careful! If hunters harvest more eggs and turtles than are replaced by babies, turtle numbers will decrease



They can even disappear!

We should preserve turtles like Piggy



If we take care, they can stay forever with us, our kids and our grandkids

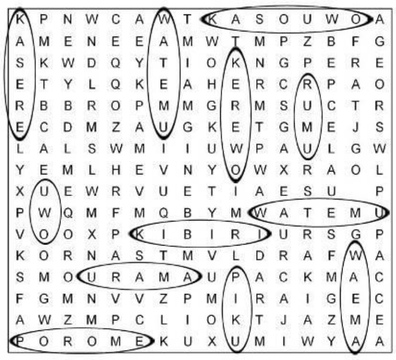
24

The end

* The Pig-nosed turtle (*Carettochelys insculpta*) is restricted to the southern rivers of the island of New Guinea and the major rivers of the Northern Territory in Australia and is listed as Vulnerable in the IUCN Red List of Threatened Species

Answers:

5 -

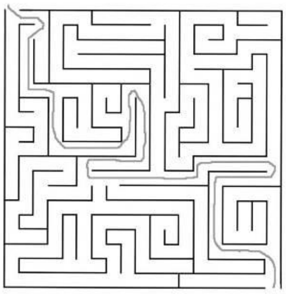


K	P	N	W	C	A	W	T	K	A	S	O	U	W	O	A
A	M	E	N	E	E	A	M	W	T	M	P	Z	B	F	G
S	K	W	D	Q	Y	T	I	O	K	N	G	P	E	R	E
E	T	Y	L	Q	K	E	A	H	E	R	C	R	P	A	O
R	B	B	R	O	P	M	M	G	R	M	S	U	C	T	R
E	C	D	M	Z	A	U	G	K	E	T	G	M	E	J	S
L	A	L	S	W	M	I	I	U	W	P	A	U	L	G	W
Y	E	M	L	H	E	V	N	Y	O	W	X	R	A	O	L
X	U	E	W	R	V	U	E	T	I	A	E	S	U		P
P	W	Q	M	F	M	Q	B	Y	M	W	A	T	E	M	U
V	O	O	X	P	K	I	B	I	R	I	U	R	S	G	P
K	O	R	N	A	S	T	M	V	L	D	R	A	F	W	A
S	M	O	U	R	A	M	A	U	P	A	C	K	M	A	C
F	G	M	N	V	V	Z	P	M	I	R	A	I	G	E	C
A	W	Z	M	P	C	L	I	O	K	T	J	A	Z	M	E
P	O	R	O	M	E	K	U	X	U	M	I	W	Y	A	A

7 - 25 eggs

9 - Turtle girls come from hot beaches and turtle boys from cold beaches

11 -



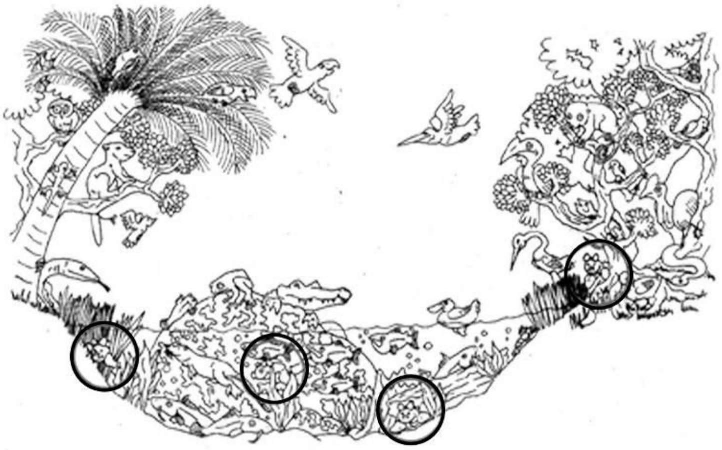
15 -

17 -

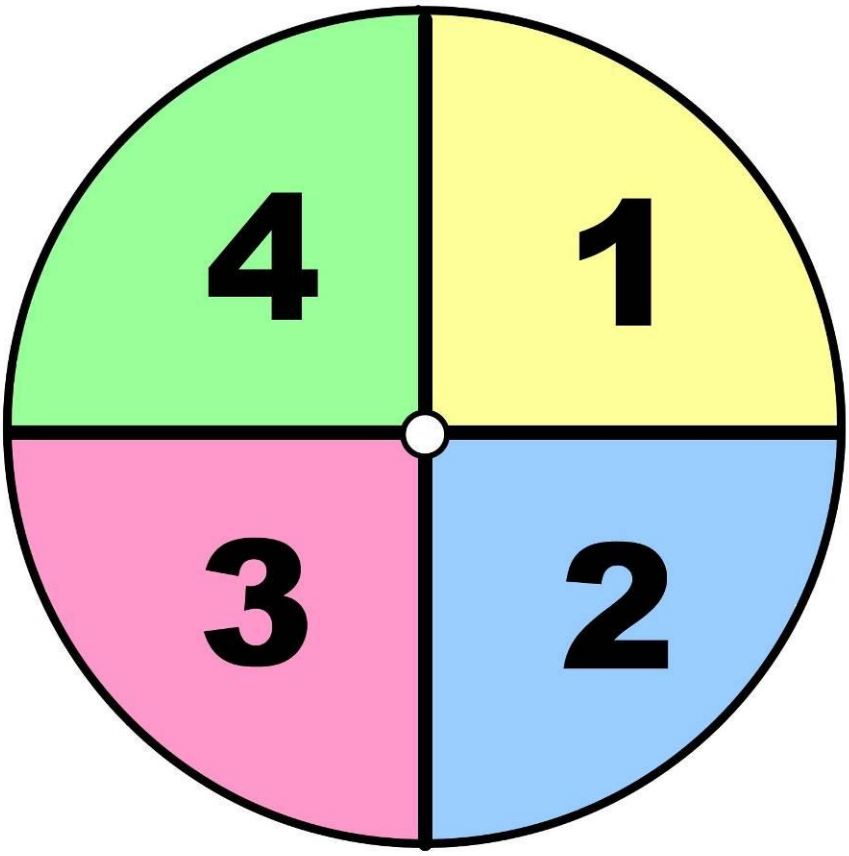
19 - Crocodile

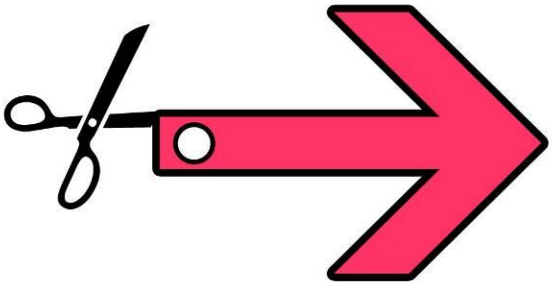
21 - 92 babies

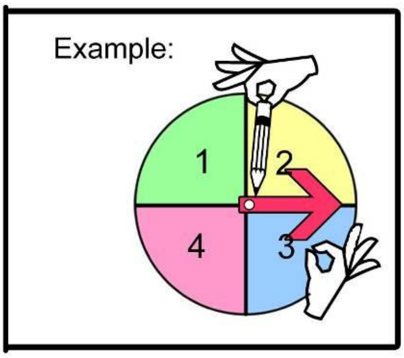
13 -

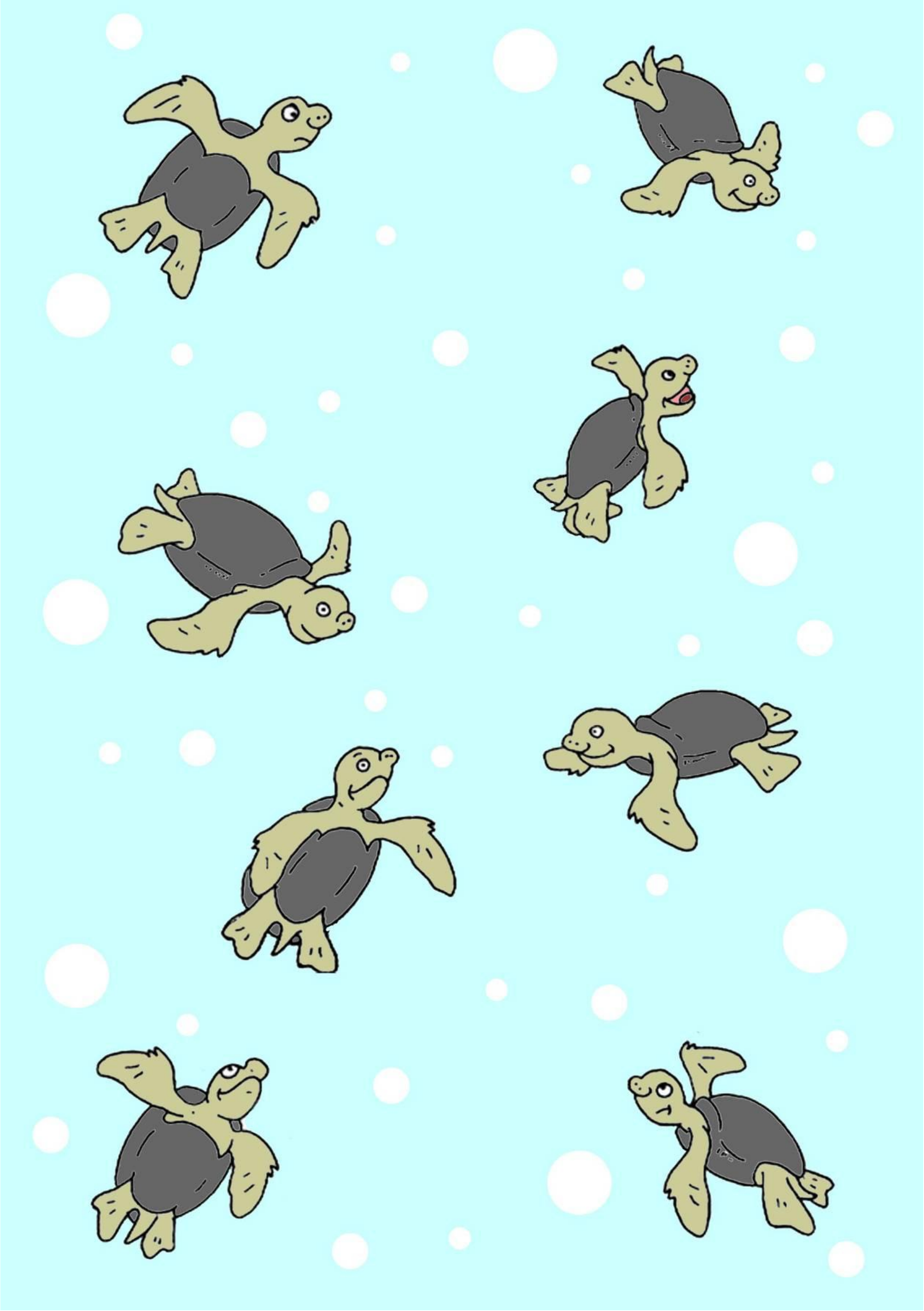


Lift-out Game: Welcome to Piggy’s Life





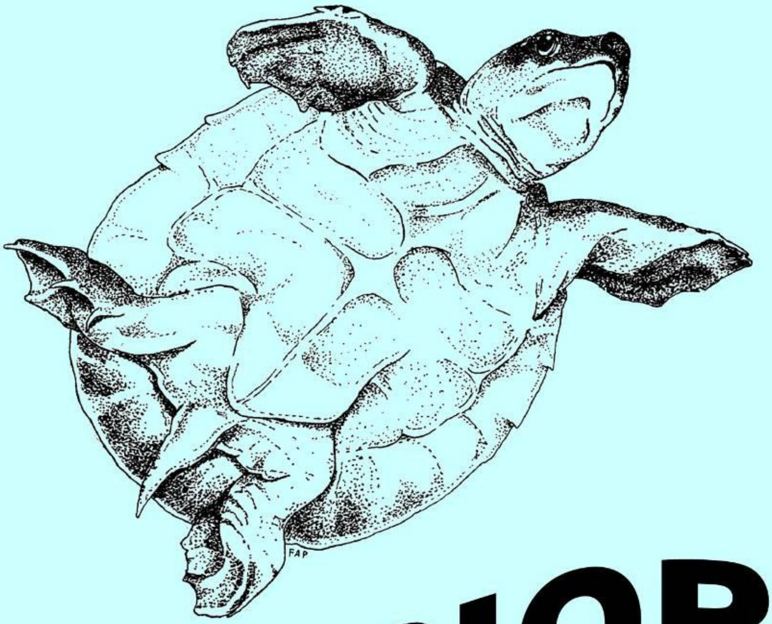

Example:



KASO-UWO WATEMUI

PIKU UWO

WAEMA WATEMU



WARRIORS

Sponsored by:

U C

OIL SEARCH LIMITED

WWF

Appendix II

Eisemberg, C. C. 2009. Piku on radio Program. CDI-FM (Community Development Initiative), Kikori, Papua New Guinea. (Programs broadcast from December 2009 to March 2010).

Kopi primary students recording the first piku-on-radio program at CDI-FM, Kikori, Papua New Guinea

Photo by Carla Eisemberg

Piku-on-Radio Project

1st script
English Version

Original participants: Kopi primary students
Susan Joe: *Susan*
Jonah Kupere: *Jonah*
Elma John: *Piggy the Turtle*
Hebbie Jeffery: *The Kikori Hunter*

Debate: Turtle X Hunter

Susan: Hello! Today we will have our 1st Piku-on-Radio Program. We prepared 6 debates and interviews with many different animals from Papua New Guinea. Piggy the turtle, Bart the Barramundi, Cassy the Cassowary, Matt the Fruit Bat, Walter the Water Rat and Dolly the Dolphin will all come here to the radio to air their points of view. This radio play was developed by the Piku Team and WWF. It is performed by the primary and secondary students from Kopi and Kikori Schools: Elma John, Johna Kupere, Hebbie Jeffery, Susan Joe, Olivia Peter, Boho Kaumi, Delilah Peter and Jerry Poikai. We hope you enjoy it!

Jonah: Good evening! Tonight we have two guests on our 1st Piku-on-Radio Program. Here with me is Piggy the Pig-nosed turtle, some of you will know her from the book "The adventures of Piggy on the Kikori River". Hello Piggy. It is nice to have you here with us tonight.

Piggy: Hello Jonah. It is nice to be here. This is my first time on radio.

Jonah: Well, you are becoming famous you know. Your book was already on EMTV and in the newspaper.

Piggy: Yes, that is really cool! I never thought I would be on TV.

Jonah: And now with me on my other side is a hunter from Kikori. Good evening hunter. Thank you for coming to our program.

Hunter: Good evening Jonah. Thank you for inviting me to come here on the Piku program.

Jonah: I was talking to you before the program started and you said something very strange happened to you last week. What was that?

Hunter: Yes! I was on a sandbank, getting some eggs for my dinner when this pig-nosed turtle came out of the water and started to yell at me.

Jonah: Was that you, Piggy?

Piggy: Yes! That was me, Jonah.

Jonah: Why did you yell at my friend the Hunter?

Piggy: Because he was taking all my babies from the sandbank!

Hunter: I was hungry. My wife and kids were waiting for me at home. We would have liked to have a nice dinner of turtle eggs that night. And then you yell at me and start to talk. Turtles are not supposed to talk.

Piggy: We are not supposed to talk, but I am so worried that I decided to start complaining.

Jonah: Why are you so worried, Piggy?

Piggy: If the hunters take all my eggs and my sister's eggs away we are not going to have babies anymore and soon you are not going to have any eggs for dinner.

Hunter: But we have always had eggs in Kikori. My father and grandfather use to eat eggs. And before my grandfather, his father and grandfather also ate turtle eggs.

Piggy: Yes, but in your grandfather's time there were not as many people around as there are today. And there were always some nests left on the sandbank for the babies to come out and go to the water.

Hunter: I don't want to stop eating eggs. Here in Kikori, we wait all year for the time when turtle mothers come to the sandbanks and lay their eggs, so we can go there and collect eggs to eat. It is not fair to make us stop eating then. They taste really good!

Piggy: But is not fair to have all my babies eaten. What is going to happen when I die? If I do not have any offspring, who is going to lay the eggs for your kids to eat?

Hunter: But I only took 20 nests from the sandbank.

Piggy: Twenty nests? How many people in your house do you have to feed?

Hunter: Nine, my wife, my father, my five kids, my young sister and me.

Piggy: Twenty nests are around 400 eggs. Do people eat more than 50 eggs in one night?

Hunter: Well, no. But I like to keep some for the next day, give some to my friends and family and maybe sell some at the market. But I think I have a suggestion.

Piggy: What is the suggestion?

Hunter: Maybe we should take some nests from the sandbank and leave some eggs to become babies, grow and become mothers.

Jonah: That is a good idea, because more babies mean more mothers in twenty years and more mothers means more eggs in the future for your kids.

Piggy: This is a great idea! We, turtles, are different from people. People have two, three, four kids. Usually humans do not have more than ten babies. Mother turtles have more than a 1000 eggs during their life. However, very few survive and usually only around ten babies from every one hundred survive and become adults.

Hunter: One thousand eggs! That is a lot of eggs!

Piggys: Yes, you see, every mother turtle you take from the sandbank to eat is one thousand eggs you and your kids are losing for the next 20 years.

Hunter: If you need only ten babies why do you produce so many eggs?

Piggy: Life is not easy for turtles in the beginning of their life. When they are in the eggs, lizards and humans can find and eat then. If a big rain comes they will drown under the water and die. When they finally hatch they will have to face many dangers such as big catfish, crocodiles and people with fishing lines and nets. From this thousand eggs, few will survive to became adults and lay their own eggs.

Jonah: I think we have agreement here. Piggy, Will you let the hunter take some eggs for him and his family to eat?

Piggy: Yes, I will.

Jonah: And hunter, Will you leave some nests in the sandbank to grow and become babies and in the future became mothers?

Hunter: Yes, I will.

Jonah: Than we are going to end the first Piku-on-Radio Program with a nice shake of flippers and hands from Piggy and the Hunter. Thank you very much for your participation here tonight. Thank you everybody who is listening to us and have a good night!

2nd script
English Version

Original participants: Kikori Secondary Students
Olivia Peter: *Olivia*
Boho Kaumi: *Bart the Barramundi*

Interview: Bart the Barramundi

Olivia: Good day! Today, we have a new exceptional guest on our 2ndt Piku-on-Radio Program. Here with me is Bart the Barramundi. Hello Bart. How are you today?

Bart: Hello Olivia. Actually, I am not feeling very well today. (In a very gasping voice)

Olivia: You don't sound very good today Bart. What happened to you?

Bart: I think I ate something that is stuck on my throat, Olivia.

Olivia: Hey! That's no good. Let me help you to take it out.

Sounds of gasping, choking and someone hitting Bart on the back.

Bart: Now I feel much better. Thanks!

Olivia: Hey, look on the floor. That is what you ate and made you feel sick. It is a plastic bag!

Bart: I remember eating this. I thought it was a new kind of fruit.

Olivia: This is not a new fruit, Bart! I am glad you were able to cough this plastic up. This is very dangerous. You could die from suffocation (or you could have suffocated).

Bart: I know. I had a Barramundi cousin that died from eating a plastic box and a catfish friend of mine died because he ate a soft-drink can.

Olivia: People should be more careful about throwing things in the river.

Bart: I agree with you. Fish like me have never seen plastic or metal before. We think it is just a new type of food. When we try to eat them we get sick or suffocate and die.

Olivia: Really? What else do people throw in the river that can make fish sick?

Bart: Many things! Any kind of plastic, styrofoam, papers, cloths, slippers and small pieces of metal like tins and cans make many fish that live in the river sick. Cooking oil also can make us ill.

Olivia: Can all this garbage make you sick? Looks like fish are very easy to make sick.

Bart: We are not the only ones that get sick with all this rubbish. Other animals, like turtles, crabs and birds that live close to the water will get sick if they eat this kind of waste.

Olivia: This is very important for people that live close to the river to know. When we throw lots of garbage in the river, many animals will die and the fishermen will not have anything to catch.

Bart: Yes, everybody loses. When you throw a plastic bag in the river maybe you are killing a very big Barramundi that you could have had for dinner in the next week.

Olivia: What about the other kind of garbage such as food leftovers? Are they dangerous for the animals in the river too?

Bart: Other food such as fruits, sago and fish are not that bad. Fish always eat these kind of things and we do not get sick from them. But, people need to be careful because if there is too much of them in the river it can be a problem.

Olivia: I think what you want is someone to throw some dinner for you.

Bart: Well, if someone wants to throw some prawns to me I will not mind. I love prawns.

Olivia: You are a very funny Barramundi Bart! But let's go back to the garbage problem. Now we know that we should not throw some types of waste such as plastic bags and tins in the river. What should we do with them?

Bart: This is a big problem, Olivia. One solution is to use as little of these things as possible. If you already have a plastic bag, you do not need to get an extra one. This will only increase the amount of waste you will have to throw away later.

Olivia: Well, I reckon we can reduce the amount of waste we produce. However we will still have some garbage to throw away. What should we do with it?

Bart: Probably the best solution is to bury it in the ground. Maybe people should choose an area away from the river where would be safe to bury this kind of waste.

Olivia: I have one concern. This place needs to be away from the houses. Nobody will want to live close to everybody's garbage.

Bart: Maybe the Villages' members should have meetings and organize themselves to find the best way and the best place to keep the garbage.

Olivia: I am sure some villages are already doing this. But the villages that are not doing this should start to think about it.

Bart: The most important thing is that everybody needs to do their part. Nobody should throw garbage or oil in the river. Oil is also very bad for the animals that live in the water. Few drops of oils can make a lot of fish, birds, crabs and turtles sick.

Olivia: Yes! This is not only going to make the river safer for the animals that live there. It will make the villages cleaner and a better place to leave.

Bart: I am sure that even the number of diseases that people get will decrease.

Olivia: Sure, if you throw garbage in the water you are making the place where you have your bath and wash the clothes dirty. This can make you sick.

Bart: That’s why we need everybody’s participation. When everyone does their part we make our world a much better place to live.

Olivia: You gave some very good advice to us today Bart. Thank you very much for your participation here today. Thank you everybody that is listening to us and have a good day!

3rd script
English Version

Original participants: Kikori Primary Students
Delilah Peter – *Cassy the Cassowary*
Jerry Poikari – *Jerry (Interviewer)*

Interview: Cassy the *Cassowary*

Jerry: Welcome to our 3rd Piku-on-Radio program. Today with me, we have a visitor from Southern Highland's province. She is Cassy the Cassowary and will talk a little bit about her home, around the Kutubu Lake. Welcome Cassy. We would like to thank you for coming here today to talk on our program.

Cassy: Hello Jerry. It is my pleasure to be here. Thank you for inviting me.

Jerry: You were telling me before the program started that Lake Kutubu is a very beautiful place.

Cassy: That's right. It is a very beautiful lake. The water is nice and clear. It is also the fifth largest lake in Papua New Guinea.

Jerry: Really? It must be very big.

Cassy: Yes, it is indeed. It is 19 km long, 4 km wide and can be 70 m deep.

Jerry: This is huge! Are there many fishes for people to catch there?

Cassy: We have many different fish. Mogurndas, Rainbowfishes, Tandans. But, do you know that we are having a problem with the fish there?

Jerry: I did not know you were having problems with the fish. What is happening? You said that there are many fish around.

Cassy: The problem that I am talking about is not about the fish we always had there. The problem is with an introduced fish.

Jerry: Introduced fish? I have never heard about this before. What is it?

Cassy: An introduced animal is an animal that is not originally from that area. There are many introduced plants and animals such as birds and fishes in Papua New Guinea.

Jerry: Ok, now I understand. Which introduced fish do you have in Lake Kutubu now?

Cassy: It is a fish called Carp. We didn't have it before. It came from China.

Jerry: How did they get there? I am sure a fish cannot buy a plane ticket (or a flight) and get into an airplane from Asia to Papua New Guinea alone.

Cassy: Ha ha ha! Of course not! Someone brought them and released in Lake Kutubu.

Jerry: Why would a person do this?

Cassy: They probably thought that it was a good idea. The Carp is a big fish. Maybe a fisherman from Kutubu was on a trip and saw this fish and thought would be nice to have this fish to eat in his home land.

Jerry: This seems like a good idea to me. What is the problem?

Cassy: First of all they do not taste as good as our own fish. They also can bring new diseases to our fish and kill them.

Jerry: This would be terrible! You have so many unique fish in the lake.

Cassy: That is right. There are 12 types of fish that only live in the Kutubu Lake. If they get sick and die, nobody in the world will be able to see them or eat them again.

Jerry: Oh. I just remembered something. I heard once on the radio that Australian's have big problems with Carp over there.

Cassy: Really? I did not know that.

Jerry: They said that Carp was brought in to South Australia many years ago and caused a lot of damage to the Murray River. Looks like the Carp can smash aquatic plants up and make the water muddy.

Cassy: This can be very bad for fisherman. Clean water is always more easy to catch fishes. If the water became muddy, it will be very difficult to get fish with a spear.

Jerry: Even your bird cousins that catch fish in the water are going to have trouble finding fish to eat.

Cassy: That's right! We must be careful.

Jerry: So... What should people do with the Carp?

Cassy: Oh, this is a very big problem. The moment someone puts Carp in a place it is very difficult to take all of them out. A mother Carp can lay over one million eggs.

Jerry: It is really good that you told us about this problem in Lake Kutubu, Cassy. People who are listening to the radio will learn that they should not bring animals from one place to the other.

Cassy: Yes. It is very important to understand this. Because it is more than likely that people who bring new types of fish, animals or plants to their community are only trying to help.

Jerry: That's right. When someone brings a new animal or plant they are also bringing unknown new types of diseases and problems to their local animals and plants.

Cassy: It will be a disaster if the local animals and plants get sick and die. People will loose their traditional food and their kids will never see them in the bush.

Jerry: I am very worried about Lake Kutubu now. Is there anything we should do about the Carp there?

Cassy: These Carp are a very important issue in Lake Kutubu. We are lucky because they are only in few areas of the lake. But we need to be careful to not spread them to the other parts of the lake.

Jerry: How do you prevent the Carp from spreading to other areas of the lake?

Cassy: Carp do not like clear and clean water. Most parts of the lake are not good for them to live. They like muddy and polluted areas.

Jerry: Oh I see. So, if people keep the lake as it is now, Carp cannot go to most parts of the lake, where the water is too clean and clear for them.

Cassy: But, if people throw too much garbage, dirt or mud in the water the Carp will be able to go everywhere.

Jerry: We have a very good message today on our program. People should not bring animals or plants from other places or countries or throw garbage and dirt in the water.

Cassy: You made a good point, Jerry.

Jerry: Thank you, Cassy. I would also thank you for your participation here today. Thank you everybody that is listening to us and have a good day!

4th script
English Version

Original participants – Kopi Primary Students**:**

Elma John: *Elma*
Hebbie Jeffery: *Matt the fruit bat*
Jonah Kupere: *The landowner*
Susan Joe: *Landowner's wife*

Interview: Matt the fruit bat

Elma: Welcome to our 4th Piku-on-Radio program. Today with me, we have a visitor from Sirebi River. Maybe some of you already saw him flying around. He is Matt the fruit bat. Hello Matt! How are you? You don't look like you are very happy today.

Matt: Hello Elma. Yes I am not happy today. Actually I came to the radio to make a protest.

Elma: A protest? Why? What is wrong Matt? Did something happen to you recently?

Matt: Actually no. It is something that is happening for a while now. I just got tired and decided to complain.

Elma: Really? What is the problem?

Matt: I am working very hard and without receiving any payment. I want compensation!

Elma: I did not know you were working for someone. What is your work Matt?

Matt: I spread the fruits seeds to keep the forest nice and big.

Elma: So that's your job? Who is employing you?

Matt: Umm… actually nobody... we fruit bats always do that. It sort of happens naturally. We eat the fruits from the trees and the seeds come out with our dung.

Elma: Let me see if I understand right. The place that you use as toilet will become a tree in the future?

Matt: Yes. But don't think this is not important. Can you imagine what will happen if all the fruit bats don't do their jobs? Humans will have to plant tree by tree and it would be a huge job.

Elma: Oh, I can see how important your job is. I just cannot understand why you are so angry and demanding compensation.

Matt: I am angry because people are cutting down too many trees! This is making my job very difficult. I cannot find food easily anymore. How can you expect me to spread the seeds if there are no fruits anymore for me to eat?

Elma: Is that right? Well we are lucky because we have here with us today on the radio a landowner and his wife. Maybe we can talk to them and ask what is happening. Hello landowner and wife. How are you today?

Landowner: Hello Elma. I am very good today. My wife and I were going to the market and we decided to stop here first to see some friends.

Wife: Hello Elma. We heard that our friend, Matt, is angry with us. Sorry Matt, we did not know we were doing something wrong to you.

Matt: Yes, I am angry. I am working too hard and people are making my job very difficult. It is not fair.

Landowner: We did not know about that. We are very sorry. How can we help you?

Elma: You see Matt. Nobody wants to do bad things to you. They just did not know that you were in trouble.

Matt: Really? Sorry for being so angry. It has been very hard for me and my family to find fruit lately. If nothing is done people will also be in trouble. We spread the seeds of many important plants and trees that are also very important for humans.

Wife: I did not know that. That is so interesting! What kind of trees do you spread the seeds of?

Matt: Oh, many fruit trees such as Bread Fruit and wild figs. Some of my relatives are also very important for the trees in a different way. They carry the pollen from one flower to the other so the tree can develop the fruit. Without them many trees will not have fruits at all.

Landowner: But you said you want compensation. I don't know how we can pay you. Do you fruit bats accept Kina as payment? I don't see how it can be useful for you.

Elma: Yes. It will be a very funny thing to see! A fruit bat with a bag going to the Market to buy papaw!

Matt: I think we wouldn't like to do this. At the time the market is open we would rather stay resting in the trees. When we wake up, it is going to be late and the market will be closed.

Landowner: We would like to help you Matt. But I don't see how. We need to cut trees sometimes to make our gardens, get bushfire and wood for our houses.

Wife: Our ancestors always did that and fruit bats never complained before. Why is it a problem now?

Matt: You do not understand me. We've never had problems with that. It is not a problem if people go to the bush and get what they need for their houses and fire. We lived pretty well with that for a very long time.

Elma: So what is the problem Matt?

Matt: The problem is that, now, people are cutting all the trees to sell. They cut down all the forest and don’t plant it back. Sometimes we fly all night and cannot find a single fruit to eat. This is very sad. We come back to the cave still hungry and don’t know if the next night we will find something to eat.

Landowner: I feel very sorry for you Matt. I can understand that you are feeling very miserable because of that. It is very bad to sleep with an empty belly. The problem is that we need the money we get for cutting down the trees.

Wife: Yes, we need to pay lots of things nowadays such as clothes and schools fees for our sons and daughters.

Matt: But this will not work. If you cut down all the trees and don’t plant them back you are not going to have anything in the future. We will both lose our food. The animals will all starve and die. You will find neither fruits nor hunting meat anymore.

Wife: Matt is right. We cannot keep cutting down trees without thinking of the consequences for the future.

Landowner: That’s true. Maybe we should select and cut the trees more carefully. We should organize the logging in a sustainable way.

Elma: That is a good idea. Sustainable logging means that you will not cut more trees than you need and you will make sure that new trees are growing in the places where the old ones were cut.

Matt: Thank you very much! This is going to make my job much easier. I will keep spreading seeds and people will be more careful. They should not cut down more trees than they could plant back in time. I think if we both help each other we will have a nice forest forever.

Elma: We just need to make sure that all the kinds of native plants will grow back. We don’t want a boring forest with only one or two kinds of trees. If we keep all the kinds of local trees we will have a very rich forest with lots of resources.

Wife: That is very important thing to consider Elma. We don’t want to lose our traditional foods and medicines.

Elma: Well, I think this was another happy ending for our 4th Piku-on-Radio program. Matt will go out of here very happy.

Matt: That’s right Elma.

Elma: Glad to know that. Thank you for coming to our program Matt. I would also like to say thanks to the landowner and his wife that helped us to solve this problem. Thank you everybody that is listening to us and have a good day!

5th script
English Version

Original participants – Kikori Primary Students**:**
Jerry Poikari – Walter the water rat
Delilah Peter – *Delilah (Interviewer)*

Interview: Walter the water rat

Delilah: Hello everybody. Welcome to our fifth Piku-on-Radio program. Here with us today we were going to have a fascinating guest, Francis, the tree frog. He was going to talk about climate change. Unfortunately, Francis could not come because he got a knot in his tongue and… wait a minute… where is all this noise coming from?

Walter: Hello Delilah, sorry to disturb you. Can I spend the night here?

Delilah: Is that you, Walter the water rat? You are completed covered in mud! What happened to you?

Walter: Oh, it was a tragedy. I lost my house!

Delilah: That's terrible news! How did it happen?

Walter: I don't know… I went on my everyday business to get fish for my breakfast and when I was getting out of my burrow everything collapsed!

Delilah: Are you alright? Do you want us to take you to the hospital?

Walter: No, thanks. I am alright. Just some scratches and a lot of mud…

Delilah: Do you know why it collapsed? Was it an old house?

Walter: No! I had made that house myself. I made it very carefully and following all the safety rules.

Delilah: Sorry Walter. I did not want to offend you. I know how cautious you are about safety.

Walter: That's right. It was in such a beautiful spot. It was on the margin of a very nice creek, surrounded by many big trees. You know... I was planning to find a nice water rat girl and get married. Now, it is going to take ages until I make another burrow…

Delilah: That is so sad. But did anything strange happen lately? Was it an earthquake? We did not feel anything here.

Walter: I don't think it was an earthquake. The only thing different that happened lately was that some people from the village up river came to cut some trees close to the river bank edge to make bush fire.

Delilah: I see. Well I think maybe I know what happened…

Walter: Really? What was it? A giant cassowary jumped on my house? A volcano erupted on its side? Terrorist attack? It must be something very big!

Delilah: Do you know anything about erosion, Walter?

Walter: No… I never heard this word before.

Delilah: Erosion is the removal of solids, such as soil and rocks, in the natural environment. It usually happens naturally and very slowly, but in many places its speed is increased by humans land use.

Walter: You've got to be kidding me. Are you telling me that you, humans, were the source of my loss?

Delilah: Calm down, Walter. We don't want you to get out of here and bite the first person you find in the streets as revenge for your loss.

Walter: But you just told me that they destroyed my house!

Delilah: Well… unsuitable land use practices such as deforestation close to the river bank usually cause erosion and your house would go under the water if big parts of the soil close to the river goes suddenly down. But people are losing almost as much as you.

Walter: What do you mean? Are they going to lose their houses too?

Delilah: All the sediment that goes under the water can make the water muddier. Besides, many fishes and other animals that are not used to lots of mud in the river would die. This could make the life for the fishermen very difficult.

Walter: Are you telling me that besides my house I am going to lose my food?

Delilah: Not only you. We, humans too. Actually sometimes the erosion is so big that we can also lose our houses. There are many stories of people living close to cliffs and river edges that have lost everything because of erosion.

Walter: Oh! I feel sorry for them. I know how they feel. But is there anything they can do to avoid this tragedy?

Delilah: I think the most important thing to do, is to not cut down the trees close to the riverbank. If the edge has been cleared of vegetation there is always a chance that you are going to lose a good piece of land in the next big rain.

Walter: So cutting the trees is the cause of the problem?

Delilah: That is right. Plants hold the soil in place with their roots. Vegetation is an excellent bank stabilizer and everybody should make an effort to keep existing trees, shrubs, flowers and grasses, which are close to the riverbank intact.

Walter: This does not look very difficult to do… wait a minute! I know that you humans need to cut down trees. How are people going to get bushfire, make sago or canoes if they cannot cut trees anymore?

Delilah: Sorry, you do not understand me, Walter. People can still cut down trees for their houses, fire and food. They just need to be careful to not cut too much or too close to the river.

Walter: Now I understand. Maybe they should make a rule not to cut too many trees in the first few metres close to the riverbank. Nobody needs to suffer with the loss of their house or food from the river.

Delilah: I agree. Many places already have this rule and respect it. Erosion can be tricky and sometimes people lose everything including their lives. But I don’t want to finish our radio program with you so sad. I have a suggestion for you.

Walter: What is the suggestion?

Delilah: Tomorrow I will talk to the people from the village that cut down the trees close to you house and ask them to help you build a new house. I am sure they will be sorry for you and help.

Walter: Yes… they probably didn’t know about erosion too. We could explain so they will be more careful next time.

Delilah: That’s right! So, we will end the 5th Piku-on-Radio program helping our unexpected visitor Walter the water rat. Thank you for your participation Walter and thank you everybody that is listening to us today.

6^{th} script
English Version

Original participants – Kikori Secondary Students**:**
Boho Kaumi: *Boho*
Olivia Peter: *Dolly the dolphin*

Interview: Dolly the dolphin

Boho: Good morning! Welcome to our final Piku-on-Radio program. Today we will interview a guest from the Coastal area of Kikori. She is Dolly the dolphin. Hello Dolly. Thank you for coming here today to be on our program. Sorry to make you come up River.

Dolly: Good morning, Boho. Thank you for inviting me. Don't worry about the river. We, the Irrawaddy Dolphins, can cope with a wide range of salinities. It is not a problem for us to spend a little bit of time in the river.

Boho: We almost don't see you around the upper river. I am glad you could come. I have a question I always wanted to ask you. Irrawaddy is a very strange name for a Dolphin. Where did this come from?

Dolly: It is the name of a river where some of my relatives live in Burma, a very distant country.

Boho: Cool! You have family in far away lands.

Dolly: That's right. We live in many countries including Australia, Indonesia, India, Thailand, Vietnam and others.

Boho: That's a big family. So do all of you have this short beak and small dorsal fin?

Dolly: Yes. We all look like this. If you see a dolphin like me on the Kikori coast, you are seeing an Irrawaddy dolphin.

Boho: I heard that the Irrawaddy dolphins can do funny things like spitting water.

Dolly: Yes! We can. Most of the other dolphins cannot do it. Because of that, many places like to have us in big glass tanks to present shows for people to see.

Boho: Would you like to be in one of the aquariums and become famous?

Dolly: No way! I like to swim free through all the Kikori Coast. I wouldn't like to be in an aquarium. I would feel like I am in jail.

Boho: I understand you. I wouldn't like to be in prison either. Do you have news from others Irrawaddy dolphins in other countries?

Dolly: Not much. It is so far away. The last thing I heard from them is that some populations are critically endangered.

Boho: Really? Why? What is happening?

Dolly: In many places people use so many fish nets that the dolphins get accidentally caught and drown.

Boho: That is terrible! Do you have this problem here in Kikori?

Dolly: Not until now. People on the coast don't like to eat us and the number of nets is not very high. But they need to be careful. If the number of nets increases the chance of one of us being caught also increases.

Boho: So the dolphin population here in this area is alright.

Dolly: Well…. we are not finding as many fish as we use to find. If the number of fish keeps going down we will be in trouble.

Boho: I also can see this happening when I go to the market. Fish is getting more difficult to get and more expensive to buy every day. Why do you think this is happening?

Dolly: I think one of the reasons is that the human population is increasing and there are many more fishermen on the river nowadays. They are all using nets. In the past they didn't use nets.

Boho: That's true. But they need to catch the fish for their families. What do you suggest? People need protein.

Dolly: Oh, I am not saying people should stop fishing. I am just saying they should be more careful. The river is big and probably has fish for all the animals and people who want to eat them.

Boho: I understand what you are saying. If people just keep killing all the fish without thinking about the future they will all disappear.

Dolly: Exactly. Fishermen need to pay attention to some basic rules of a sustainable fishery.

Boho: What would they be?

Dolly: People should not get female fish with eggs or young fish that are too small to eat. But I don't know everything. I think it depends on each place and what type of fish people would like to eat more.

Boho: We should also protect the environment close to the rivers so the fish can grow big and healthy.

Dolly: Good idea! Nobody likes to eat a fish from a polluted river. They taste bad and make you sick.

Boho: So Dolly, I think we learned something very important today on our 6th and last Piku-on-Radio program. We should be careful when we are taking fish out of the river. If we don't pay attention to our acts it is going to be our kids who are going to suffer in the future.

Dolly: That’s right. And be very careful with the nets! I don’t want to get entangled in one.

Boho: Right! Again, thank you Dolly. You are our guest today, so come and have some lunch with us. We can compensate you at least a little bit for the lack of fish in the River.

Dolly: Hey! Thank you. This will be very nice!

Boho: On behalf of all the Piku Team, I would like to say thank you to everybody that followed our six programs. We hope you enjoyed and learned a little bit about conservation and wildlife management. We are very grateful to everybody who helped us with this project. Thank you very much and have a good day!