Marine Turtle Conservation and Management in Northern Australia

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Proceedings of a Workshop held at the Northern Territory University
Darwin, 3–4 June 1997

Edited by

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Published by

CENTRE FOR INDIGENOUS NATURAL AND CULTURAL RESOURCE MANAGEMENT
CENTRE FOR TROPICAL WETLANDS MANAGEMENT

NORTHERN TERRITORY UNIVERSITY

Published by the Centre for Indigenous Natural and Cultural Resource Management and the Centre for Tropical Wetlands Management, Northern Territory University 1998. The views and opinions expressed in this document are not necessarily those of the Centre for Indigenous Natural and Cultural Resource Management, the Centre for Tropical Wetlands Management or the Northern Territory University.

ISBN 1 876248 16 5

CITATION:

R Kennett, A Webb, G Duff, M Guinea and G Hill (eds), 1998. *Marine Turtle Conservation and Management in Northern Australia*, Proceedings of a Workshop held at the Northern Territory University, Darwin, 3–4 June 1997, Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.

Available from:

Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetlands Management, Northern Territory University, Darwin, NT 0909.

CENTRE FOR INDIGENOUS NATURAL AND CULTURAL RESOURCE MANAGEMENT

The Centre for Indigenous Natural and Cultural Resource Management (CINCRM) was established at the Northern Territory University in February 1997 as a partnership of eight institutions and organisations, under the Commonwealth Government's Indigenous Higher Education Centres Program. The Centre aims to be a national and international focal point for research which meets the needs of indigenous Australians and which facilitates career opportunities for indigenous researchers. Full details of CINCRM activities, including all CINCRM publications, are available on the CINCRM Web site: http://www.ntu.edu.au/cincrm/

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The Centre for Tropical Wetlands Management (CTWM), established in 1996, is a Northern Territory University based Research Centre which aims to establish partnerships with external agencies involved in the monitoring and management of tropical wetlands. The CTWM promotes and supports research; provides a regional, national and international focus for tropical wetlands management; and undertakes award and non-award education and training relevant to tropical wetland environments.

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Cover art by Camilla Lawson
Copy edited, designed and typeset by Ann Webb
Printed by NTUniprint, Darwin

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FOREWORD

Marine turtles have inhabited the earth for some 100 million years. In the last few hundred years there has been a dramatic decline in their numbers, and the last seven extant species are in imminent danger of extinction. The destruction of foraging and nesting habitats, the intentional and unintentional slaughter of turtles in fisheries, and the slow poisoning of the world's oceans with pollutants have taken their toll. Most populations are declining, and many are extinct.

Northern Australia is home to six species of the world's marine turtles and has globally significant nesting rookeries for four species. Clearly our regional efforts to conserve and manage marine turtles are of global significance. The workshop on Marine Turtle Conservation and Management in Northern Australia, held at the Northern Territory University on 3 and 4 June 1997 was a critical event in the history of regional efforts to conserve and manage marine turtle populations.

I am pleased, as the Director of the Centre for Indigenous Natural and Cultural Resource Management (CINCRM), which co-hosted the Workshop with the Centre for Tropical Wetlands Management, to write a foreword for these proceedings and, in so doing, to emphasise some important features and outcomes from that gathering, some of which will be evident in the following papers.

The diverse range of papers in this collection cover marine turtle biology, legislation and protection, and indigenous perspectives, and bring together important data, findings and perspectives for future conservation and management. The collection is thus a comprehensive source of the recent work of experts, both indigenous and non-indigenous, on marine turtles. It provides knowledge and advice, which, if heeded by all of us who share a stake in the future of these species, might prevent their population decline and extinction.

Some 45 people attended the workshop from 17 institutions directly concerned with marine turtle conservation, demonstrating the need for review of the present status of marine turtles and of research and monitoring progress. Six of those institutions were indigenous organisations: the Kimberley, Northern and Anindilyakwa Land Councils, Bawinanga Aboriginal Corporation, Dhimurru Aboriginal Corporation, and the Larrakia Nation. Batchelor College, a special Aboriginal post-secondary educational institution, sent speakers and representatives, as well.

The delegates from these indigenous bodies participating in the workshops are all involved in the management of their marine domains and species, whether through their own traditional management regimes, such as sanctions on traditional harvesting, or through collaborative projects with scientists, such as Dr Rod Kennett, convenor of the Workshop. Djalalingba Yunupingu of Dhimurru Land Management Aboriginal Corporation, Yolngu elder and Adjunct Fellow with CINCRM, for instance, recounted his own efforts to restrict damage to nesting areas:

> That's the gate… We protect the [turtles]… No-one going to be driving around, only one road, and we put the gate on. Some people, Nhulunbuy residents, drive around everywhere and run over sand dunes. Nobody look after properly. Only one track, we put him in. That's why we look after and protect that country. We look after it and put the gate on. Nobody going to be go up the other end [of the beach area in the *Nanytjaka* estate at Cape Arnhem]. There are nesting beaches up the other side. (See page *n*)

He also attested to the expansion of his own formidable knowledge of marine turtles following a research visit to Queensland, an experience which provided new understandings of the loggerhead turtle's breeding locations:

> I didn't believe the people who told me, in my community, about the loggerhead turtle. Where they're nesting right in underwater, somewhere. And I didn't believe them when they told me. Why, should it be that turtle going to be lay at the beach. And then I had a trip to Bundaberg and talked to Col (Limpus), one of the guys talking to you mob. I met him and I proved to myself, with my eyes, and then I go back and I tell my community.

> That loggerhead is a long traveler, long way away to swim. The loggerhead, should be a special place they lay eggs, somewhere. And I showed them the picture, that is the picture, and they believe. Because loggerheads not to lay eggs down at our country. Maybe too hot. (See page 9)

The mutual respect shown by indigenous and non-indigenous participants for each other's knowledge and points of view was a gratifying feature of the workshop and evidence of the developing collaboration between the two cultures in efforts to conserve the marine turtle species.

Nanikiya Mununggurritj, also of Dhimurru Land Management Aboriginal Corporation, pointed to the recognition of the need for the 'two-way' approach, developed earlier by Yolngu education experts, such as Raymattja Mununggurritj, in marine turtle conservation:

> Most of our outstations are along the coastline, which myself, old man Djalalingba and Rod Kennett have travelled, talking to various people. What we want to do is look after these turtles. Not just for the benefit of us, this time, but for our children's children. Turtle is an important food for Aboriginal people. Most balanda (non-Aboriginal) scientists, along with the traditional owners of this land, could learn and work in relationships together. (See page *n*)

Recognition that marine turtle conservation requires genuine cooperation is much more than a local issue. Regional cooperation between a wide range of groups including fisheries, conservation agencies, recreation groups and indigenous organisations is needed to address the many threats currently facing marine turtles. Several speakers talked of the long distance migrations by turtles between nesting beaches and feeding grounds. These migrations cross regional and national boundaries and mean that turtles spend large parts of their lives living in other people's sea countries. Genuine cooperation between all the custodians of our turtles is needed if our management efforts are to succeed. The papers by Chris Devonport and colleagues from the Faculty of Science NTU on the use of GIS, and by Ray Chatto from Parks and Wildlife Commission NT on aerial surveys of nesting beaches illustrate how modern technologies can be harnessed to provide a broad regional picture of sea turtle distribution that will contribute greatly to regional cooperation in sea turtle conservation. The paper by Michael Guinea illustrates many of the NTU research and education activities that promote greater understanding of sea turtle conservation and management.

Although northern Australia is largely free from many of the development pressures which threaten marine turtles elsewhere in the world, the reports from Dhimurru Corporation of frequent beach strandings of sea turtles tangled in fishing nets discarded in international waters shows that threats do exist. Anticipated increases in coastal development will require *Yolngu* skills and knowledge to assist in the protection of marine turtles, while allowing their traditional harvests to continue.

The Larrakia Nation representatives explained their Turtle and Dugong Conservation Management Committee and Plan which aims to assist in the conservation of their populations. The Larrakia traditional lands and seas incorporate the cities of Darwin and Palmerston, and surrounding region, including the Cox Peninsula, and the surrounding seabeds and islands. These lands and seas, then, are the most heavily populated and used in northern Australia. Bill Risk and Robert Browne, who presented the Larrakia proposal at the Workshop, explained their approach in applying Aboriginal customary law in their coasts and seas. They recommend that traditional hunters from areas outside the Larrakia domain seek the permission of the management committee to be established under their proposal. The management committee would consist of key Larrakia traditional owners and members from Parks and Wildlife NT and Environment Australia. This very practical and urgent proposal demonstrates further the necessity of the 'two-way approach' (see page *n*).

Aboriginal customary law, such as Djalalingba's example of the decision of Yolngu elders to close beach areas, and the Larrakia Nation's example of the Aboriginal dictum of asking permission to enter 'country', whether land or seascapes, and to use resources, provide evidence of indigenous management strategies which complement the strategies which their *balanda* scientific colleagues develop, such as the turtle exclusion devices (TEDs) discussed by Bruce Wallner and Margot Sachse of the Australian Fisheries Management Authority (see Pages 83, 100 & 103).

And as with all successful meetings, this workshop provided an opportunity for the participants to meet other people who are working towards common goals in this field. In many cases, the participants had been unaware of each other's work and thus new links and networks were established. An exciting outcome of this workshop was the proposal to establish an indigenous community marine conservation network. Support for the proposal has come not just from CINCRM, but also from Environment Australia.
The workshop could not have succeeded without the financial support of Environment Australia, the Northern Territory University and Dhimurru Land Management Aboriginal Corporation.

Marcia Langton
Director, Centre for Indigenous Natural and Cultural Resource Management
Northern Territory University
March 1998

PREFACE

Northern Australia is home to six of the world's species of marine turtle, including the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricata*), the loggerhead turtle (*Caretta caretta*), the olive ridley turtle (*Lepidochelys olivacea*), the leatherback turtle (*Dermochelys coriacea*) and the endemic Australasian species, the flatback turtle (*Natator depressus*).

Globally, marine turtles have suffered dramatic population declines in recent decades with many populations facing extinction in the near future. Widespread concern at the decline of marine turtle populations is reflected in their conservation status under both national and international legislation as 'endangered' or 'threatened' reptiles. Threats to the long-term survival of sea turtles include incidental capture and death in fisheries, habitat loss and modification of nesting beaches and feeding grounds, marine pollution and entanglement in discarded nets and fishing equipment, and the spreading fibropapilloma disease. Prime causes of sea turtle declines in many regions is the overharvesting of eggs and adults.

Australian marine turtle populations are believed to be amongst the healthiest in the world but for many species and regions we lack ecological data necessary to develop sound conservation plans. This is especially true of the vast sparsely-populated coastline of the Northern Territory for which there are limited data on the distribution and abundance of marine turtles. These data suggest that the Northern Territory has nationally, and probably internationally, significant nesting populations of four species of sea turtle but we are presently unable to determine if these populations are stable or declining. Given the current massive harvests and alarming declines in turtle numbers in neighbouring countries with whom we share our turtles, this is cause for concern.

Despite some valuable initiatives by a number of government and non-government agencies, strategies for conservation of marine turtles in Northern Territory are in their infancy. The very isolation and difficulties of access that have buffered local turtle populations against some threats have also constrained the information gathering needed to underpin effective long-term conservation programs. It is time to develop a more coordinated approach drawing on a range of resources and expertise. The participation of a wide range of government and non-government agencies, and many community groups is a sign of the broad support for this view.

Initially this workshop was conceived of as a Northern Territory gathering as a step towards developing a coordinated marine turtle conservation program in the Northern Territory. It was viewed as an opportunity for workers in the Northern Territory to meet and discuss the latest research and management issues and programs. However, during early planning stages the workshop attracted considerable interest from outside the Northern Territory and it expanded to include participants from other states bringing a wider range of experience and perspectives to the workshop.

In all, the workshop involved some 45 participants representing a broad range of government and non-government, indigenous and non-indigenous organisations including Northern Territory University, Environment Australia, Parks and Wildlife Commission Northern Territory, Northern Land Council, Dhimurru Land Management Aboriginal Corporation, Anindilyakwa Land Council, Larrakiah Association, Batchelor College, Kimberley Land Council (Bardi people at One Arm Point), Great Barrier Reef Marine Park Authority, Northern Territory Department of Primary Industry and Fisheries, Northern Territory Environment Centre, Wildlife Management International, Australian Fisheries Management Authority, Queensland Department of Environment, WA Conservation and Land Management, and Bawinanga Aboriginal Corporation.[1]

The workshop covered a range of topics including aerial surveys of turtles and nesting habitat, turtle bycatch in fisheries, goanna predation on turtle nests, marine turtle tagging programs, marine turtle feeding behaviour, the use of GIS and satellite technology to map marine turtle habitat, and indigenous knowledge and management of turtles.

Like marine turtles, our conservation efforts and programs must also traverse state and territory boundaries. The need for greater coordination between programs and agencies became apparent as the workshop progressed. Key issues highlighted during the workshop included the need for more detailed information on turtle population status and biology, current threats and threat management strategies; increased and active involvement of indigenous people in developing and implementing monitoring and conservation programs; greater recognition

[1] While the address given on the first page of each paper was correct at the time of the Workshop, the Directory of Participants includes the current addresses of participants at the time of going to press.

of the cultural significance of marine turtles to indigenous people, and of customary law and property rights relating to marine turtles; and ongoing communication and networking to ensure a wider distribution of current information on turtle biology and research and management activities. A proposal to establish a national community network for marine turtle and dugong conservation was strongly supported by all delegates. In addition to improving communication, this network could facilitate the community involvement and consultation sought by Environment Australia in the development of national threatened species recovery plans
A key ingredient of the success of the workshop was the active participation of many indigenous turtle researchers and managers. Indigenous Australians are the original custodians of our marine turtles and they remain active as directors of, and participants in, marine turtle management across most of Australia's northern coastline. An important message from Aboriginal participants was that consultation meant listening and it was important to take the time to hear what Aboriginal people have to say. They also emphasised that the 'cultural conservation' of marine turtles (ie the conservation of stories, songs and traditional ecological knowledge) is equally important as the 'biological conservation' of marine turtles—the conservation of the animals themselves. There are two messages that should be heeded as we seek to establish working relationships between people from different cultures and regions.

The Northern Territory is the custodian of globally and nationally significant populations of marine turtles. It has a major role to play in ensuring that the tragic decline of marine turtles seen elsewhere do not occur in our region. It is an awesome task and will require cooperation between government and non-government agencies, and across cultural, political and geographical boundaries. The outcomes of this workshop, coming some 7 years after the first Australian Marine Turtle Conservation Workshop was held on the Gold Coast in 1990, are a valuable contribution to the task. Much remains to be done.

Rod Kennett October 1997
Workshop Convenor

ACKNOWLEDGMENTS

The workshop 'Marine Turtle Conservation and Management in Northern Australia' was held at the Northern Territory University, Darwin, in June 1997. The organising committee comprised Rod Kennett (Faculty of Science NTU, convenor), Michael F Christie (Faculty of Education NTU, facilitator) and Alison Pouliot (Centre for Tropical Wetlands Management, administrative support). The workshop was hosted jointly by the Centre for Indigenous Natural and Cultural Resource Management and the Centre for Tropical Wetlands Management at the Northern Territory University.

The organising committee and the two centres gratefully acknowledge the significant financial contribution from Environment Australia (Parks Australia North) towards the cost of organising and running the workshop.
Additional financial support from the Vice Chancellor's office (NTU) and Dhimurru Land Management Aboriginal Corporation is also gratefully acknowledged.

Many people contributed to the running and success of the workshop. Rachelle Bargh helped with the design and compilation of the program and other materials, Debbie Crouse and Mike Atkinson recorded the workshop on video, Sue Cooper and Stephen Hall organised rooms and audiovisual equipment, Wendy Ruscoe and Cath Elderton catered and cooked for the BBQ and drinks, and NTU Catering organised refreshments.
Post-workshop, Gordon Duff, Greg Hill, Mick Guinea and Rod Kennett reviewed manuscripts and Ann Webb copy-edited and formatted the papers and managed the production of the proceedings. Cover artwork was designed by Camilla Lawson; printing and pre-press work by NTUniprint.

The workshop was well attended by over 40 participants whose interest and support contributed to the success of the event, and in particular those who presented papers and led discussions. Given the short time between notification and running of the workshop it was a great effort by everyone and reflects the commitment of the participants to marine turtle conservation.

Gordon Duff
Deputy Director, Centre for Indigenous Natural and Cultural Resource Management

Greg Hill
Director, Centre for Tropical Wetlands Management

Rod Kennett
Faculty of Science & Centre for Indigenous Natural and Cultural Resource Management

Overview of Marine Turtle Conservation and Management in Australia

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Conservation Strategy Branch, Queensland Department of Environment

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ABSTRACT

*Six of the world's seven species of sea turtle occur in Australian waters including the green turtle (**Chelonia mydas**), loggerhead turtle (**Caretta caretta**), hawksbill turtle (**Eretmochelys imbricata**), olive ridley (**Lepidochelys olivacea**), leatherback turtle (**Dermochelys coriacea**) and the Australian endemic the flatback turtle (**Natator depressus**). Sea turtles share common life history features including: fidelity to, and long distance migrations between, nesting beaches and feeding grounds; multiple mating followed by the laying of several nests at two to three week intervals; no parental care of eggs and hatchlings; sex of hatchlings and incubation period determined by nest temperature; and typically high egg and hatchling mortality compared with typically low (excluding anthropogenic) mortality of adults. Growth is typically slow and turtles may be many decades old at first reproduction and may breed for many more decades. Anthropogenic mortality in Australian waters includes bycatch in fisheries, entanglement in discarded nets and ingestion of plastics, boat strikes, modification of nesting and feeding habitat including light pollution, and the harvest of eggs and adults by indigenous people. Predation on eggs and hatchlings by feral animals and/or goannas and dingos may be significant in some localities. Turtles that nest or reside in feeding grounds outside Australian waters face greater risk of mortality especially from large scale commercial and subsistence harvest in the southeast Asian and Pacific regions. The current high levels of mortality combined from all sources is unsustainable. Genetic studies indicate that Australian populations may be subdivided into distinct population groupings (demes) that need to be managed individually.*

KEYWORDS: life history, mating, nesting, feeding, mortality, management, population status

LIFE CYCLE

Seven species of marine turtles are well recognised worldwide and five species have a global distribution in tropical and temperate waters. Two species have a restricted distribution: the flatback turtle is confined to the waters of the Australian continental shelf while the kemps ridley turtle occurs in the Gulf of Mexico and the northwestern Atlantic Ocean. While aspects of the nesting biology have been understood for centuries, since 1980 there have been major advances in many other aspects of marine turtle biology:

- stock identification with population genetics;
- temperature dependent sex determination;
- geomagnetic imprinting of hatchlings to the area of their birth;
- oceanic dispersal of post hatchlings;
- extended life to first breeding; fidelity of adult turtles to both their feeding and nesting areas;
- migratory dispersal of adults and population modelling.

Marine turtles have many common features in their life cycles that are summarised in figure 1.

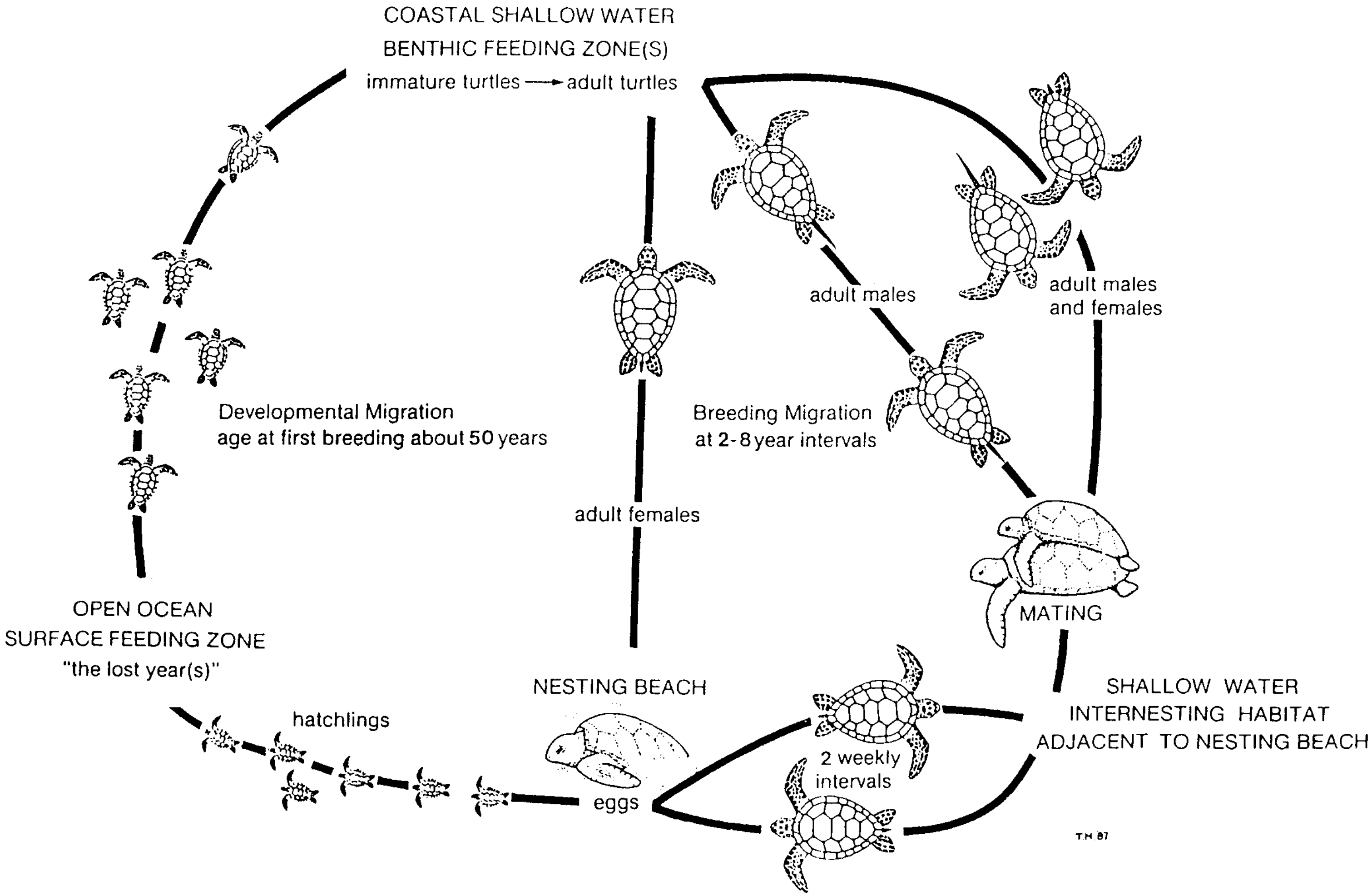

Figure 1 Generalised life cycle of marine turtles (after Lanyon et al. 1989)

Marine turtles utilise feeding grounds often far removed from the nesting beaches.

With the onset of the breeding season adult males and females migrate to copulate near the nesting area. There is no pair bond between individuals and copulation may occur with several different partners during the mating season. At courtship the female stores the sperm from her mate(s) for use later in the breeding season. At the completion of mating the males depart, presumably returning to the distant feeding grounds.

Each female moves to an area adjacent to her selected nesting beach and commences making eggs, fertilising them from her sperm store. Because of the mixture of sperm she carries, several males may contribute to the fertilisation of any one clutch. The female comes ashore, usually at night, to nest several weeks after her first mating. For those beaches fronted by reef flats, nesting coincides with the higher tidal levels. Within the one nesting season each female typically lays several clutches at about two-weekly intervals. During that two-week period she does not need to find a new mate, she moves just offshore from the nesting beach to make the next clutch of eggs, again fertilising them from her sperm store.

The breeding turtles do not feed, or else feed to only a limited extent, while migrating, courting or making eggs at the nesting beach area. They live off the stored fat reserves they accumulated before the breeding season began.

Each female usually chooses to return to the same beach or island to lay several clutches within the one nesting season. However, several per cent of females can be expected to lay on more than one beach within a few hundred kilometres of the initial nesting site.

At the completion of the nesting season the females do not use the adjacent shallow water habitats as year round feeding grounds but return to their respective distant feeding grounds, each female to the same area that she left at the start of her breeding migration. After two to eight years many of these females will make yet another breeding migration, each generally returning to nest on the same beach as before. This behaviour and the annual use of traditional nesting beaches have led to the assumption that a marine turtle returns to nest on the precise beach of her birth.

In reality the homing is probably not that exact. Genetic studies suggest that the female returns to breed in the general region of her birth. For example, when a turtle born in the southern Great Barrier Reef grows up, it should return to breed in the southern Great Barrier Reef or a turtle born in northeastern Arnhem Land should return to breed in northeastern Arnhem Land.

Females lay their eggs high up on the beach usually within the vegetated strand. No parental care is exercised. The incubation period and the sex of the resulting hatchlings are a function of the temperature of the surrounding sand. A warm nest at mid incubation results in all or mostly female hatchlings while males come from cool nests.

The eggs hatch about 7 to 12 weeks after laying (Miller 1985). The hatchling turtles dig their way unaided, as a group, through the 50 cm or more of sand to the surface. On surfacing they immediately cross the beach to the sea. This hatchling emergence is almost entirely nocturnal. During the beach crossing they orient towards low elevation bright horizons. The hatchlings are imprinted to the dip and strength of the earth’s magnetic field at the beach.

For most eastern Australian turtle rookeries only a small percentage of hatchlings is lost to terrestrial predators during the beach crossing. Immediately the hatchlings reach the water they begin oriented swimming into the wave fronts that takes them away from the beach and into deep water. The hatchling at this stage is living off a yolksac internalised just prior to hatching. Hatchlings do not feed while on the beach or while swimming out to sea.

In coral reef areas when the hatchlings are crossing the reef flat, they are probably exposed to the greatest level of predation during their life cycle. This is a period of transfer to predatory fish of nutrients derived from adult turtles via eggs and hatchlings. For all except flatback turtles, the hatchlings, on reaching the deep-water areas, continue to swim out to sea and this activity presumably brings them under the influence of the open ocean currents where they drift for the first few years of their lives. The post-hatchling flatback turtles remain over the continental shelf. Post-hatchling turtles do not feed nor take up residence in the vicinity of where they were born.

When the hatchlings disperse from the nesting beach they are virtually lost to study for the next few years. While in this drifting phase the turtles presumably feed on the macroplanktonic animals and/or algae at the surface. The young of all marine turtles except the leatherback turtle ‘reappear’ at about the size of a large dinner plate (curved carapace length 35–40 cm, age undetermined but possibly 5–10 yr old). Loggerheads recruit at a larger size, >70cm in carapace length.

At this size they take up residence in the shallow water habitats of the continental shelf, feeding principally at the bottom on plants and animals depending on the turtle species.

Green turtles feed mostly on seaweed, seagrass and mangrove fruits. Loggerhead turtles feed mostly on shellfish and crabs.

Flatback turtles feed mostly on soft corals and sea pens. Olive ridley turtles feed mostly on small species of crab and shellfish. Hawksbill turtles feed mostly on sponges. These turtles will also eat jellyfish and Portuguese man-of-war on occasions.

These immature turtles may remain in the one feeding ground for extended periods, perhaps years, before moving to another major area. Several such shifts may occur in the life of the turtle in this coastal shallow water benthic-feeding phase. The offspring of a particular female will not all recruit to the same feeding area but are expected to recruit throughout the entire region occupied by the breeding unit. The leatherback turtle, which remains an inhabitant of oceanic waters for almost all its life, feeds mostly on jellyfish.

Tagging studies of turtles living within the Great Barrier Reef show that they are many decades old at first breeding and can have a breeding life spanning many more decades. At no stage in their life are sea turtles free of predation. The young to adult sized turtles are potential prey to large cod, grouper, sharks, crocodiles and killer whales. However, in Australia and the neighbouring countries of South East Asia and the western Pacific Ocean, human actions continue to be the most significant threat to survival of marine turtles.

Studies in the Great Barrier Reef indicate that marine turtles have very high annual survivorship throughout their lives in the absence of human impacts. This high annual survivorship appears to be essential for marine turtles to maintain population stability. Small increases in annual mortality over extended periods at any stage of the life cycle can be expected to cause population declines.

Green and olive ridley turtles have been harvested in large numbers especially for meat. The hawksbill turtle has been hunted excessively for tortoiseshell. All species are hunted for leather, oil and their eggs. Incidental capture in fishing gear can also cause significant mortalities of marine turtles, especially in prawn trawls, drift nets, large mesh set nets and long lines.

In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality. Boat strikes are common in shallow areas with high density recreational boating.

Wherever there has been organised harvesting or large-scale killing of the turtles and/or their eggs over several decades, the turtle population has undergone significant decline. No one has ever successfully managed to maintain marine turtle populations at stable population levels while subjecting them to large-scale mortalities.

AUSTRALIAN MARINE TURTLE POPULATIONS AND POTENTIAL THREATENING PROCESSES*

Six species breed in Australia. The least studied turtle species within Australia are the olive ridley and leatherback turtles. However, for all species there is a paucity of data on age structure, annual survivorship, breeding rates and other demographic data for the feeding populations. For all species, there is inadequate quantification of harvest rates and other mortality rates within Australia and in neighbouring countries.

Green turtles, *Chelonia mydas*

Australia has at least 4 large management units of green turtles (a management unit is identified by the main concentration of breeding: southern Great Barrier Reef, northern Great Barrier Reef, Gulf of Carpentaria and Northwest Shelf). These breeding populations supply green turtles to feeding areas in Indonesia, Papua New Guinea, Vanuatu, New Caledonia and Fiji, as well as in tropical and temperate waters of Australia (figure 2). In addition, green turtles from nesting populations in Indonesia, Papua New Guinea, and New Caledonia have been recorded in feeding areas within Australia.

There are large interannual fluctuations in breeding numbers for green turtles because the proportion of adult females that prepares to breed in any one year is a function of the El Nino Southern Oscillation climate event two years before the breeding season. This high variability in annual breeding numbers is making it difficult to determine the stability of the Australian stocks in the face of the large harvest of green turtles that occurs within the migratory range of the turtles from the Australian rookeries. It is estimated that approximately 100,000 green turtles, mostly big females, are harvested per year within the migratory range of the Australian breeding turtles (Limpus 1995). Additional mortality occurs in trawl and gill net fisheries, from boat strike and from ingestion of synthetic materials. In Queensland, feeding areas like Moreton Bay have a high incidence of fibropapilloma disease in green turtles. Even with the large nesting populations in Australia, the current high mortality of green turtles cannot be sustained.

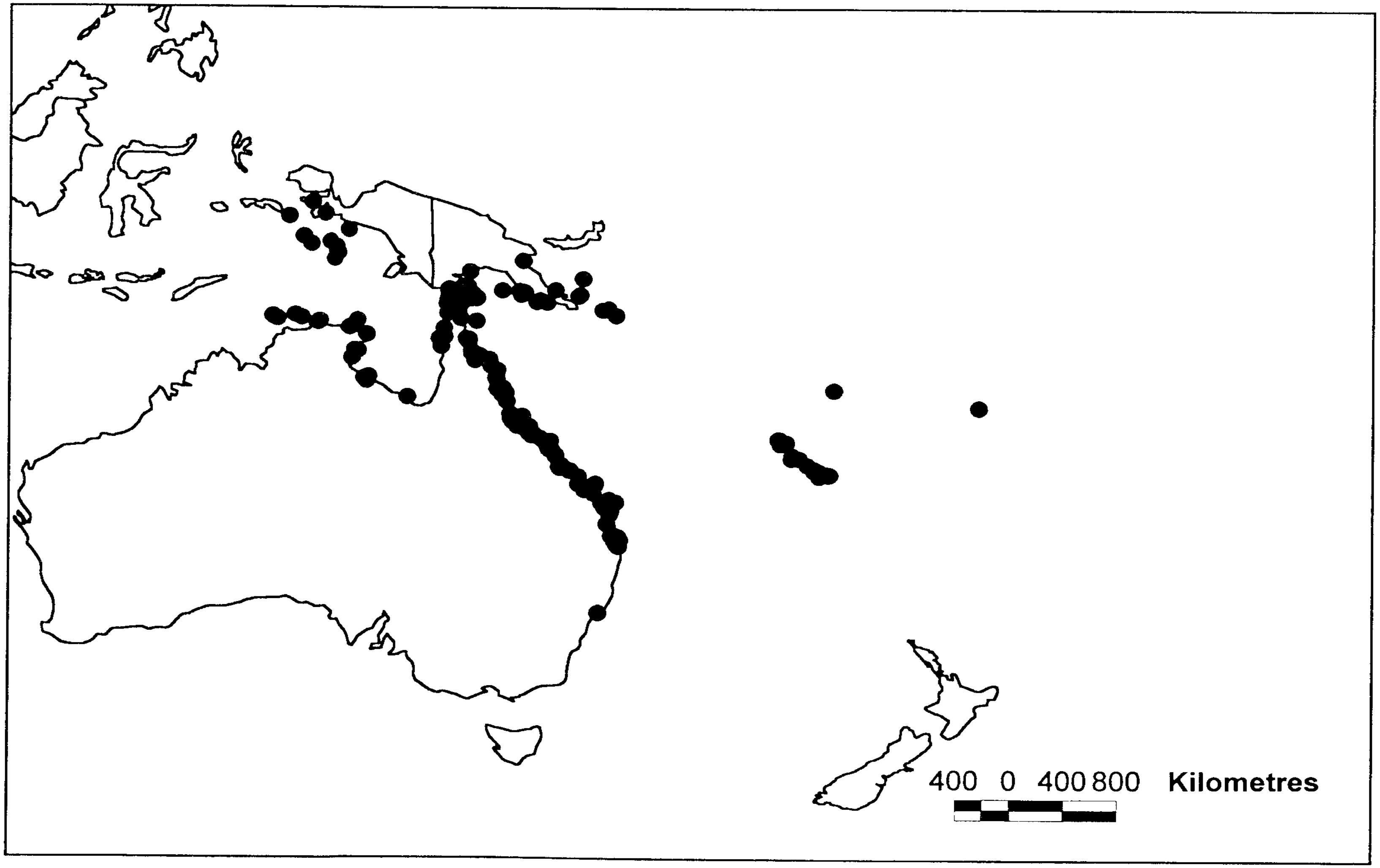

Figure 2 Distribution of feeding areas for green turtles, *Chelonia mydas*, that breed at rookeries within the Great Barrier Reef (northern GBR and southern GBR management units) based on recaptures of adult female green turtles originally tagged while ashore for nesting

Loggerhead turtles, Caretta caretta

Australia has 2 large management units of loggerhead turtles (eastern Australia and Western Australia) that supply loggerhead turtles to feeding areas in Indonesia, Papua New Guinea, Solomon Islands and New Caledonia as well as in tropical and temperate waters of Australia (figure 3). In addition, loggerhead turtles from the small nesting population in New Caledonia have been recorded in feeding areas in Queensland.

There has been a 50–80% decline in the annual number of breeding female loggerhead turtles in eastern Australia since the mid 1970s. Hundreds of large loggerhead turtles die annually in northern and eastern Australia from bycatch mortality in trawls, entanglement in crab-pot float lines, boat strike, ingestion of fishing line, and from other human related impacts. An annual mortality of only hundreds of large immature and adult loggerhead turtles may be sufficient to cause a continuing population decline (Crouse et al 1987).

In addition, since the late 1970s there has been significant fox predation of loggerhead turtle eggs laid on the mainland beaches near Bundaberg. This is expected to cause further population declines with our nesting loggerheads in perhaps another decade.

Hawksbill turtles, Eretmochelys imbricata

Australia has at least 2 large management units of hawksbill turtles (northeastern Australia–eastern Arnhem Land and Western Australia) that supply hawksbill turtles to feeding areas in at least Indonesia and tropical Australia. In addition, hawksbill turtles from the nesting populations in Papua New Guinea, Solomon Islands and Vanuatu have been recorded in feeding areas in Queensland.

There has been no census of the Australian hawksbill turtle breeding populations. However, there are very large harvests of hawksbill turtles for tortoiseshell and meat in neighbouring countries that include turtles from the Australian breeding populations. In Torres Strait and Arnhem Land there are substantial harvests of hawksbill eggs for human consumption. There is addition substantial mortality from drowning in trawl nets, boat strike, ingestion of fishing line and entanglement in lost or discarded nets. It is highly probable that the combined annual mortalities are beyond the sustainable limits that our populations can replace. It is suspected that the Australian populations are already in decline.

Olive ridley turtles, Lepidochelys olivacea

Australia has a genetically distinct population of olive ridley turtles that breeds in Arnhem Land. There is no indication that the Australian ridley turtles form the synchronised nesting aggregations (arribadas) that occur in Central America and India.

Very little research has been conducted with this species in Australia. Hundreds of large olive ridley turtles die annually in northern and eastern Australia from bycatch mortality in trawls and entanglement in discarded or lost nets. Eggs are harvested by coastal communities in Arnhem Land. Given the apparent small size of the total nesting population, an annual mortality of only hundreds of large immature and adult olive ridley turtles in addition to the egg harvest probably is a significant threat to this species in Australia.

Flatback turtles, Natator depressus

This species is endemic to the Australian continental shelf (including the south coast of Irian Jaya and Papua New Guinea) but nesting is restricted to Australia. Australia has several large management units of flatback turtles (eastern Queensland, northeastern Gulf of Carpentaria, Arnhem Land and Western Australia) that supply flatback turtles to feeding areas in tropical Australia and neighbouring countries.

There has been no reliable census of most of the flatback turtle breeding populations. There is an unquantified harvest of flatback turtles and their eggs by coastal communities in northern Australia and Indonesia. Many hundreds of flatback turtles drown in trawl and gill net fisheries in northern Australia. Addition mortality occurs from drowning in lost or discarded nets, boat strike and ingestion of synthetic materials. A major portion of the annual egg production in western Cape York Peninsula is lost through predation by feral pigs. In Arnhem Land, large losses of eggs occur from predation by apparently unnaturally high populations of goannas.

It is highly probable that the combined annual mortalities are beyond the sustainable limits for the species. It is suspected that the species is in decline.

Leatherback turtles, Dermochelys coriacea

This species is regularly encountered feeding in the temperate waters from southern Queensland to south Western Australia. The Australian nesting population is very small—less than 10 individuals annually in south Queensland, northern New South Wales and Arnhem Land. There is a very poor hatching success from natural nests in eastern Australia. Elsewhere in the Indo-Pacific leatherback turtles have experienced major population declines in the last 20 years.

Given the very small size of the Australian nesting population, there is concern regarding the regular mortality of the species from entanglement in float lines to lobster pots and fish-traps in southern Australia and gill nets throughout Australia.

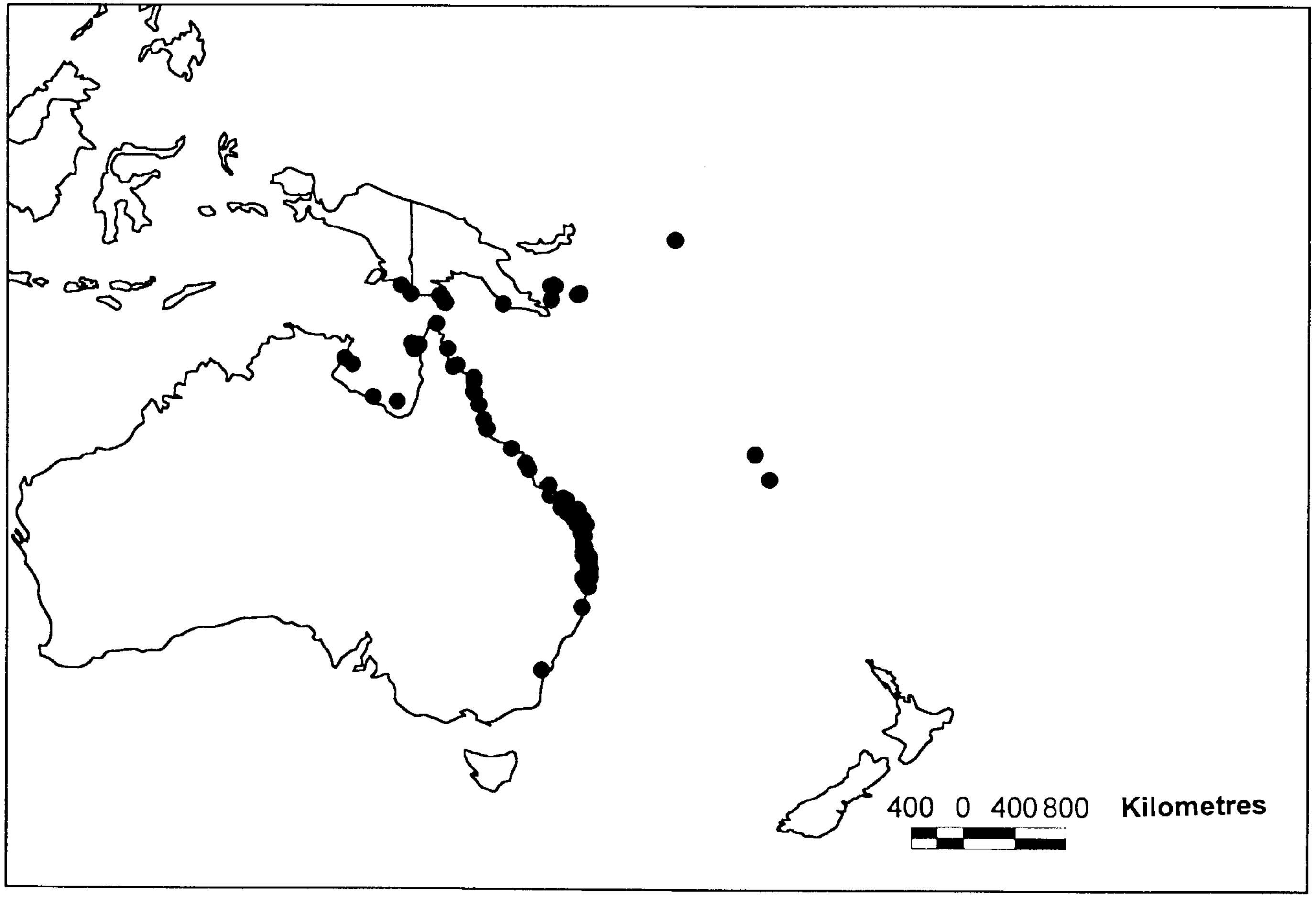

Figure 3 Distribution of feeding areas for loggerhead turtles, *Caretta caretta*, that breed at eastern Australian rookeries (southern Great Barrier Reef and adjacent mainland of south Queensland) based on recaptures of adult female loggerhead turtles originally tagged while ashore for nesting

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Nhaltjan Nguli Miwatj Yolngu Djäka Miyapunuwu: Sea Turtle Conservation and the Yolngu People of East Arnhem Land

Djalalingba Yunupingu

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That's Northern Territory, Arnhem Land. Right near Yirrkala, near Gove (see fig 1 in Kennett, this vol). This is all Aboriginal homelands, and it is a hunting area for the turtles. That area, all the land, all the homelands, like that country and down Groote Eylandt way and inland, that my country. I'm interested in all the turtles and the people who hunt around in that area, down in the country. They collect eggs. See that young man, sitting down counting the eggs (plate 1).

I went myself to collect the eggs, and I knew that a fresh one coming up and I got down and pick them up (plate 2). And some I collect and some of them I put back. That's my picture, at the Cape Arnhem area. It's got a long beach there and a good beach for looking for the nesting turtle. This area (pointing to a map). It is half way, and we caught the turtle and I bring them up and cut some meat, same as the other places. These turtles, this time of year, for our people. The turtle is shell, and some of them are rough with how we cook the turtle. And some of them we eat the meat. See that little rock, round rock, where we cook them (plate 3). We put it under the ground... underground it will warm up and it cooks here and then we eat that and cut it up. That's how we make it.

See, we're lining up the shells, how much we caught them (plate 4). Young men were learnt, understanding...the shell and how much we have got it and we're count it...that young boy.

When I was running around all over the place, talking to the local Aboriginal people, talk about their turtle, same thing. And old man where he is traditional landowner, I ask him, 'What we going to do with that turtle? We going to be look after and protect him properly, not to kill that turtle, like eat and waste it. We kill to eat only, not to waste it. This turtle, and I'm talking to this old man here, that old man sitting up there, and we talk about the old Aboriginal local people and the way they living. You know.

I pointed out the homeland and the name of the country and where we're living separate. All Aboriginal people are going to walk around and drive around and talk to them (plate 5).

That's the car, the ranger car. See that badge, the Dhimurru badge. We're driving along the beach and protect the turtle (plate 6). Another ranger from Darwin we work together for Yolngu. We work together and it's been a long time we need those people. They've given us the ideas, what's going on, and what's protecting the turtle area. Any animals, bush animals, sea animals or any kind. We going to be learning the right thing to do to look after the country, to look after any animals.

That's the gate (at Cape Arnhem) (plate 7). We protect the (turtles)... No-one going to be driving around, only one road, and we put the gate on. Some people, Nhulunbuy residents, drive around everywhere and run over sand dunes. Nobody look after properly. Only one track, we put him in. That's why we look after and protect that country. We look after it and put the gate on. Nobody going to be go up the other end. There are nesting beaches up the other side.

I didn't believe the people who told me, in my community, about the loggerhead turtle. Where they're nesting right in underwater, somewhere. And I didn't believe them when they told me. Why, should it be that turtle going to be lay at the beach. And then I had a trip to Bundaberg and talked to Col (Limpus), one of the guys talking to you mob. I met him and I proved to myself, with my eyes, and then I go back and I tell my community.

The loggerhead is a long traveller, long way away to swim. The loggerhead, should be a special place they lay eggs, somewhere. And I showed them the picture, that is the picture, and they believe. Because loggerheads not to lay eggs down at our country. Maybe too hot.

Plate 1 Yolngu elder Bawurr Munuyarryun shows a young man how to excavate a Guwarrtji (hawksbill) nest and count the eggs. (photo R Kennett)

Plate 2 Djalalingba Yunupingu examines eggs from a Garriwa (flatback) nest at Cape Arnhem. (photo R Kennett)

Plate 3 A cooking site where a Dhalwatpu (green turtle) was prepared and eaten. The turtle is killed then placed on a bed of coals. Heated rocks (seen in photo) are inserted into the shell to ensure the internal organs are cooked and the turtle is covered with bark, leaves and earth. (photo R Kennett)

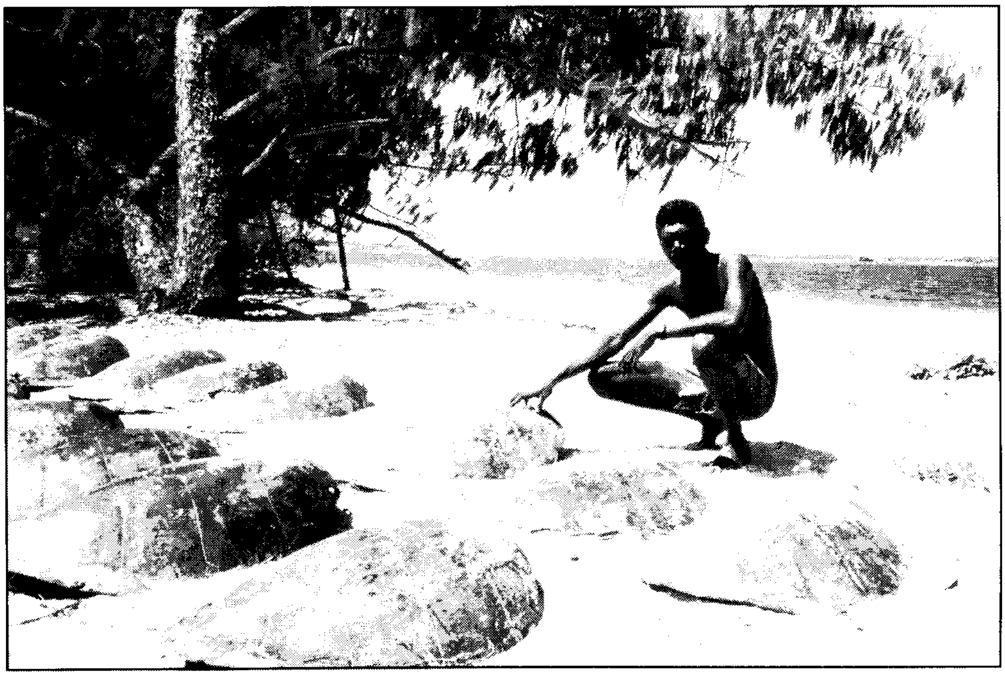

Plate 4 Turtle hunters at Dhaniya are stockpiling their turtle shells as part of the program to monitor the harvest of turtles. (photo R Kennett)

Djalalingba Yunupingu

Plate 5 Djalalingba Yunupingu (front left) discusses the miyapunu project with senior Yolngu at a coastal community. (photo R Kennett)

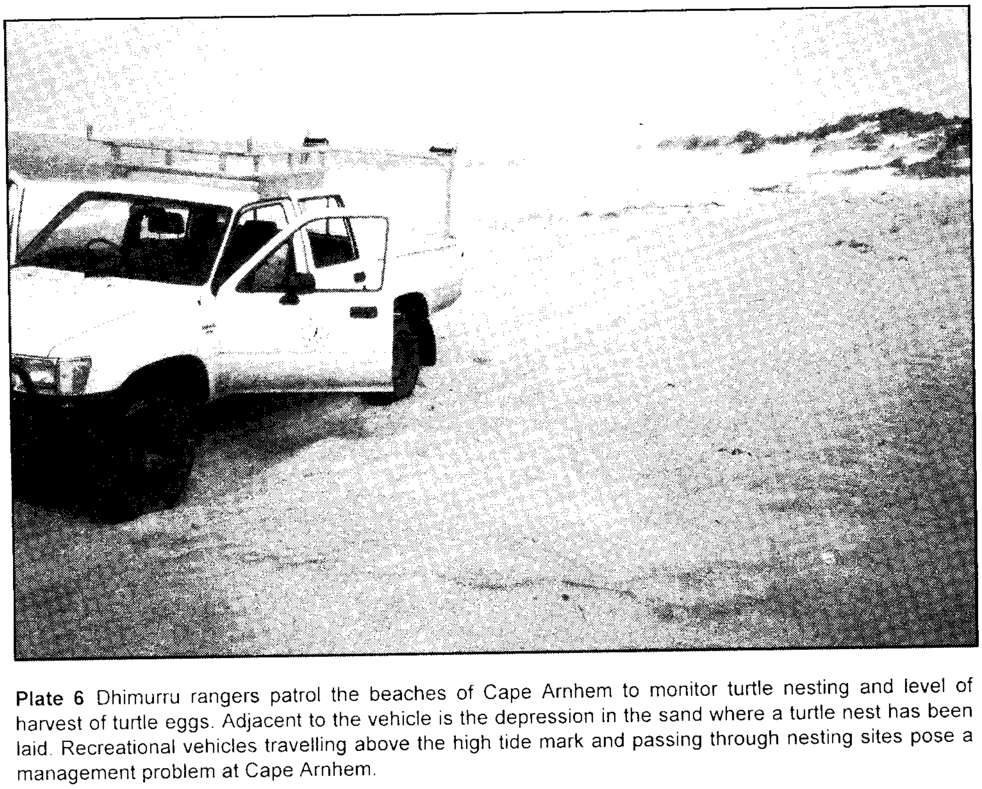

Plate 6 Dhimurru rangers patrol the beaches of Cape Arnhem to monitor turtle nesting and level of harvest of turtle eggs. Adjacent to the vehicle is the depression in the sand where a turtle nest has been laid. Recreational vehicles travelling above the high tide mark and passing through nesting sites pose a management problem at Cape Arnhem.

Plate 7 Vehicle access to important nesting beaches at the northern end of Cape Arnhem is restricted by a fence and a locked gate. The fence was constructed in response to concerns at impact of recreational vehicles on nests and at high levels of harvest of turtle nests.

Plate 8 A Garun (loggerhead) turtle nesting on the beach at Mon Repos. The visit to Mon Repos Sea Turtle Study Centre was the first time that a Yolgnu person had observed Garun nesting. (photo Dhimurru Land Management Aboriginal Corporation)

Djalalingba Yunupingu

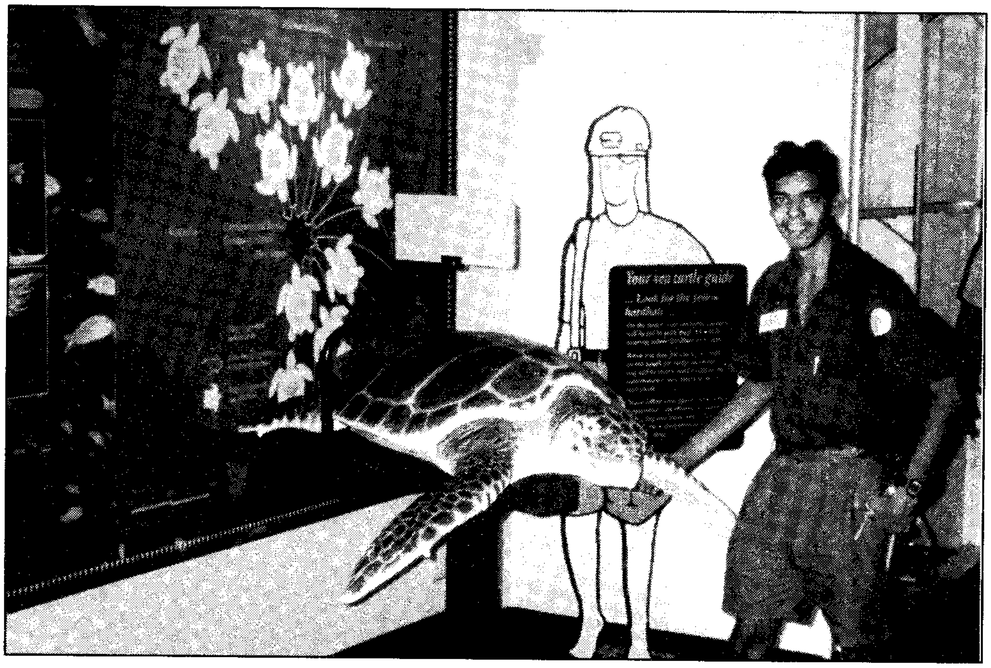

Plate 9 Grant Gambley, Dhimurru trainee ranger, stands near an exhibit at the Mon Repos Sea Turtle Research Centre that shows Garun (loggerhead) turtle) migration patterns. (photo R Kennett)

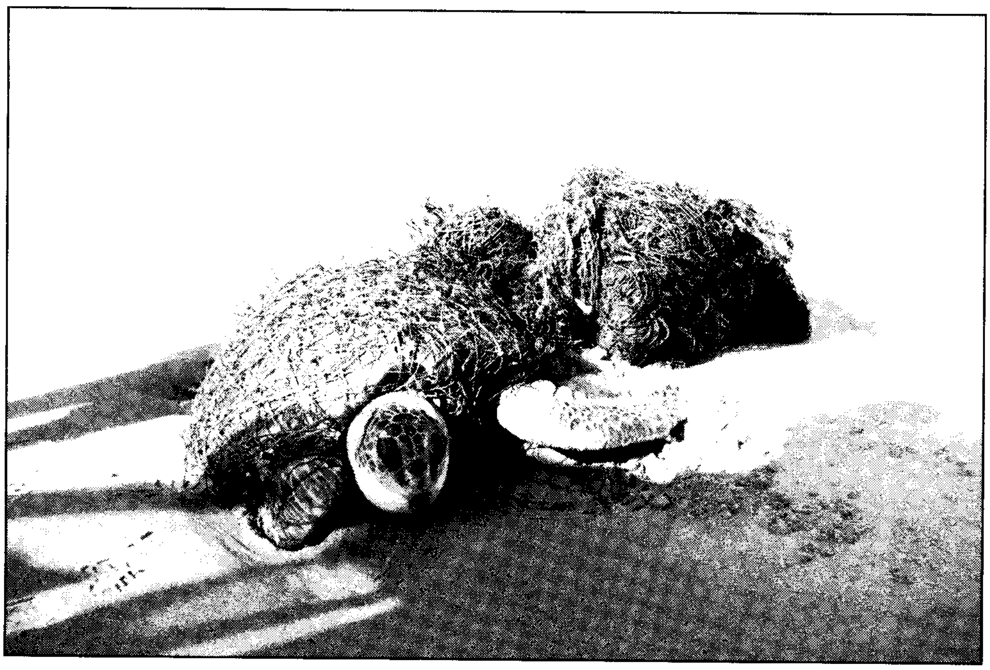

Plate 10 A Dhalwatpu (green turtle) entangled in fishing net that washed ashore on Cape Arnhem. The entanglement and stranding episodes happened in 1996 and 1997 and rescuing entangled turtles is a priority management concern for Dhimurru. (photo Adrian Wagg)

I understand that two area, like Bundaberg (Queensland), some of them in Western Australia and some in Malaysia. I can see on the map. They point it out for me. They believe it and I told them, my community. I reckon no, I don't believe it, what you told me, and I showed them photographs. Look at this, this is the loggerhead laying egg right in the soil (plate 8).

This is Grant and he was at Bundaberg with me (plate 9). I was there. I was very sick that day. I went down to the hospital. At that place he worked with me, and some of the other boys worked with me. Young people, they learning from the ranger. That's why I am talking to every clan, community. They're learning from the ranger, understanding how we protect the land, any kind of food, bushfood, seafood, animal. And when we need the ranger from Conservation, work with us and helping us. Ah, you know, to work together, that's all. Nothing serious in anything... push the people from the other end. Work together. That's why we need the Conservation people out there.

Like, I'm a man who is a traditional cultural adviser, and the white people, anyone, we work together. I think it's a good idea.

Ah, fishery. I don't know, fishery mob going to throw the net. Caught in the net is a young turtle. It floated into the shore and lying down. Lots, a couple of bundles of them. We found it. They killed them, because the fishery is throwing the net. And look at this picture (plate 10). All along the coast, they fishing out there. And they throw the net and caught it, or it may be a fishing line or whatever, rubbish stuff, floating all over the place. The net is very dangerous for the sea animals, to kill. Not any more grow up. You know, I'd like to be big population for turtle in the area. Look after and protecting country.

And that's all. Thank you for that, today

Developing Recovery Plans for Marine Turtles

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ABSTRACT

Five of the six species of marine turtle found in Australia are listed as vulnerable or endangered under the Endangered Species Protection Act 1992. The Act provides a process for the preparation of a recovery plan for marine turtles. There is a recognition of the need to consult and discuss the preparation of the recovery plan through the formation of a recovery team. The plan should be based on the best available information and should provide actions for the recovery of marine turtles. It is the intent of the Commonwealth to facilitate the preparation of a draft recovery plan with substantial actions identified.

KEYWORDS*:* marine turtles, threatened species, recovery plans, conservation legislation

INTRODUCTION

In this paper we discuss the preparation of Recovery Plans under the Commonwealth endangered species legislation and discuss how this may translate into a process for the preparation of a recovery plan for marine turtles.

The historical need for and the establishment of the Commonwealth *Endangered Species Protection Act 1992* has been documented in Male (1996) who also identified the need for the Commonwealth to interact with and legislate on international issues.

The Act provides for the listing of endangered and vulnerable species (Schedule 1) endangered ecological communities (Schedule 2) and key threatening processes (Schedule 3).

The Act then provides for the preparation and implementation of:

- recovery plans for listed endangered and vulnerable species;
- recovery plans for listed endangered communities;
- threat abatement plans for key threatening processes.

A recovery plan must be prepared and implemented for each listed species and ecological community that occurs in Commonwealth areas (TSCS 1997). A threat abatement plan must be prepared and implemented for each key threatening process (Schedule 3) that occurs in Commonwealth areas. These Commonwealth areas are:

- land owned or leased by the Commonwealth or its agencies;
- Australia's external territories and Jervis Bay Territory;
- the coastal sea (except areas vested in a State or Territory);
- the seabed and waters of the continental shelf;
- the Australian Fishing Zone;
- land or sea declared a park or reserve under the *National Parks and Wildlife Conservation Act 1975* (Cwlth).

Where these species or threats also occur on State/Territory land the plans must be written in co-operation with those States or Territories. Furthermore where species do not occur in Commonwealth areas, the jurisdictions are encouraged to prepare a recovery plan that can be adopted under the Act, but this is not a legislative requirement.

The content of these plans is defined in the Act and for recovery plans in particular, contained within the *Recovery Plan Guidelines* that have been prepared by the Commonwealth to assist in the preparation of recovery plans. Some major points to take from these guidelines are that a recovery plan must identify the research and management actions necessary to stop the decline and support the recovery of the species or community so that its chances of long-term survival in nature are maximised. In doing so, the plan must:

- state an objective;
- state the criteria against which the objective is measured;
- specify the actions needed to satisfy the criteria;
- state the estimated duration and cost of the recovery process;
- identify affected interests and those involved in the evaluation of the plan;
- specify the major benefits to non-target species.

Not only must a recovery plan deal with these specific issues, but it must also have regard to:

- the objects of the Act;
- the most efficient and effective use of resources;
- be consistent with the principles of ecologically sustainable development.

The objects of the Act recognise the interest the Australian community has in the management of 'vulnerable' parts of the natural estate. In satisfying the objects, progress is made in addressing the needs of the species or addressing the threat and satisfying the needs of the community's interest. Simply put, the objects may be satisfied by activities such as: the preparation of plans that identify objectives and actions; involving stakeholders in the preparation of plans, and so on (table 1).

DISCUSSION

In conserving native species and fulfilling its statutory obligations, the Commonwealth has to prepare plans with actions to ameliorate the decline of, or threats to, endangered or vulnerable species and communities, as outlined above. Importantly, these Acts also allow for working co-operatively with States, Territories and stakeholders. Recovery plans provide the mechanism to identify research and management actions and achieve the conservation objectives collectively.

Currently five of the six marine turtles found in Australia are listed as endangered and vulnerable under the Act (table 2). The flatback turtle (*Natator depressus*) was recommended by Limpus (1995) for inclusion on Schedule 1 as a vulnerable species.

In addition, the listing of prawn trawling as a key threatening process for marine turtles is under consideration by the Endangered Species Scientific Subcommittee. The Subcommittee was established to provide advice to the Minister for the Environment on the listing process under the Act.

Previous recovery plans for other species have concentrated on managing a species within a particular area, but marine turtles present a management challenge because:

- they have a wide distribution, across many jurisdictions;
- there is a range of impacts, both domestic and international;
- they are important to indigenous people in a cultural context;
- they are valued by non-indigenous Australians as integral components of the environment.

Table 1 Objects of the *Endangered Species Protection Act 1992 and some actions to satisfy those objects*

Objects of the Act	Action
Promote the recovery of species and ecological communities that are endangered or vulnerable	Prepare recovery plans with identified objectives and actions
Prevent other species and ecological communities from becoming endangered	Prepare threat abatement plans (TAPs) to manage impacts of key threatening processes
Reduce conflict in land management through readily understood mechanisms relating to the conservation of species and ecological communities that are endangered or vulnerable	Stakeholder membership on recovery teams and TAP teams Through the planning process develop agreed cross jurisdictional management strategies
Provide for public involvement in, and promote public understanding of, the conservation of such species and ecological communities	Community membership on recovery teams and TAP teams eg Develop a communication strategy
Encourage co-operative management for the conservation of such species and ecological communities	Collective implementation of plan actions

Table 2 Status of marine turtles under the *Endangered Species Protection Act 1992*

Species	Common name	Status
Caretta caretta	loggerhead turtle	E
Chelonia mydas	green turtle	V
Eretmochelys imbricata	hawksbill turtle	V
Lepidochelys olivacea	olive ridley turtle	V
ermochelys coriacea	leatherback turtle	V

E = endangered;
V = vulnerable

Conservation actions will be determined at the national level through consensus at the recovery team meetings. A recovery team provides advice to the lead agency preparing the recovery plan and is generally formed prior to the writing of a recovery plan.

We are fortunate that much of the collection of baseline data and review of scientific literature concerning marine turtles has already been collected and collated by Limpus (1995) and others. This will provide the basis from which we may make decisions about future actions.

Environment Australia is now formulating an approach to the recovery plan process for marine turtles. One model that could be considered is currently being used for the preparation of the threat abatement plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations. This model offers a means to separate the decision-making and advice-giving mechanisms.

Under this model a recovery team of stakeholders has been formed. Providing advice to the recovery team is a technical working group made up of scientists and technical experts. The task of the recovery team is to prepare the recovery plan. The technical working group is formed to answer questions of a scientific or technical nature from the recovery team who then acts on the advice provided. This approach allows the resolution of technical issues while not impeding the preparation process.

This approach, for marine turtle recovery planning has yet to be finalised and will be subject to negotiation with State and Territory agencies. Agreement on a national approach to the recovery plan process for marine turtles will assist the development of strategies for the identification of recovery objectives and action.

In acknowledging the need to manage marine turtles locally, we must also acknowledge the international interests of Asia/Pacific nations. The Commonwealth will take a lead role in international relations with relevant nations who are also stakeholders in marine turtle management.

To date the Commonwealth has provided support for Indonesian initiatives and is intending to engage with South Pacific Nations through the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (SPREP, South Pacific Regional Environment Programme). Other areas of interaction will be through the Convention on Migratory Species (Bonn Convention), the Convention on the International Trade in Endangered Species (CITES) and the Torres Strait Treaty. The outcomes of these engagements will necessarily impact on domestic issues and will be subject to discussion and agreement.

CONCLUSION

- There is legislation that provides a process for the preparation of a recovery plan for each listed species and ecological community.
- There is a recognition of the need to consult and discuss the preparation of the recovery plan through the formation of a recovery team and consultation with interest groups.
- A successful recovery plan is based on the best available information.
- Finally, within the next 12 months it is the intent of the Commonwealth to have facilitated the preparation of a draft recovery plan with substantial actions identified.

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Implications of Nest Site Selection on Egg Predation at the Sea Turtle Rookery at Fog Bay

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ABSTRACT

*Four beaches in Fog Bay, Northern Territory, were surveyed over two time periods to find the number of flatback (**Natator depressus**) and olive ridley (**Lepidochelys olivacea**) sea turtle nests laid on each beach and the locality of the nests with respect to the primary dune. Nests were monitored for predator activity. Between 50% and 60% of the nests were raided by goannas (**Varanus panoptes**). Nests on the dune slope attracted either less, or at least as much, predation as nests laid below the dune slope. Between 78% and 85% of nests were laid below the dune slope each year. This area, despite higher predation rates, has the potential to contribute markedly to the productivity of the beaches in terms of hatchling sea turtles surviving to enter the sea. Management practices that transplant sea turtle eggs from high-risk areas may exploit, on a limited basis, areas of low predation. Caution should be applied to active control of native predators of sea turtle nests until more is know about the productivity of rookeries in terms of supplying hatchlings to the sea.*

KEYWORDS*:* eggs, nest, Natator, Varanus, Lepidochelys

INTRODUCTION

Sea turtles are vulnerable at each stage of their life (Stancyk 1982). Various population dynamics models have been produced to investigate sea turtle demography (Crouse et al. 1987, Heppell et al. 1996) yet survivorship at most stages, is poorly known. Survivorship of eggs and hatchlings at rookeries has been reduced to lists of predators and gross estimates of hatchlings entering the water per nest in an normal breeding season (Parmenter & Limpus 1995). Hence, predators of sea turtle eggs and hatchlings are well documented and their presence is usually conspicuous, but their impact, although obvious, remains largely unquantified (Stancyk 1982). This destruction is not uniform across the rookery, as green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtle nests laid in exposed sites have a greater risk of predation (Fowler 1979, Sivasunder & Devi Prasad 1996).

A complete list of all predators of sea turtle nests would include most of the vertebrate and invertebrate carnivorous and omnivorous species that live near a rookery (Carr 1973). Both Stancyk (1982) and Marquez (1990) gave a global review the importance of various predators on sea turtle eggs. Predators such as ghost crabs (*Ocypode* sp.), which were ranked as important overseas, are only of minor importance on Australian rookeries (Limpus 1971, Limpus et al. 1981, Limpus et al. 1983a, b, Guinea 1994). In Australia, several species of goannas (*Varanus* spp.) raid sea turtle nests. These include *V. indicus* on Campbell Island (Limpus et al. 1983a), *V. giganteus* on Barrow Island (King et al. 1989.) and *V. gouldii* on Field Island (Vanderlely 1996). Other predators of sea turtle eggs in Australia include the introduced fox (*Vulpes vulpes*), pig (*Sus scrofa*) and dingo (*Canis familiaris dingo*) (Limpus 1978, Limpus 1982).

Of the six species of sea turtles that breed in northern Australia, the flatback (*Natator depressus*) nests widely on a number of mainland and offshore island habitats (Limpus 1982). A variety of predators and differing predation rates are therefore expected throughout its geographic range. As with this and other species of sea turtle, high predation rates on the mainland may encourage the formation of significant rookeries on offshore islands (Limpus 1978, Limpus et al. 1981, Limpus et al. 1983b). Flatbacks may establish even on a rookery with heavy predation, as suggested for greens (Fowler 1979) and leatherbacks (Sivasundar and Prasar 1996)—a nesting behaviour that utilises localities where their eggs have a higher chance of survival. Flatback sea turtles prefer to nest above the beach slope and even on top of the dune where they can gain access (Limpus 1971). In Fog Bay, flatbacks nest from March to October (Guinea 1994). This paper examines predation on flatback and olive ridley sea turtle nests over two time periods at a mainland rookery to determine if nest site selection by the turtles is a factor in the observed predation rates and implied survivorship of hatchlings.

METHODS

The study site was on the mainland coast of Fog Bay (12°41'S, 130°21'E). Four beaches were surveyed by foot to assess the number of sea turtle nests laid on respective beaches (fig 1). Each beach contains areas of rock and sand in the intertidal regions. The berm (Segar 1997) was backed by dunes that varied in height from about 1 m to 7 m (Guinea 1994). Successful nests were identified by the return track to the water, emerging from a disturbed patch of sand that had been well covered by the nesting female. Tracks that were not associated with disturbed sand and those that emerged from depressions containing the impressions of a body pit and or an egg chamber were recorded as unsuccessful. Nests raided by predators were identified by the presence of the predator's tracks and the remains of eggs or their shells in the immediate vicinity. Predation rates were calculated as the percentage of total nests that were raided during the study. We erased, in part, each turtle track so that it would not to be included in subsequent surveys. Surveys lasted for up to five days and were conducted on a monthly basis from April to July 1989 and on a two-weekly basis from March to May 1997.

Successful nests were recorded according to the beach number, ie 1 to 4, and locality, ie below the dune slope, on the dune slope and above the dune crest. Nesting activity was recorded as the number of successful nests laid over the study period. An estimate of the age of the nest was determined in days by examining the turtle tracks at their points of exit from, and entry to, the water on successively diminishing high water marks as the tides moved from springs to neaps. As the tide heights increased to springs, the maximum tide of the day obliterated existing tracks in the intertidal zone. Their associated nests were recorded as being prior to the last springtide. The area experiences semidiurnal tides with a spring tidal range of 8 m (Guinea 1994).

The species of sea turtle associated with the nests were determined by the morphology and width of the track (Limpus 1971, Guinea 1990, Guinea 1994), clutch size and the size of individual eggs. Flatbacks lay a small clutch of approximately 50 eggs with a diameter that ranges from 44.7 to 52.7 mm (Guinea 1994). Olive ridleys lay larger clutches of about 100 eggs with a diameter ranging from 38 to 41 mm (Cogger and Lindner 1969, Guinea 1990).

RESULTS

Beach 1 supports occasional sporadic nesting, however, no nests were recorded during this survey. Beaches 2, 3 and 4 had regular seasonal nesting by flatback sea turtles. Flatbacks climbed the dune slope in a number of places on beach 2. However, on beach 3 and most of 4 the presence of beach rock at the dune base and the unstable unvegetated sands on the dune slope deterred many turtles from moving past the berm.

Only two olive ridley sea turtle nests were recorded. Both of these were in 1997. They nested near the high water mark below the dune slope and both nests were destroyed by goannas within a week of being laid.

In the 1989 and 1997 study periods, 85 and 50 flatback nests were recorded respectively on the three productive beaches. In both years, nesting sites were restricted to the dune slope or below the dune slope for most of the beaches except for a single turtle that climbed the dune on beach 4 to nest on the dune crest (table 1). Up to 22% of nests were laid on the dune slope in the study.

Table 1 Nesting beach and locality of flatback sea turtle nests at Fog Bay during 1989 and 1997 study periods. The total number of nests inspected is given, as are the predation rates in parentheses

Beach	Locality	1989	1997
Beach 2	< dune	25 (88%)	5 (20%)
	dune slope	–	1 (0%)
	> dune	–	–
Beach 3	< dune	21 (67%)	20 (60%)
	dune slope	–	4 (75%)
	> dune	–	–
Beach 4	< dune	27 (41%)	14 (43%)
	dune slope	11 (27%)	6 (33%)
	> dune	1 (100%)	–

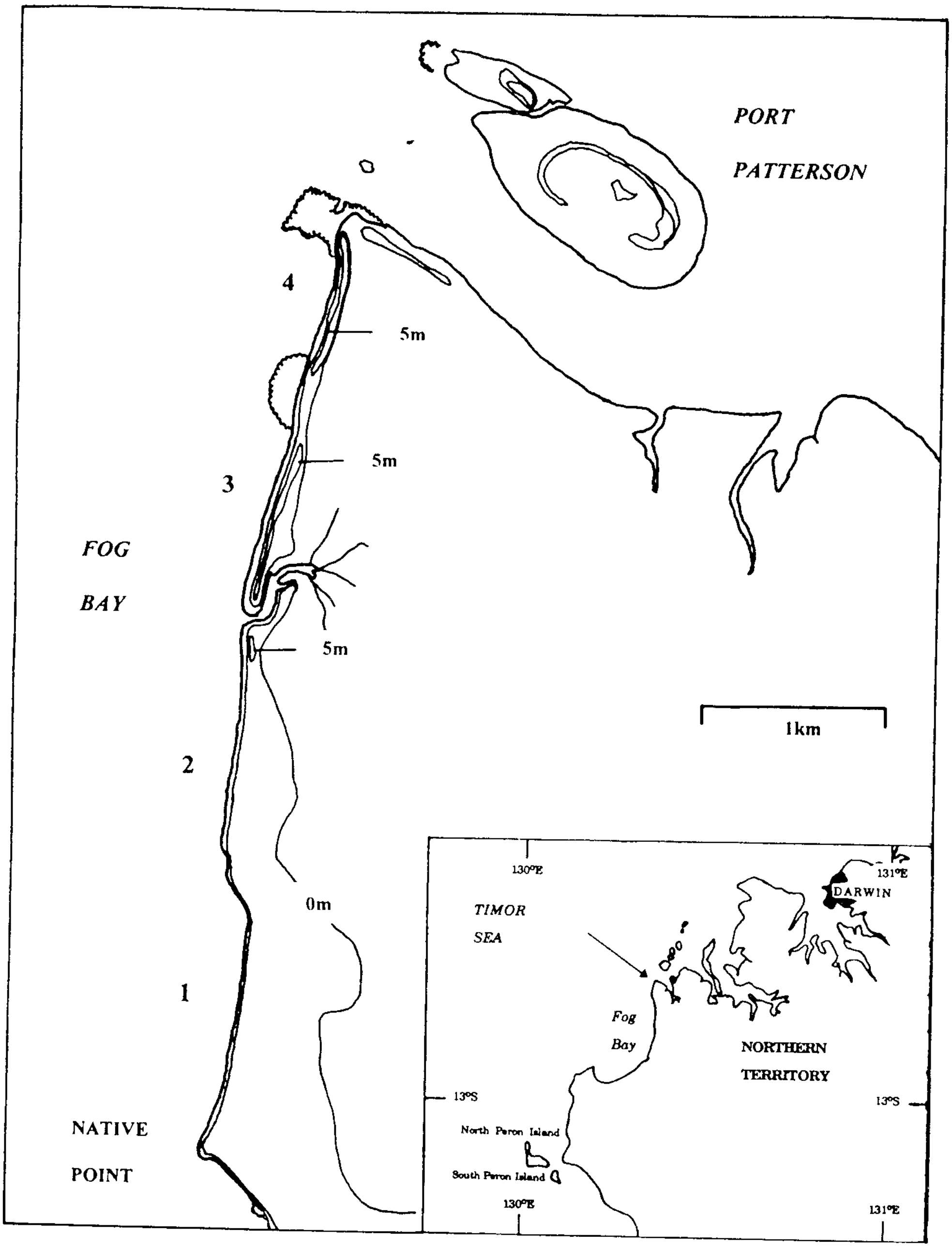

Figure 1 The study site at Fog Bay consists of 4 beaches north of Native Point. Dunes to a height of 7 m back the beach. Contours are at 5 m intervals.

Goannas (*Varanus panoptes*) were the only recorded predators of sea turtle eggs in the study eriod. The overall predation rates in both 1989 and 1997 study periods were 60% and 50% respectively. Predation varied with the nesting beach.

Nests on beach 2 experienced the minimum predation rate of 20% in 1997 and the maximum of 88% in 1989 (table 1). Overall predation rates on the other beaches were between 38% and 67%, regardless of year. A closer inspection of the data for all beaches revealed that not all localities, ie below the dune, dune slope and above the dune, were nesting sites. In 1989, 73 nests (85%) were laid below the dune, as were 39 nests (78%) in 1997. The dune slope received 11 nests in 1989 (13%) and 1997 (22%). One nest was laid above the dune crest in each year.

When data from all beaches are combined to form a single rookery, the majority of nests below the dune slope are found to be raided by goannas. In 1989, the predation rate on nests below the dune was significantly greater than that of nests on the dune slope ($\chi^2 = 4.03$, df = 1, $p < 0.05$). However, in 1997, these predation rates were not significantly different ($\chi^2 = 0$, df = 1, $p > 0.05$). Nests on the dune slope, therefore, receive either less, or at least

as much, predation as those on the laid below the dune.

DISCUSSION

On mainland beaches in the Northern Territory, goannas (*Varanus* sp.) are a significant and obvious predator of turtle eggs and hatchlings. In the period of the study, between 50% and 60% of the nests laid by flatback turtles were destroyed. Both olive ridley nests were destroyed by these predators. The lower predation rate of nests laid on the dune slope in 1989, supports observations made on other species (Fowler 1979, Sivasundar & Devi Prasad 1996) that nest sites on dunes and amongst vegetation have reduced predation rates and therefore increased chances of hatchling survival. The near equal predation rates of nests laid on the dune slope and below the dune slope in 1997 require closer investigation; more definitive results will be forthcoming as the present study continues through the nesting season.

Any implied advantage to the survival of the hatchlings gained by the female selecting the dune slope as a nest site has to be viewed holistically with regard to the number of hatchlings produced from each nest, ie surviving at least to enter the water. To accomplish this, the numbers of hatchlings produced from different locations on the same beach need to be examined. In the present study of flatbacks, the number of eggs below the dune that survived predation would be in the order of 1300 eggs (26 nests) in 1989 and 1000 eggs (20 nests) in 1997. Similarly, those nests laid on the dune slope would contain in the order of 400 eggs (8 nests) in 1989 and 300 eggs (6 nests) in 1997. The area below the dune clearly contained the majority of nests (table 1) and therefore eggs. Any enhanced survivorship of nests on the dune slope may be obscured by the total egg production from the nests below the dune slope. In addition to providing nest locations less susceptible to predation, dune slope nest locations may provide better protection against inundation by high seas or flooding from heavy rainfall (see Limpus 1978).

Predation was heavier in the first two weeks after nesting. Nests were often raided within 24 hours and raids continued over a period of days (Guinea 1994). But other nests were not opened for nearly two weeks. Some nests that survived the initial two weeks were raided either during or after the emergence of hatchlings approximately thirty-five days later. Goannas were very adept at locating fresh and hatched nests. This suggests that the scent of the nesting turtle, as has been suggested for other predators (Stancyk 1982), has little to do with indicating the location of the nest.

Goannas visit the nest regularly within the first couple of days until the entire clutch or at least most of it is consumed. Remnants of clutches as small as 11 eggs have hatched in the study area. This is similar to Campbell Island hawksbill (*Eretmochelys imbricata*) nests that hatch after predation, yet contain only 25% of the initial clutch (Limpus et al. 1983a). Clearly, information on the full impact of the predator is required before survivorship estimates of eggs can be formulated. In this study, more information is required about the goannas and other predators as well as the non-predatory mortality of clutches.

The level of predation is variable not only spatially across the beach from the berm to the dune crest, but also temporally throughout the nesting season. Carr (1973) speculated that predators in Central America migrate from far inland to the beaches during the sea turtle nesting season. Hence, seasonal estimates of the size of the goanna population are required, as are indices of their relative activity, home range and foraging behaviour, to assess any migration to the nesting beaches.

Some clutches that escape goanna predation still failed to hatch. The exact cause was not known but invertebrate predation should not be discounted, although it may be difficult to distinguish this from non-predatory mortality. Other egg predators such as crabs and insects take their toll of eggs but these activities are generally inconspicuous because subterranean predation and insect infestation of clutches reduce hatchling productivity.

In macro-tidal areas such as Fog Bay, spring tides and strong onshore winds inundate sections of the beach. This is of particular concern on beach 3 where nesting females are prevented from nesting on the dune slope because of beach rock at its base. A number of these nests are flooded and their eggs killed by saltwater each year.

Usually up to 20% of a clutch fail to hatch due to either infertility of the eggs, or to the death of the embryos and hatchlings in the nest (Limpus 1978). Although these reduce the overall hatchling survivorship of the rookery, they tend to be independent of predation pressure. The overall hatchling survivorship at the rookery is further reduced by diurnal and nocturnal avian predators. In addition, sand temperatures at nest depth on the Fog Bay rookery increase with the approach of the southern summer (December) (Guinea 1994). Temperatures at nest depth are in excess of 35°C in November that is the upper thermal tolerance for embryogenesis in sea turtles (Limpus 1978, Ackerman 1997). The negative impact of conspicuous predators such as goannas needs to be placed in perspective with all other factors that reduce hatchling production on a rookery.

Wildlife managers who have a responsibility to reduce the threat to protected species could utilise the areas that attract low predation rates as sites for transplanting nests that are in danger of being destroyed by high seas or heavy rainfall. In the study area, a number of nests each season could be transplanted from below the dune on beach 3 to the dune slope. Caution should be applied to any active control of indigenous predators of sea turtle nests until more is known about their impact on the productivity of a rookery. At Fog Bay, the question remains to be answered: 'Had the nest not been destroyed by the goannas, would it have produced hatchlings into the water?'

ACKNOWLEDGMENTS

This research was conducted with financial assistance from the Director's Research Fund, Darwin Institute of Technology, the Australian Geographic Society and The Queen's Trust for Young Achievers. Dr Colin Limpus kindly provided equipment and inspiration. The Lodge of Dundee and H&K Earthmoving allowed us access to the study area for which we are grateful. Scott Whiting provided constructive criticisms of a draft of this presentation.

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‘How can a Whitefella know it all?’ Indigenous Science–Western Science and Marine Turtles

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ABSTRACT

This paper argues that indigenous people are still having to compete with western sciences for acknowledgment that their own indigenous information concerning the environment is worthwhile, worthy of respects and should not always be seen as something from which western science can take at will. It puts forward the view that neither western science nor indigenous science should continue to contest each other but rather they should stand as equals in humankind’s search for understanding the world in which we find ourselves. Case study material will be provided from research undertaken with the Yanyuwa people of the south west Gulf of Carpentaria over the previous 18 years.

Keywords: indigenous ecological knowledge, yanyuwa, sir edward pellew islands

INTRODUCTION

> I have listened to these words, these words concerning the dugong and sea turtle, these words from the scientists, but tell me, what does it do to the Law of my father, is it too now just merely words?’

These are the words of a senior Yanyuwa woman on hearing the results of scientific research done on sea turtle and dugong on her country within the area of the Sir Edward Pellew Group of Islands (fig 1). She was shocked to learn of the things which she had been told, which at first glance, seemed to contradict the knowledge she had accumulated from her ancestors and a lifetime of observing the environment which both she, the dugong and sea turtle called home.

The question must be asked: what was the knowledge that shocked her and that she found so difficult, and secondly does it have to be like this? Are there not other ways in which indigenous people can share and work with western science that are not provocative leaving some indigenous people feeling, at times, as if the Law and knowledge of their ancestors is worthless? A ‘catch-cry’ of many indigenous people towards the western scientific world is, ‘Listen to us.’ It is both a cry of emotion but also one for common sense to prevail.

There is at the moment a growing movement, yet to be accepted as mainstream, which sits within the discipline generally known as anthropology. It seeks to explain the relationship of people to the land that they find themselves in, and the ways in which knowledge about that land, and all that it contains is encoded.

Generally speaking this study is called traditional ecological knowledge (TEK), ethnobiology, ethnoscience, ethnozoology and any other number of combinations. At its most basic it is the study of a scientific system within the context of a culture. Thus, strictly speaking, western science could fit within this paradigm because for all its ideas and claims for objective truths it is not and cannot be exempt from close scrutiny.

However, even within this relatively new school of the so-called ethnosciences there is a very damaging tendency to still hold western knowledge as the measuring rod against which all other scientific knowledge should or could be measured. There is also the danger to try and understand indigenous perceptions of science by asking *what* indigenous people know as opposed to *how* they know it. That is, how is the scientific knowledge embedded within the matrix of the culture.

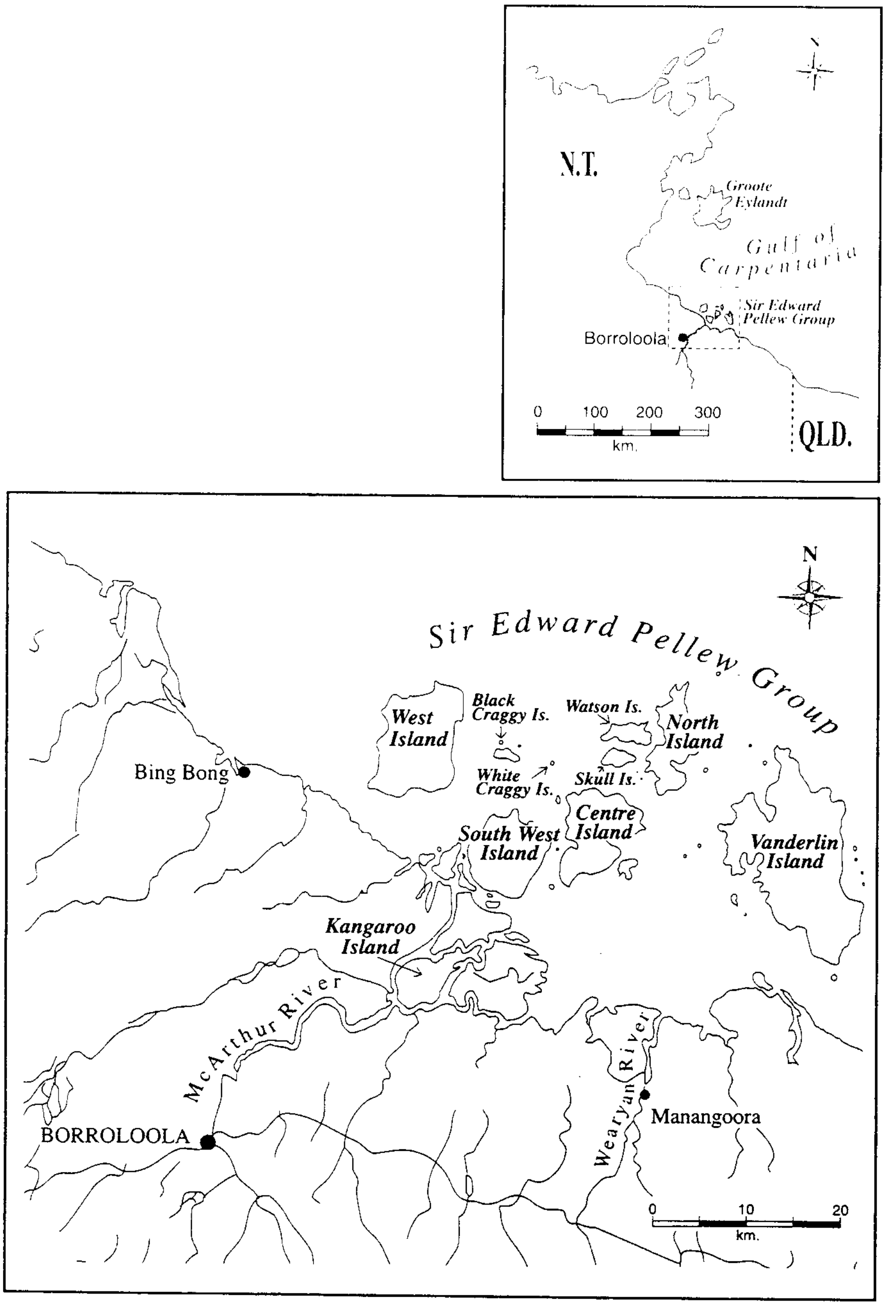

Figure 1 South-west Gulf of Carpentaria, Borroloola and the Sir Edward Pellew Islands

The issue here is that the *what* questions can lead eventually to many lists of species, but these lists do not in any way help explain the complexity of indigenous environmental perspectives.

The *how* questions allow the integrity of indigenous knowledge and the system's own values and sources which it carries to be an intrinsic part of its dynamic and to be seen as valid and appropriate in all contexts. It does not need to be put within a paradigm of western knowledge versus indigenous knowledge which only leads to further contest.

Perhaps the greatest difference between western and indigenous ecological systems is that for indigenous people the environment is not totally disconnected from everyday human existence. The distinction between the natural, spiritual and social worlds, and the (at times) damaging tendency to see these worlds as distinct scientific paradigms, is not made. It is a system where such a term as 'spiritual' must be given legitimacy and not associated with forays into some blind 'new age' mentality. Because of the ways in which indigenous science is encoded, mythology, narrative and song all become important sources of how to understand the environment in which people and all other living things exist.

The other issue that arises out of a fuller exploration of indigenous scientific knowledge is that the much used term of 'community' can become redundant—it is an artificial structure. In many indigenous communities, knowledge of the resources that are to be found in the environment belongs to specialist men and women. Not all knowledge is jointly owned. For example, sea turtle knowledge will be best known by those people who are the owners and managers of turtle Law and culture and secondly by those people who are recognised as being the expert hunters. Such an understanding has implications for the nature and conduct of research with indigenous people, as it must take into account the ownership and control of cultural resources. Included within the notion of cultural resources are not just things like language and song but also the plants and animals that help animate the landscape.

Ultimately what is at issue is indigenous people's right to negotiate the changes to knowledge structures which western science can impose upon indigenous environmental perspectives. Changes within such knowledge structures can have profound and lasting effects upon people and may take a long time to be worked through. I will explore some of these issues in the following section.

'The Law for that sea turtle is there on our country, we got a feeling for it.' The Yanyuwa and the sea turtle: a brief case study

The Yanyuwa people have as their heartlands the coastal regions and the Sir Edward Pellew Group of Islands (fig 2). The sea turtle and dugong are two of the most important animals that inhabit the area. When I first began to explore the Yanyuwa knowledge in relation to sea turtles I was told by a number of biologists to be aware of a problem when engaging in biological research with indigenous people. I was informed that indigenous people lack broad temporal and spatial scales in relation to the wider national and international knowledge in relation to sea turtle conservation. I was told, for example, that the Yanyuwa have no idea what happens to turtles when they swim over the horizon. While this may be so, the negotiation of tradition allows for new information to be included, and then the core of traditional biological knowledge does indeed become broader in terms of both temporal and spatial scales. An example will illustrate this. A Yanyuwa dugong and turtle hunter returned from the sea turtle research station at Mon Repos in Queensland with knowledge concerning these creatures. Some of this knowledge on his first recounting appeared to many of the older Yanyuwa men and women to be quite alien when seen in the light of Yanyuwa knowledge concerning these creatures. However, after much discussion and thought and the taking of a few green turtles with tags showing they had come from Queensland, people began the process of absorbing this new knowledge in a way that did not contradict the old. As Mussolini Harvey, senior Yanyuwa dugong and sea turtle hunter, commented:

> Old people they never knew, they used to say that *malurrba* (green turtle) belonged only on the islands, but now we know it goes a bloody long way to lay eggs, they lay eggs here too, but not all of them, they go far away to Queensland and Indonesia, but still the Dreaming is there on the islands, we have the Law for that turtle...that other turtle, *wirndiwirndi* (flatback turtle) that one too he's there on the islands, we got Law for him too he makes a lot of nests on the islands. (Mussolini Harvey, field diary 1994)

In the above quote Mussolini Harvey fuses both indigenous knowledge and more recently acquired western knowledge into a framework of traditional Law. In the end it makes little difference to him that the green turtle is known to travel great distances to lay eggs, except that it explains the finding of tags on the turtles and they learn what to do with them, knowing that it helps the 'whitefellas' try to understand sea turtles. This new knowledge passes into a general knowledge of law concerning sea turtles—information which he as a senior hunter of these sea creatures is expected to know. What is also important for him is the notion of holding the Law for the sea turtle; it is not seen as a totally free agent, the turtle and humans are bound together in a web of interdependence. Such an example of synthesis as illustrated above is not always the norm; there is other information, especially concerning the loggerhead turtle which the Yanyuwa found hard to accept because it challenged the whole structure of Law associated with this particular species. I will illustrate this below since it is a good example of how western scientific knowledge should be sensitively imparted to indigenous communities.

Limarrwurrirri/*kalumaluwardma* (the loggerhead turtle) is sometimes seen around the Sir Edward Pellew Islands. The Yanyuwa know that it does not appear to lay eggs on the islands; so how do they account for its presence in the sea? Older Yanyuwa men and women believe that this turtle makes nests for its eggs under water. It is thought that when submerged, these turtles make a lot of 'dust' with their flippers, and this was the turtle in the process of making a nest into which it would lay its eggs.

Within the Law of sea turtle knowledge as possessed by the Yanyuwa, the sacred song cycles associated

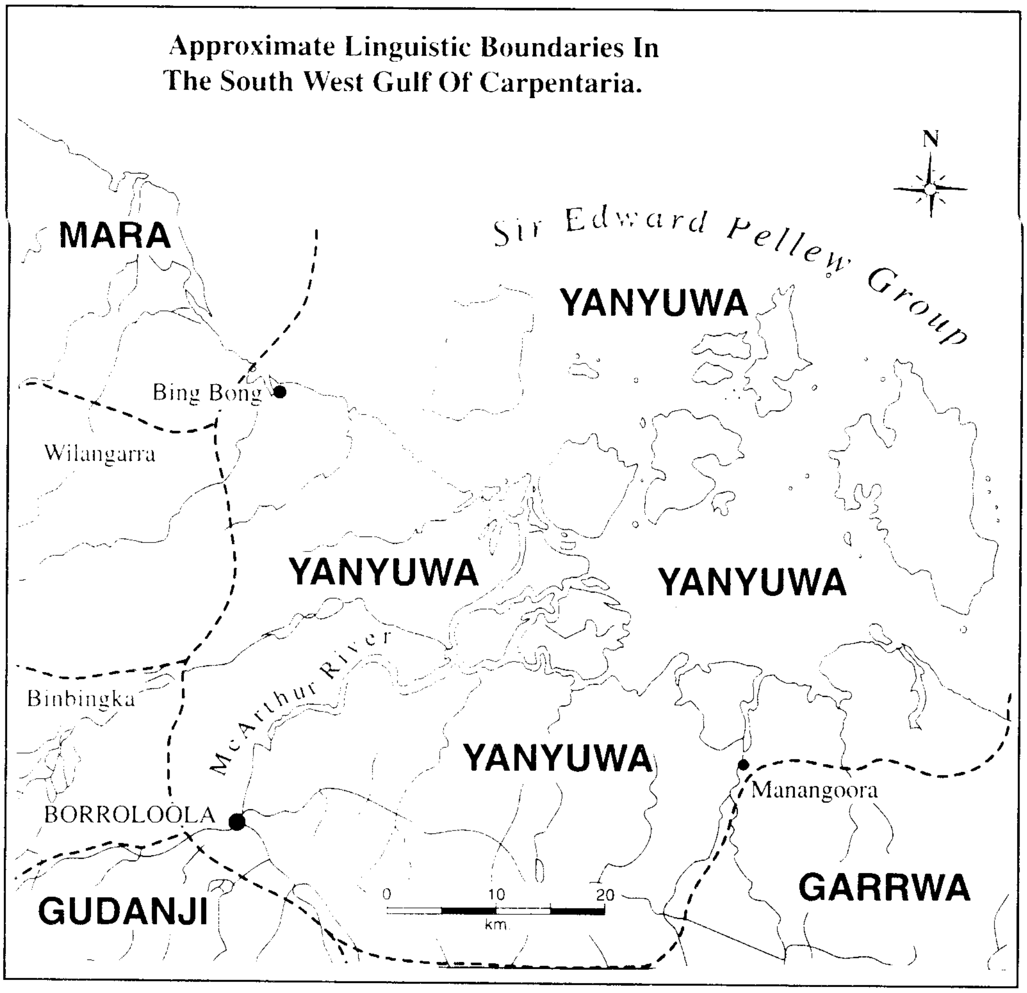

Figure 2 Approximate linguistic boundaries in the south-west Gulf of Carpentaria

with this turtle record such information—its ritual movements in certain ceremonies are associated with these activities. When the young hunter mentioned above returned from Mon Repos and recounted how he had seen loggerhead turtles nesting it caused a degree of confusion and in one instance, from a senior man, anger: What right did this young man have to challenge the Law of his senior relatives and the Law as given by old people. What did such knowledge do to the sacred songs and rituals? Did they now no longer make sense?

To an outsider such a revelation may not be considered to be that important, but in a community where people stand at the heart of the total ecology to which they are intimately connected, and where knowledge is the basis of power and authority, such information had profound implications. A similar parallel may be seen in our own culture when conflicting theologians gather to discuss the nature of God within the universe. Ultimately the old people, in this instance, chose to ignore the information. Though the young people may accept it at a day-to-day level, they have no right to dismiss the traditions of their forefathers and foremothers. Thus no synthesis of information was made, but any uneasy alliance of old and new coexists together.

Ultimately the Yanyuwa do possess knowledge in relation to sea turtle which does have considerable breadth and detail. Such details as nesting beaches (fig 3), sea grass areas (fig 4) and seasonal movements are as much Yanyuwa traditional knowledge as they are important western biological knowledge. Freeman (1985) believes that these indigenous observations are important because they are usually based upon observed fact. But unlike western ways of recording biological knowledge, differences and deviations from what is considered to be normal are measured in a qualitative sense, for example the following observations: sea turtle are rarer when there are large floods, sea turtle are fat just prior to nesting and mating, certain areas are known for finding large numbers of a particular sex of turtle, certain species and sizes of turtles occur in differing areas and sea turtle eat porpita before mating.

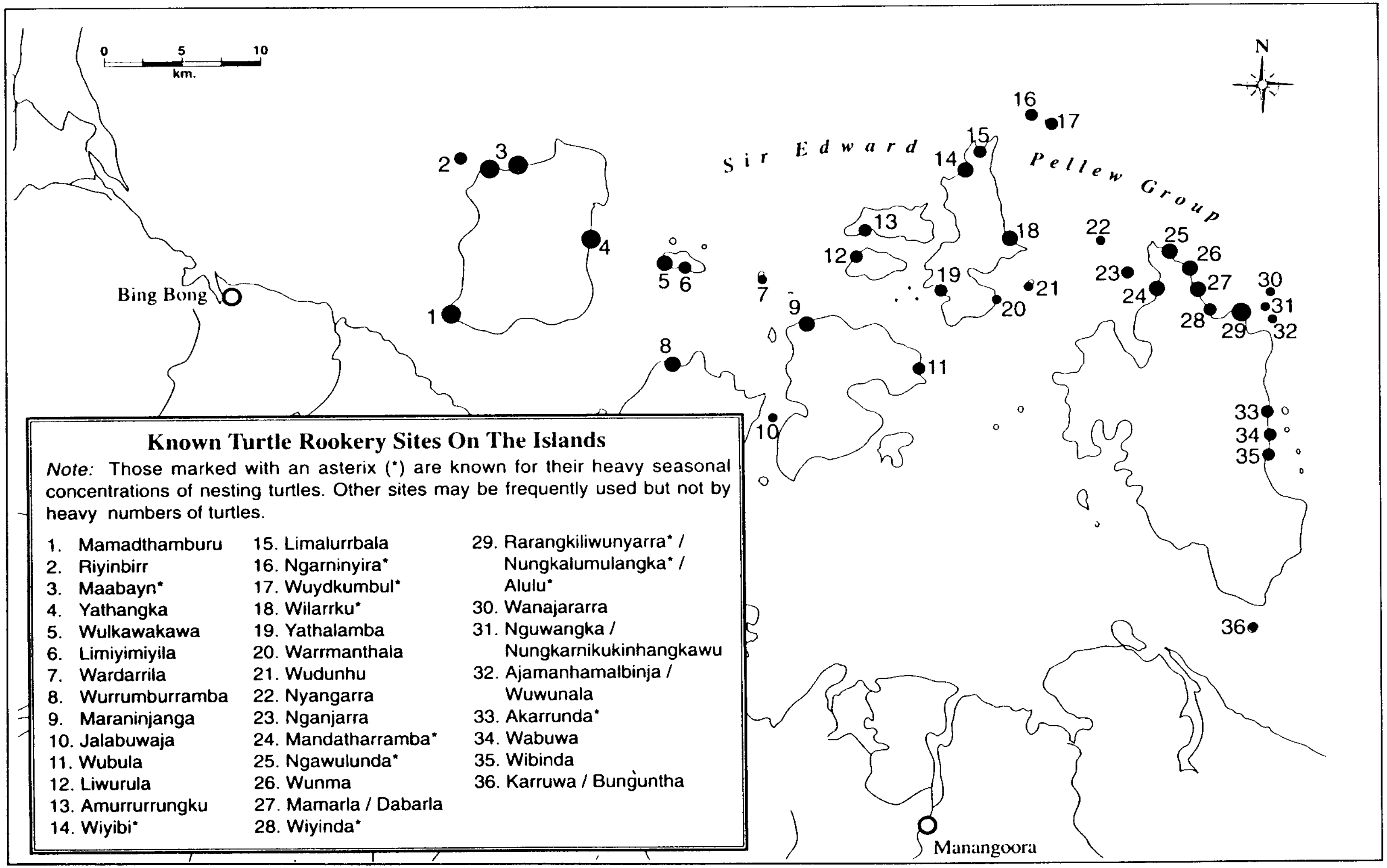

Figure 3 Known turtle rookery sites on the Sir Edward Pellew Islands

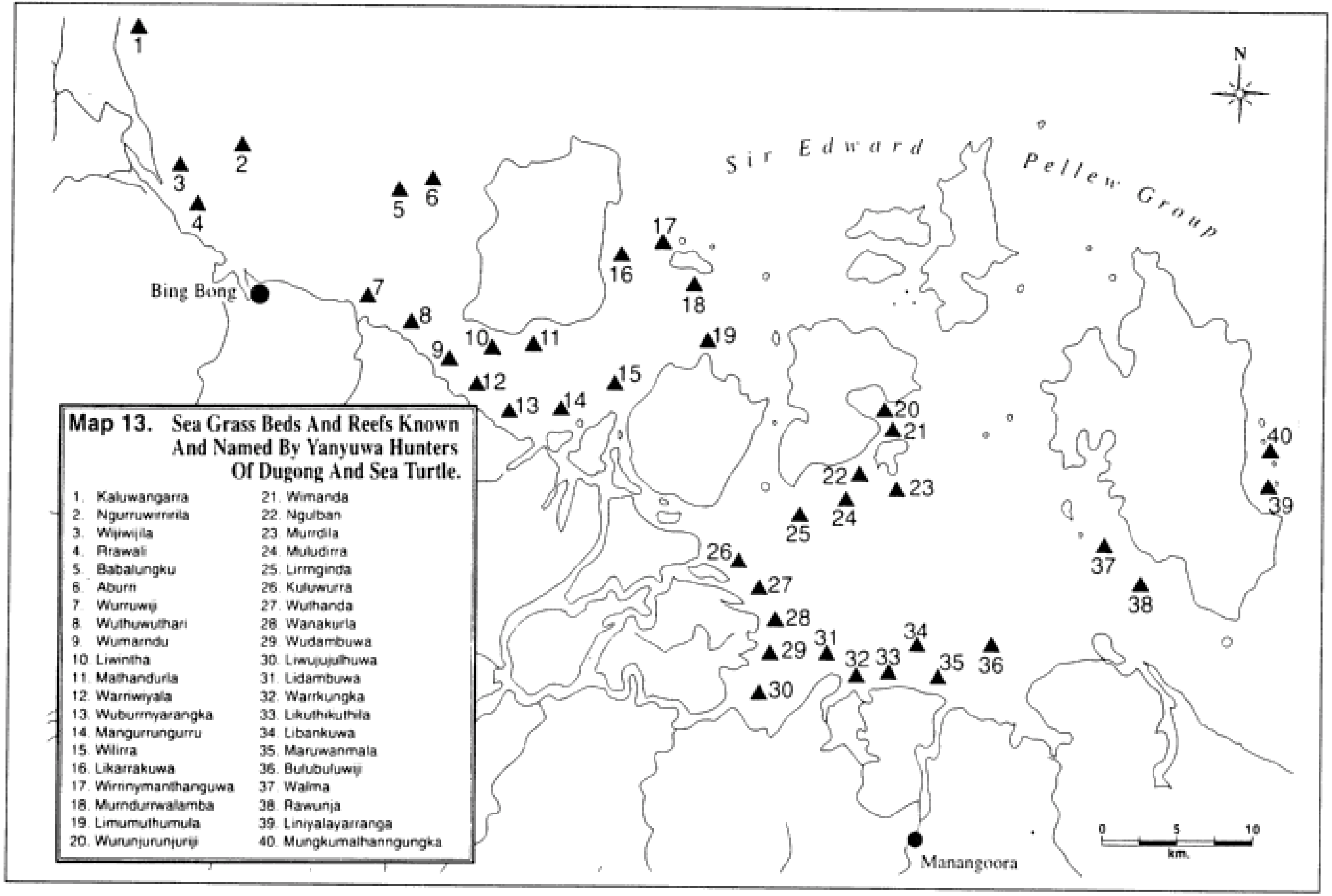

Figure 4 Sea grass beds and reefs known and named by Yanyuwa hunters of dugong and sea turtle

All of this information is evidence of trends in population dynamics throughout the year. However, if people find or observe events which are not familiar to them, such as large black ulcerations (wunakathangu) in older green turtles, then collective knowledge on such incidents becomes important, as there may be others who have observed the same thing at another time, or there may be spiritual issues associated with the current unusual event. Knowledge acquired by Yanyuwa hunters over generations of observations and discussions often stands in contrast to the sometimes stark and attenuated data available from scientific studies in the same area.

Perhaps of greatest concern to modern biologists interested in sea turtle numbers are the annual take numbers by indigenous hunters—a matter which also has implications for resource management of the species under consideration. This is an area which needs to be approached very carefully; and as Healey rightly comments,

> the concept of 'management' of natural resources must be applied with great caution in traditionally orientated communities. Traditional ecological knowledge is certainly the basis of much behaviour that results in human husbanding of resources, but the context and motivation for it are often rather different from that of modern western resource management. (Healey 1993, 23)

In the Yanyuwa context this is a very important point. What at first may look like wise management of sea turtle eggs, for example, may have more to do with the good fortune of the nesting area being within the confines of a restricted area due to the presence of sacred objects. Such areas also change, and an area once off-limits to hunting and gathering can, after negotiation and appropriate ritual, be opened for hunting again. A Yanyuwa notion of a healthy sea turtle population is also seen to be dependent upon how often the creatures are hunted and how their remains are disposed of. Concepts of resource management in Yanyuwa terms may have more to do with the maintenance and well-being of the environment and the society in general.

CONCLUSION

The complexity of indigenous understandings in relation to how the environment is perceived does not preclude the working together of indigenous science and western science. What it does mean, however, is that the culture of western biological knowledge continually contesting indigenous scientific structures has to cease. Aboriginal science presents to the western scientific world a system of knowledge production that has developed to allow human beings to exist within, rather than outside, the environment and the ecology that operates within it. It is a system of science in which all the endeavours of the human species are allowed to have a dimension; social, economic, political and spiritual spheres of life are all integrated and interpreted within, and in relation to, the rest of the physical environment. There are those of us that come from a background of western traditions who would now also argue that we need a scientific paradigm that allows us to discover and maintain ourselves as part of the total ecology, rather than remaining separate from it, as empirical observers. However, on the whole it appears that there is still a lot of reserve and argument about the potential of indigenous science to teach us how this can be achieved—usually because indigenous science is seen to have too much to do with mythology and spiritual issues. However, these self same sources ie song cycles and ceremony for example, are often full of meaning about the ecology to which they belong. The division of species throughout the indigenous social structures and their individual songs and ceremonies can tell us not only of the importance of the species to any given group of people but also who are the key experts in relation the species under question. The key words in any joining of western and indigenous scientific knowledge are 'listen' and 'take time'.

Ultimately, however, both indigenous and western scientific systems are in many ways alike. They both consist of many layers and webs of interpretations and propositions that are debated and finally agreed upon. There is a requirement in both systems that the upholders of the systems have some faith or acceptance in any given particular view of the environment. Both, too, are pictures of the environment which are negotiated and which provide information about the ongoing nature of the particular environment. There are strengths and weaknesses in both systems. The western system is often far too presumptuous about its ability to provide answers, whereas indigenous people are prepared to accept that not all answers are known. The ongoing tension between indigenous science and western science is the belief on behalf of the latter that only purely empirical data can be allowed as hard data, which in turn produces a view of the environment where all the vagaries of the human experience are removed.

Incorporated into any view of the environment are historical, sociological and spiritual sensitivities. Such a web in interrelationships and metaphors is still virtually unknown in the traditions of western science. I am not denying the use of western science but rather it needs to be seen in the light of other structures of thought. Both indigenous and western scientific knowledge systems have pursued and developed their own dimensions of any given 'truth' usually at the expense of others, which is usually due to the internal fluctuation within the societies that have produced them.

ACKNOWLEDGMENTS

The author also acknowledges with many thanks the following Yanyuwa people who have contributed much to the information and feelings provided within the context of this paper: Annie Karrakayn, Dinah Norman Marrngawi, Mussolini Harvey, Johnson Timothy, Tim Rakawurlma, Steve Johnson, Don and Jemima Miller, Phillip Timothy and Barbie McCarthy. I would also like to thank Dr Chris Healey and Dr Deborah Rose for comments and discussions during the preparation of this paper.

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A Preliminary Overview of the Locations of Marine Turtle Nesting in the Northern Territory

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ABSTRACT

Ongoing aerial and ground surveys to locate and document significant sites for fauna around the Northern Territory coast, offshore islands and coastal floodplains commenced in 1990. While the initial focus was on seabirds and waterbirds, observations of marine turtles were systematised from 1992 onwards. Marine turtles nest on mainland and island beaches around much of the Northern Territory coast. However, the most favoured regions include the North-west Top End, the North-east Top End, the Groote Eylandt area, and the outer Sir Edward Pellew Islands. Four of the six species of marine turtle found in the Northern Territory were recorded breeding in substantial numbers. They are the flatback (***Natator depressus***)*, the green* (***Chelonia mydas***)*, the hawksbill* (***Eretmochelys imbricata***) *and the olive ridley* (***Lepidochelys olivacea***)*. The leatherback* (***Dermochelys coriacea***)*, breeds infrequently in the Northern Territory and was not confirmed during the current survey program. The loggerhead* (***Caretta caretta***) *does not breed in the Northern Territory. This report is an early assessment of the survey results and greater detail will be presented in other places.*

KEYWORDS*:* nesting, aerial survey, species distribution, nesting season

INTRODUCTION

The Northern Territory has an extensive coastline and many islands. Prior to 1990 very little was recorded about the distribution and status of 'coastal' fauna, including marine turtles. While the Northern Territory is fortunate in having a relatively undisturbed and sparsely populated coastline, it is important that the distribution and status of coastal fauna be clearly established. Local traditional harvest, commercial fishing, human disturbances at nesting beaches and a number of other factors currently do, and will in the future, combine to have some effect on the status of marine turtle populations. We have a unique opportunity to develop conservation and coastal management strategies that take account of the needs of marine turtles, before pressures on the coast threaten the values that sustain them. This paper provides a brief description of a project designed to give the basic information needed for the development of such strategies. In particular, I report a preliminary assessment of the distribution of the marine turtle nesting sites around the Northern Territory coast and the species using them.

METHODS

The project has three phases. Phase 1 involves locating and documenting significant sites on the coast, coastal floodplains and offshore islands, as an inventory of coastal wildlife values. Phase 2 involves further monitoring to assess ongoing status and to provide more detailed descriptions of sites, and phase 3 will involve the instigation of management programs where necessary. This paper deals with some of the results of phase 1 of the project, concerning marine turtles.

The general method here was to initially survey areas in fixed wing aircraft to locate 'hot spots', undertake total counts (though not always to species level) and then to return in either helicopter or boat to do ground surveys.

Early in the program, surveys were opportunistic, involving alteration of flight paths on returns to base from surveys of magpie goose populations, so as to take in components of the coast. It was not until 1992 that specific coastal surveys began in addition to those carried out in conjunction with other surveys. Consequently, knowledge of additional areas of the coast and a better seasonal coverage developed. During 1992 ground surveys involving access by helicopter were also conducted. From 1993 to 1996 the specific aerial and ground surveying of the coast and islands continued to build, so that all the coastline and islands had been aerially surveyed, and many sites checked on the ground, at a number of different times of the year.

RESULTS AND DISCUSSION

Marine turtles nest around much of the Northern Territory coastline and on virtually all islands that have sandy beaches. In general most of this nesting occurs east of Darwin with the best areas found between Bathurst and North Goulburn Islands, from the east of Elcho Island, east and south to the southern end of Groote Eylandt, and the outer Sir Edward Pellew Islands.

Peak nesting

A summary of the peak densities of turtle tracks/nests recorded, irrespective of season and species, around the Northern Territory coast and islands during the years between 1992 and 1996 is shown on figure 1. For the purposes of this paper three classifications of nesting density have been applied for geographical comparisons of densities within the Northern Territory. High density nesting is defined as the areas where an estimation of 100 or more tracks and/or nests per kilometre were recorded on at least one survey. Medium density nesting has between 10 and 100 tracks or nests per kilometre, and low density has less than 10 per kilometre. Obviously this last classification will incorporate sections of the coast with no nesting. Work to accurately categorise areas of the coast in which marine turtle nesting can be regarded as absent or very insignificant is continuing and will be reported elsewhere.

The majority of the highest density nesting sites in the Northern Territory are on offshore islands. Most smaller islands which have at least reasonable sand beaches have medium to high turtle densities, whereas many of the bigger islands (especially those close to the mainland) or islands with narrow beaches fronted by mudflats or bordered by mangroves have a much lower density of nesting. Islands which appear to support large nesting aggregations include North Perron Island, parts of Melville and Bathurst Islands, most of the islands between Croker and North Goulburn Island (including the latter), North West Crocodile Island, and then a large number of islands from the Cunningham Islands around to the Sir Edward Pellew Islands which are too numerous to mention separately here.

There are a few sites around the Northern Territory mainland which have high density nesting. However, many mainland beaches have medium to low density nesting. Better areas on the mainland for turtle nesting include the northern section of Fog Bay, the northern points of Cobourg Peninsula, and much of the coast between Gove and the northern margin of Blue Mud Bay. At the other end of the scale, areas for which there is little or no nesting include much of the mainland coast from the south side of Cobourg Peninsula around to the Western Australian border, most of the coast between Maningrida and Gove and the coast between the northern margin of Blue Mud Bay and the Queensland border. Much of the mainland coast in these areas is unsuitable for nesting—being mudflat and mangrove dominated. Large expanses of suitable sandy beaches that are totally devoid of nesting are not common.

Individual species

Figure 2 illustrates nesting sites around the Northern Territory coast where confirmed, to species level, identifications, have been made during these surveys. It also includes sites where the level of identification can be narrowed down to one of two species, namely a green or flatback nest/track, or a hawksbill or olive ridley nest/track. These two groupings can be easily classified from any one of a number of characteristics, however, definite species separation for olive ridley and hawksbill have been made only when adult or hatchlings have been seen. In the case of separating flatbacks and greens, eggs can be used in addition or instead of the observing of hatchlings or adults to confirm which species is involved. Although identification of species to a probable level can be made at times from a combination of identifying characteristics, they have not been included at this stage. Additional analysis of existing data will further separate more of the current records of the two groups into separate species. This will be reported elsewhere. Similarly information about species nesting gained from other sources (eg discussions with traditional owners) but not personally confirmed on site as yet, have not been included here and will be reported elsewhere.

Flatback turtle (*Natator depressus*)

Flatback turtles were found to nest on virtually all nesting beaches around the entire Northern Territory coastline and offshore islands, and it is this species which has the most widespread breeding range in the Northern Territory.

Preliminary analysis of the data collected thus far also suggests that the flatback is the species which nests in the overall highest numbers in the Northern Territory. At sites where few turtles nest, flatbacks usually dominate, often being virtually the only species nesting. They also dominate a substantial proportion of the medium and high density nesting sites around the Northern Territory which were shown in figure 1.

Some of the better flatback nesting areas in the Northern Territory (fig 3) include Turtle Point (1), North Perron Island (2), Bare Sand and Quail Islands (3), south-west Bathurst Island (4), parts of the northern coast of Melville Island (5), Greenhill Island (6), most of the islands to the east of Croker Island (7), the north coast of North Goulburn Island (8), North West Crocodile Island (9), Moorooggna Island (10), Drysdale, Burgunngura and Stevens Islands (11), Warnawi and Bumaga Islands (Wessel Islands) (12), the islands to the north-east of Bickerton Island (13), North East Isles (14), south Maria Island (15), and North West Island (16).
Flatbacks were found nesting in all months of the year, although in most areas the middle of the year, from about June to August, is the peak time.

Green turtle (*Chelonia mydas*)

Green turtles also breed on both mainland and island sites in the Northern Territory, but prefer the bigger, wider, dune-backed sandy beaches. In contrast to flatbacks, greens tend to concentrate in fewer locations but in much higher densities, with some of their nesting beaches having the highest density nesting in the Northern Territory. Green turtles probably breed in total numbers second only to the flatback turtle in the Northern Territory.
Some of the better green turtle nesting areas (fig 4) are Smith Point on Cobourg Peninsula (1), the mainland coast beaches facing open ocean south from Gove to the top of Blue Mud Bay (2), the south-east corner of Groote Eylandt (3), and the outer (northern) beaches on West, Watson, North and Vanderlin Islands in the Sir Edward Pellew Group (4).
Like flatbacks, greens can be found breeding in any month of the year but they have a more pronounced seasonal peak, mostly from about October to December.

Hawksbill turtle (*Eretmochelys imbricata*)

Hawksbill and olive ridley turtles are a little more difficult to discuss separately at this stage because of the greater difficulty in identifying which of the two species is nesting, using criteria such as egg diameter or track width. Both have egg sizes and track widths which overlap in size, so at this time comments to individual species level are drawn only from confirmed observations, ie of hatchlings or embryos big enough to identify, where adults were not sighted.

Most hawksbill nesting occurs on islands with only occasional nesting being found on mainland beaches. They appear to prefer narrower beaches where they frequently go under vegetation to nest, or smaller white sand beaches in bays between rocky points. They are also not averse to nesting in coral shingle ‘beaches’ on islands or mainland.
Most confirmed hawksbill breeding in the Northern Territory was found between north-east Arnhem Land and Groote Eylandt with some of the better sites (fig 5) being Wigram Island and the associated small islands to the east (1), Truant Island (2), the eastern Bromby Islands (3), Dudley Island (4), North East Isles (5), and the south-east Groote Eylandt area (6). It is also possible that further work may also add the islands to the east of Croker Island and Sandy Island in the south-west Gulf of Carpentaria to this list.

In the Northern Territory the hawksbill nesting appears to peak in the latter half of the year.

Olive ridley turtle (*Lepidochelys olivacea*)

Olive ridleys breed both on the mainland and islands, though like hawksbills, they more commonly prefer the latter. Olive ridleys do not appear to breed anywhere in the Northern Territory in densities as high as any of the other three species. They do, however, appear to breed over a wider range of sites than hawksbills so it is difficult at this stage to say which of the two has the highest number of animals breeding in the Northern Territory. Olive ridleys often nest just above the last high tide mark and possibly suffer more than the other species in regard to losses through tidal inundation.

Most breeding appears to occur across the north of the Top End with better sites (fig 6) including the islands to the east of Croker Island (1), North West Crocodile Island (2), Drysdale, Burgunngura and Stevens Islands (3), and Warnawi and Bumaga Islands (Wessel Islands) (4). Other sites probably used with some frequency include Seagull Island (off the north-west of Melville Island), Black Point on Cobourg Peninsular, Moorooggna Island, the inner islands of the Wessell Islands chain, islands to the north-west of Groote Eylandt and Sandy Island in the south-west Gulf of Carpentaria.

Leatherback turtle (*Dermochelys coriacea*)

I have not recorded leatherbacks breeding during my surveys. However, a small number of confirmed records exist for the Cobourg Peninsula area (F Woerle pers. comm.) and it appears they occasionally nest on the Pellews (Steve Johnson pers. comm.). One specimen came ashore in north-east Arnhem Land a year or so ago but it does not appear to have actually nested.

Loggerhead turtle (*Caretta caretta*)

Loggerheads are not uncommon in Northern Territory waters, at least from Fog Bay around to north-east Arnhem Land. However, the evidence from these surveys and from anecdotal accounts suggests this species does not breed in the Northern Territory.

CONCLUSION

Although it is difficult to compare sites used by marine turtles for nesting with those used in the past, it appears that the Northern Territory mainland coastline and adjacent islands have retained a relatively healthy population of breeding marine turtles in most areas. All four species that breed here do so in reasonable numbers, with flatbacks and greens being the most common. In addition, all four species breed over large expanses of the Northern Territory coast, particularly flatbacks whose breeding range appears to encompass most of the Northern Territory coast that contains suitable sandy beaches.

These factors in combination with the remoteness and lack of disturbance over much of the coast compared with other parts of the Australian marine turtle breeding range, suggest that the Northern Territory, with careful future management, may play a major role in the future security of marine turtles in the broader region.

Complacency, however, would be ill-advised. As the human population and economic activity grow and access to areas of the coast improves, localised declines in turtle numbers and breeding are possible. Moreover, turtles breeding on Northern Territory beaches may be subject to harvest outside Australia's national waters, which may have much greater impact than the quality of management of nesting sites here. Recognition that the Northern Territory remains an important haven for marine turtles increases the obligation to develop pro-active conservation strategies, and carefully monitor their effectiveness.

ACKNOWLEDGMENTS

It would be remiss, even in this preliminary paper, not to acknowledge the skill and preparedness of the many Northern Territory fixed wing and helicopter pilots to fly and/or land in some very precarious situations during the surveys. In addition John Scott, Irene Rainey and Charmaine Tynan have all spent many hours transcribing tapes. Thanks also go to Greg Connors who prepared the maps and to Peter Whitehead and Dr John Woinarski for commenting on the initial draft.

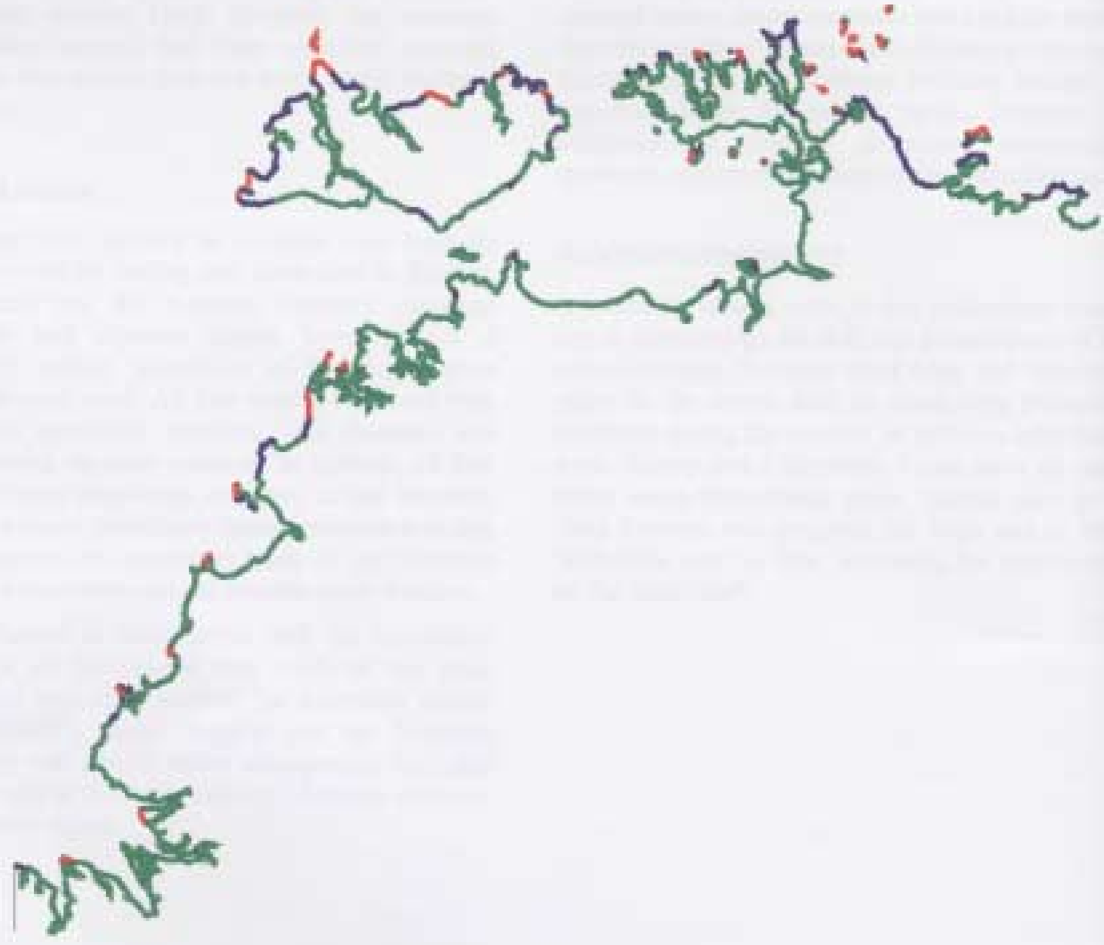

Figure 1 Marine turtle nesting in the NT: a summary of peak nesting

High Density - (>100 Tracks/km)
Medium Density - (10 - 100 Tracks/km)
Low Density - (<10 Tracks/km)

Figure 1 Marine turtle nesting in the NT: a summary of peak nesting

Figure 2 Marine turtle nesting in the NT: species nesting sites

▲	Flatback turtle	▲	Hawksbill turtle
▲	Green turtle	▲	Flatback and/or Green turtle
▲	Olive ridley turtle	▲	Hawksbill and/or Olive ridley turtle

Figure 2 Marine turtle nesting in the NT: species nesting sites (continued)

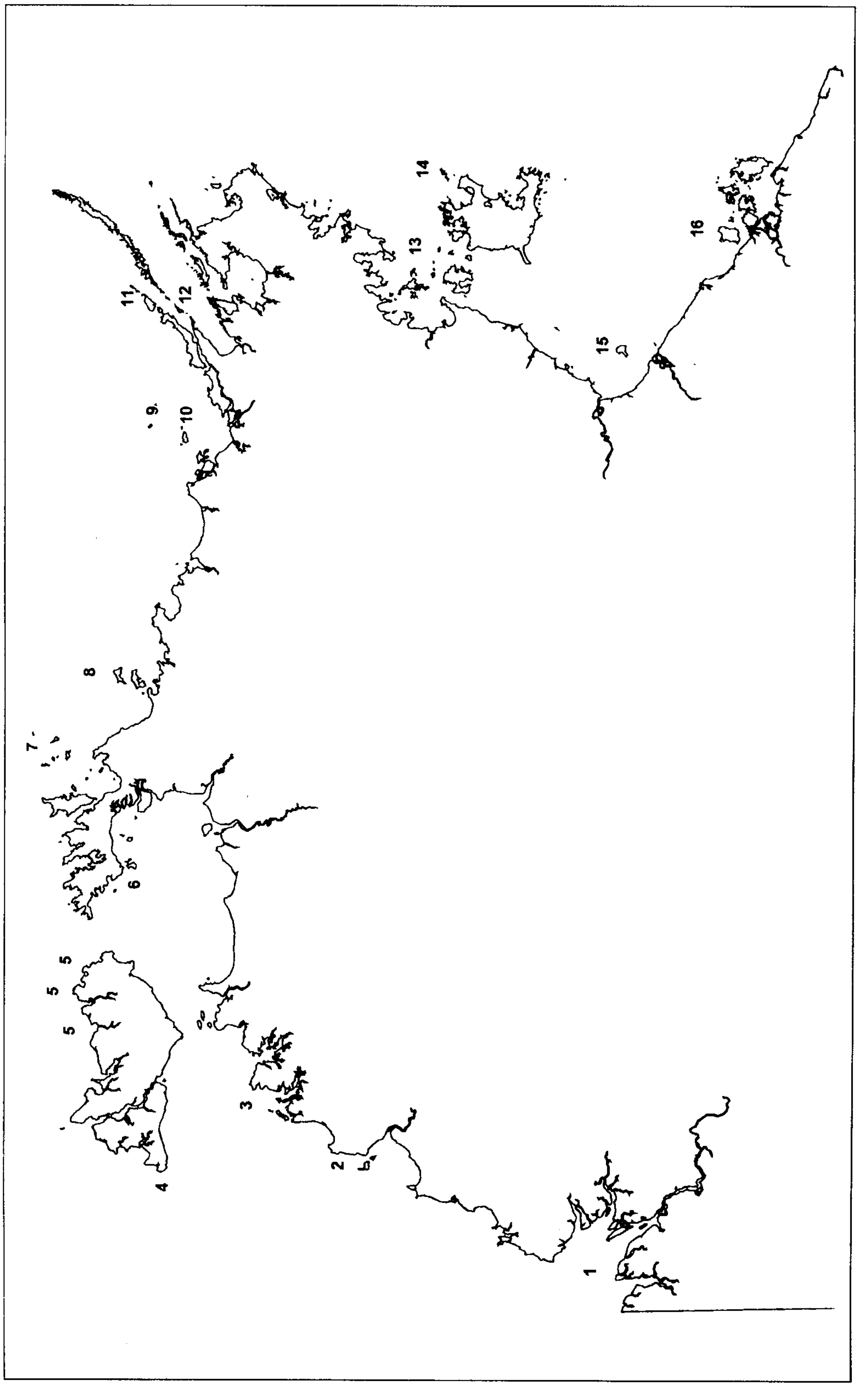

Figure 3 Major flatback turtle nesting sites in the NT (refer to text for explanation of numbered locations)

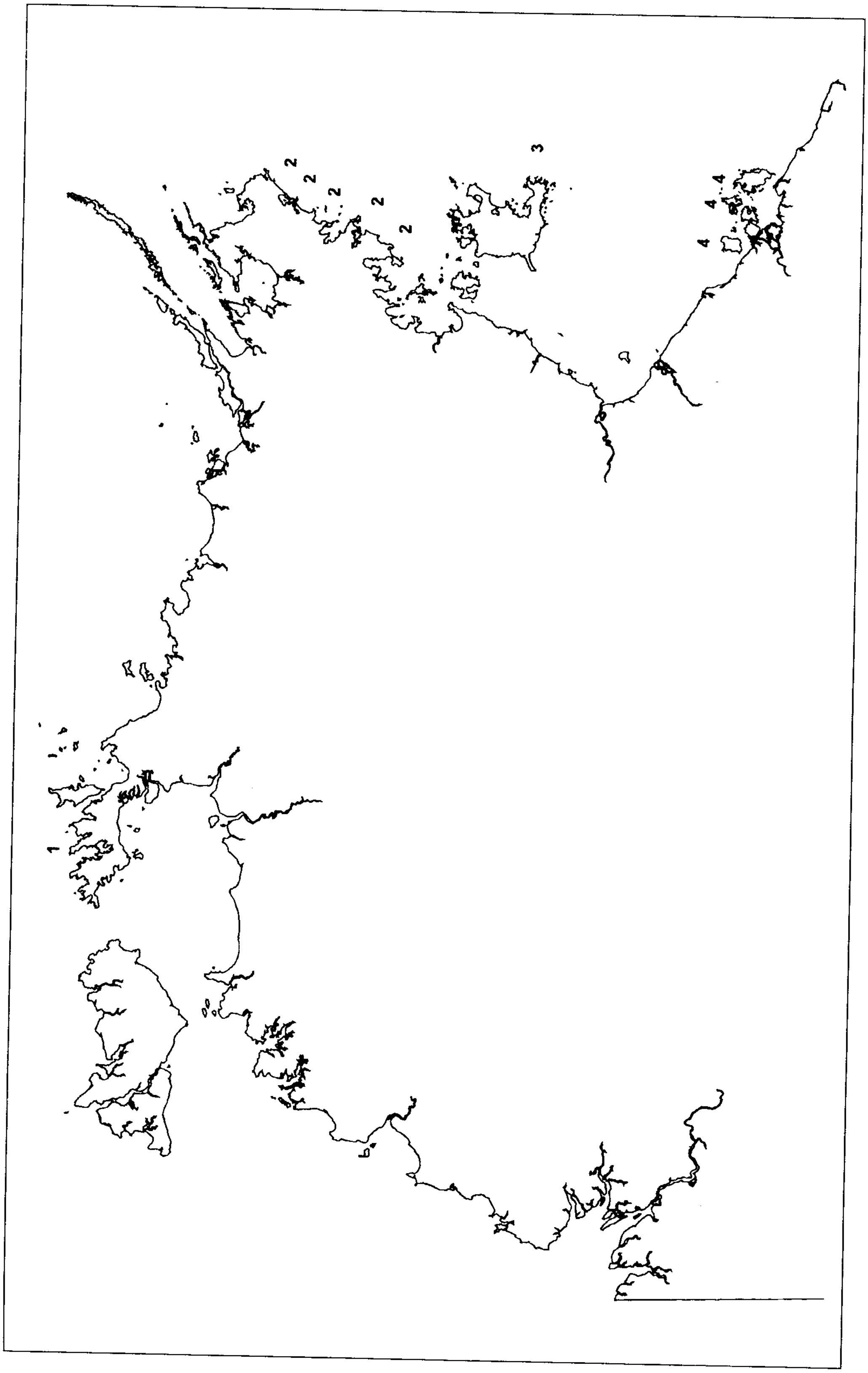

Figure 4 Major green turtle nesting sites in the NT (refer to text for explanation of numbered locations)

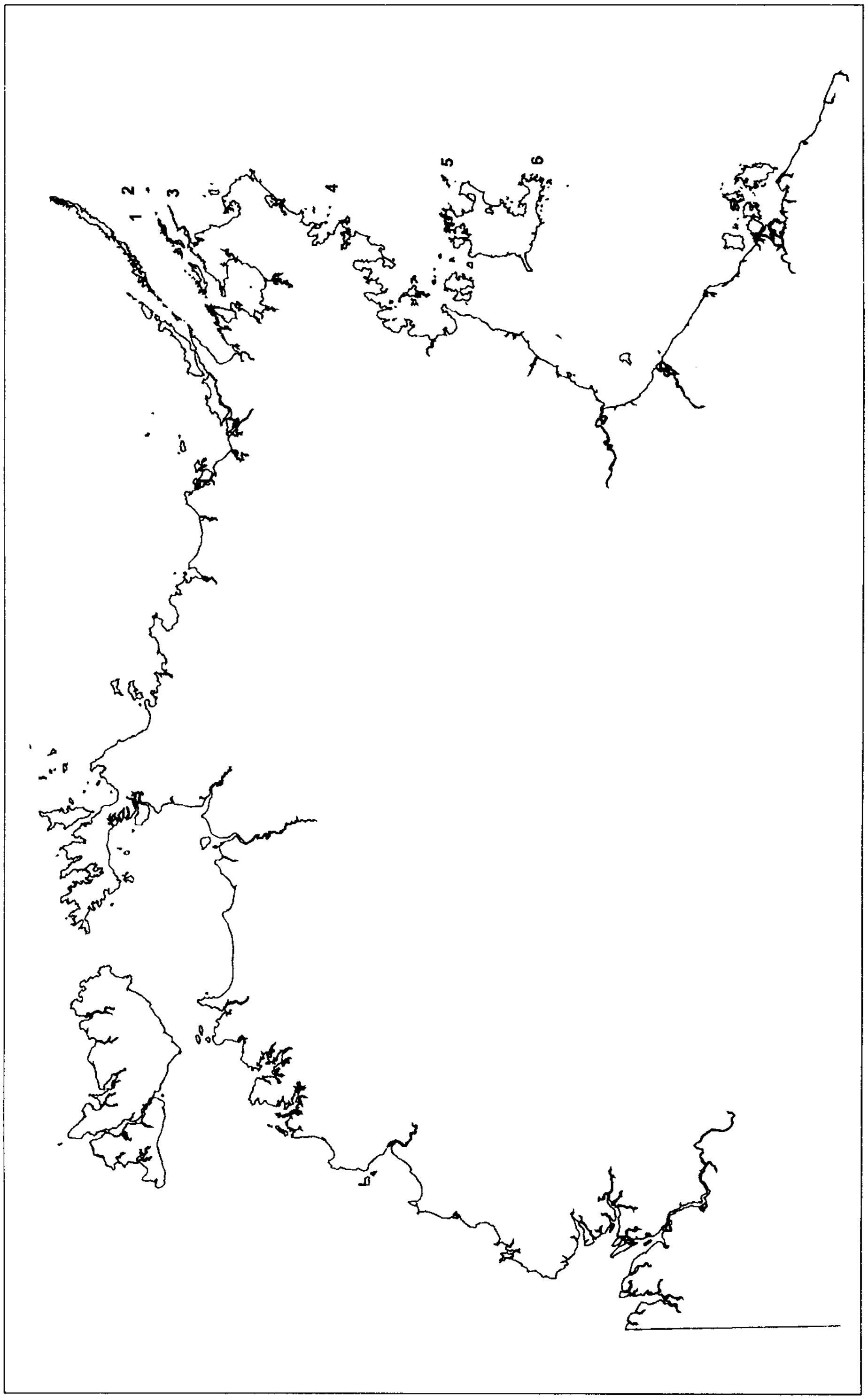

Figure 5 Major hawksbill turtle nesting sites in the NT (refer to text for explanation of numbered locations)

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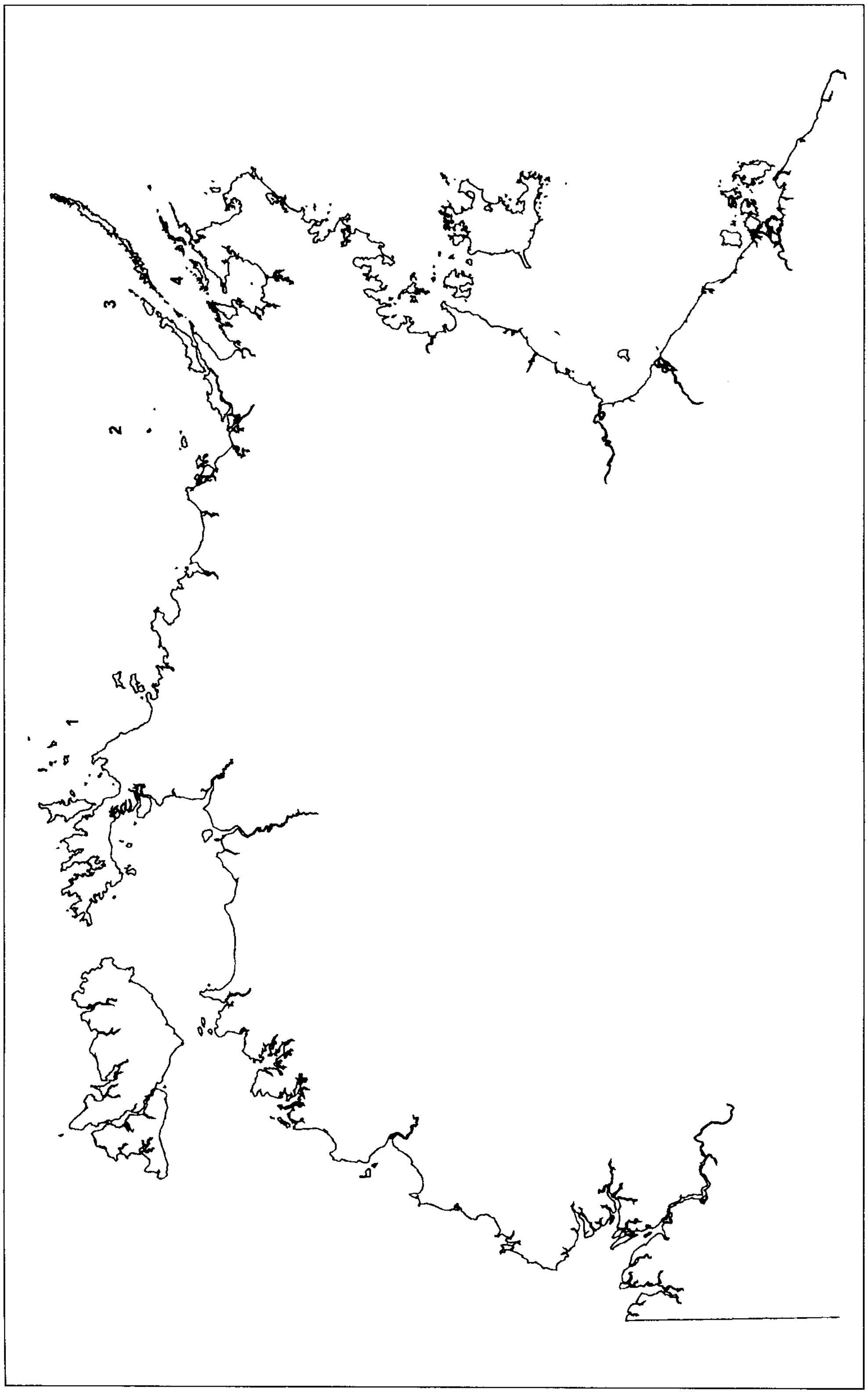

Figure 6 Major olive ridley turtle nesting sites in the NT (refer to text for explanation of numbered locations)

GIS FOR MARINE TURTLE CONSERVATION AND MANAAGEMENT IN NORTHERN AUSTRALIA

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ABSTRACT

Advances in technology are facilitating the study of large, relatively unpopulated and inaccessible areas like the coast of northern Australia and providing valuable information for tropical environmental management information and decision support systems. This paper introduces the concepts underlying GIS (geographic information systems) and remote sensing and provides some specific research that demonstrates how these technologies may be used to map, monitor and model marine turtle movements and their habitat. Examples include mapping major reef zones and characteristics of intertidal zones using satellite imagery. The use of GIS and remote sensing for turtle conservation and management is summarised and some suggestions for workshop outcomes are made. Literature and internet resources on this topic were found to be scarce and those found are included.

KEYWORDS*:* marine turtle, GIS, remote sensing, reef zonation, intertidal zones

INTRODUCTION

The role of this paper is to present a broad overview of the current capabilities of natural resource inventory, spatial analysis and modelling using geographic information systems (GIS) and remote sensing (RS) technologies with particular reference to turtle conservation and management in northern Australia. The underlying theme is that advances in information technology continue to facilitate the study of large, relatively unpopulated and inaccessible areas like the coast of northern Australia and to provide valuable information for tropical environmental management information and decision support systems.

Management requires information

Turtles are a significant part of the marine fauna in northern Australia as is highlighted in other papers in this volume. In order to maintain and enhance turtle populations and their habitat as a natural resource, environmental managers need information on which to base their decisions. Some of this information is political, legal and socio-economic but in many respects the most significant component is environmental. Managers need to know the current status of natural resources, to monitor changes in these resources over time, and to predict and evaluate the impact of proposed courses of action.

GIS provides a framework

Geographic information systems provide the necessary framework to input, manipulate, analyse and retrieve spatial data and related attributes of spatial features. They can store data collected from a variety of sources and bring them together in a way that enhances the information that can be gleaned from them. The enhancement may simply take the form of a map of a particular area with specified information included in it, or may involve spatial analysis and modelling. Data stored may be relatively static, such as bathymetric maps, or dynamic, such as oil spill dispersion. An important source of dynamic data is remotely sensed data from spaceborne or airborne platforms as it can periodically provide a synoptic view of large areas.

Effective management and conservation of marine turtles therefore requires information from a GIS which in turn provides a framework for data from many sources including remotely sensed data. In the first instance, the application of these technologies is required to provide baseline information for turtle and turtle habitat inventory. When this baseline information has been collated it will be possible to begin monitoring change and model alternative management scenarios. This paper provides an introduction to GIS and remote sensing technology and their integration for mapping, monitoring and modelling turtles and their habitat.

GEOGRAPHIC INFORMATION SYSTEMS

There are as many definitions of geographic information systems as there are authors and an exhaustive definition will not be attempted here. The important characteristics of a GIS in the context of wetland inventory are that it provides a framework for the collation and analysis of spatial data from disparate sources as well as information for input to management decision support systems. The requirements for a GIS with a particular emphasis on data are briefly discussed hereafter as well as the outcomes necessary for a successful GIS implementation.

GIS components

The essential components of a GIS are easily identified—hardware, software, data and people. Hardware includes computing power, data storage and backup facilities, and output in the form of monitors or hard copy plots or reports. Software provides a means for the user to easily use the hardware to manipulate, analyse and visualise the underlying data. Data (not to be confused with information) are an obvious prerequisite to any GIS application and are discussed further below. People, perhaps the most important component, need knowledge, understanding and skill in both environmental management and GIS to enable useful outcomes from the system. It is the responsibility of the manager to assemble these components in a way that produces useful information for decision making.

In general, the cost, availability and complexity or depth of knowledge of each of these components is inter-related and dependent on the scope and complexity of the task at hand. This relationship can be visualised using a graph with four axes each representing a component (fig 1).

An arrow on each axis indicates increasing cost and complexity. For example, low-end hardware and software might be a PC with Windows 95 and desktop mapping software whereas a high-end system might be a Unix workstation or supercomputer with specialised GIS software. Low-end data requirements might be readily available vector or raster data whereas high-end requirements could be a comprehensive digital elevation model for an area. People skills can range from a PC end user with limited or no training in GIS/RS to experienced and highly qualified professionals.

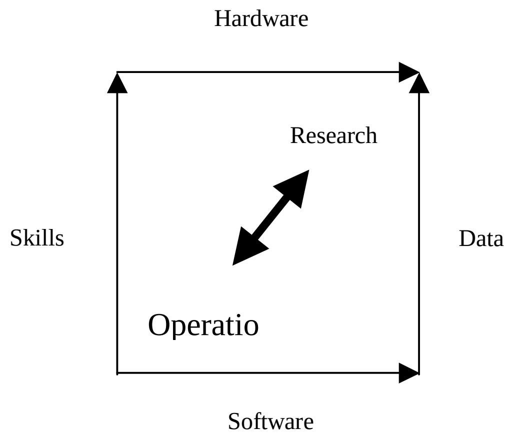

Figure 1 The relationship between the components of a GIS and operational/research activities

The bottom line is that to achieve a successful GIS implementation where cost and benefits are balanced, management generally needs to keep operational activities at the low end of these scales. High-end activities should be entered into sparingly, perhaps through out-sourcing or consultancies, to achieve specific one-off tasks or develop protocols for operational activities that once developed can be migrated to a less complex and more cost-effective environment.

GIS data

GIS data can come in digital or analogue forms. Analogue data can be an important source of information since most information collected in the past was recorded and mapped using analogue techniques. Currently, with the notable exception of aerial photography, most information is recorded in a digital format. Historical information is important when attempting to establish baseline data or determine whether change has taken place and it should not therefore be overlooked. It does need to be converted to a digital form before it can be integrated into a GIS and this can be an expensive exercise.

Geographic information has location, time and attributes. Location is generally expressed in a coordinate system often 2-dimensional but sometimes 3-dimensional (for example, digital elevation data). Time is not a dimension that is well handled at present by conventional GIS and is usually the date of data collection. Attributes include any information relating to the spatial features in the GIS (including dimension, images, text, video, sound, etc.). It is important to bear in mind that data are only a representative sample of the real world that is being modelled in the GIS.

Data are generally recorded and stored in one of three formats:

- Vector data are represented by coordinate pairs that on their own are point features (for example, bores or sample sites). A series of coordinate pairs is a line feature (for example a road or river), and a series of coordinate pairs that start and finish at the same point is a polygon or area feature (for example, vegetation types or land use). This method of recording and manipulating spatial information works well for some data and is efficient in terms of storage space.
- Raster data are stored in a grid cell or pixel format the size of which can vary. This variation in cell size is called the spatial resolution and may be dictated by the resolution of the data available or the task for which the data are required. Digital remotely sensed data are stored in this manner (discussed separately below) and are often used where continuous surfaces are of interest (for example, digital elevation models).
- Attribute data are conventionally stored in a relational database management system (RDBMS). Each spatial object in the raster or vector spatial database has a unique identifier that is used to provide a key to the related aspatial or attribute data associated with those features. The key can be used either way—spatial features can be selected by attribute selected in the RDBMS or attributes can be listed for spatial features identified through a spatial selection.

An important aspect of all spatial data is that they must be registered to a common coordinate system if they are to be useful. Commonly, a map projection such as AMG (Australian Map Grid) or geographic latitude and longitude is used to register all data. This is a necessary prerequisite to any comparison or overlay analysis. Although space precludes their discussion it should be noted that spatial resolution and scale are important issues to consider when collating and analysing data in a GIS.

GIS outcomes

It is particularly important from a management perspective to have a clear picture of what might be expected to come out of a GIS implementation. In the first instance, a GIS can provide the efficient storage and retrieval of data with spatial characteristics that might otherwise be difficult to manipulate. The retrieval can take the form of maps and reports that contain selected themes for areas of interest and characteristics of the spatial features that can be found. These may be spatial characteristics (area, length, perimeter, etc.) or aspatial attributes (description, land type, species, etc.). There are many advantages over traditionally prepared maps including the ability to generate quickly and easily updated maps when new information comes to hand.

These factors alone are enough for many people and organisations to implement GIS but once the system is in place and baseline data have been collated users begin to look for answers to more complex questions which require some analysis of the data. Typically these will include questions relating to suitability of specific areas for a defined use, risk analysis and the monitoring of change over time. As the database matures in terms of quantity and quality of data it becomes possible to use the GIS to assist in simulations, and the evaluation of alternative courses of action. Modelling may be done within the GIS or involve the integration of external models (for example, hydrological models).

A GIS is a tool for the use of management and the outcomes need to be integrated with other sources of information. GIS can provide useful ways for managers to visualise impacts of various courses of action and demonstrate these to others (perhaps their managers or funding bodies). A map can be worth a thousand words!

REMOTE SENSING TECHNOLOGY

The extent and remoteness of many of the turtle habitats in northern Australia combined with their inherent inaccessibility make remotely sensed imagery the only viable option for collecting synoptic data on a regular basis. After processing, this dataset then becomes input to the GIS and contributes to the flow of information available to environmental managers.

Remotely sensed data are a surrogate for the actual features of interest on the ground and are collected in a manner that suits integration in GIS. Satellite data contain attribute information (a spectral response) about a particular location on the ground at a particular time. They offer significant advantages in that it presents a synoptic view of the earth at periodic intervals, is (with some limitations outlined below) readily available and accessible, and it provides a relatively economical means to build a spatial database. It also offers the possibility of visiting and revisiting the past through the use of archived data. Aerial photographs provide the longest lived historical record of most areas but even satellite imagery can be obtained for the last twenty years.

Like most new technologies, remote sensing brings challenges as well as advantages. The large number of variables that play a role in the data collection can make it hard to interpret and use in a consistent manner. For example, features of interest such as vegetation will appear markedly different between seasons. These changes (for example, greening and browning) can come about over very short time periods. Images can also consume large amounts of storage space and processing capacity.

Remotely sensed data

Remotely sensed imagery is generally collected through measurement of the electromagnetic spectrum. The signals may be passively generated through the reflection of light energy from objects on the surface of the earth such as aerial photographs or optical satellite imagery. Alternatively, signals may be actively generated from airborne or spaceborne platforms using radar or laser technology. The data collected are stored in raster format as an image made up of one or more bands (the wavelengths measured) each of which has pixels (grid cells) with a measured value (usually between 0 and 255) which is the attribute of the pixel. This information is then processed and interpreted to identify objects and/or areas of interest using digital image processing techniques.

Digital image processing

Digital satellite imagery contains huge amounts of data that generally need to be reduced in order to be useful as input to a GIS and consequently provide information for environmental managers. For example, a Landsat Thematic Mapper (TM) image has 7 bands of information at a spatial resolution of 30 metres (for 6 bands and 120 metres for the seventh). Techniques for data reduction are well established and a number of computer software applications are available to assist in this process. A brief description of the standard method follows.

Each pixel represents a location on the ground at a particular time and an attribute that is a measurement of the average reflectance of the spatial objects on the ground in that cell. Since the energy reflected, absorbed and transmitted by different objects varies it is possible to differentiate between objects and identify those of interest. After pre-processing (for example eliminating atmospheric effects), enhancement techniques can be used to highlight areas or features of interest. Once identified, the spectral characteristics can be described as a spectral signature. This signature can then be used to identify other similar features in the image using classification functions available in image processing software.

Following classification, post-processing techniques are required to make the data suitable for integrating into a GIS. The most important of these are smoothing the classified image to create a thematic map and registering the image to known coordinates on the ground. Ground truthing of the results of this data reduction process is absolutely essential. This involves going out into the field to sites identified on the image (usually located using a GPS receiver) and ensuring that the classification is accurate. Without an evaluation of this nature managers cannot rely upon the quality of the data. There are other techniques for verification of results within a GIS that can augment or reduce the need for fieldwork that may be particularly difficult and/or expensive in remote coastal areas.

Integration of GIS/RS/MIS

Management requires information to make decisions. This information is normally the synthesis of information integrated into a management information system from a number of sources, a significant one of which is the GIS. The GIS, in turn, also integrates data from a number of disparate sources including remotely sensed data. The GIS also provides information to aid the data reduction process for remotely sensed data. For example, a digital elevation model may be used to reduce the area to be classified for mangrove vegetation by masking out areas above a certain elevation in the image. This reduces the chance of an overlap in spectral signatures of different vegetation types.

The integration path for the application of these techniques to turtle management and conservation should now be clear. Remote sensing provides synoptic and dynamic data at varying spatial and temporal resolutions that after digital image processing are used as input to a GIS where analysis and modelling can be performed. The output of the GIS is then fed up the line directly to management or into a management information or decision support system.

Remote sensing and turtle habitats

Within tropical Australia, the authors have been involved in a range of remote sensing applications that have relevance to marine turtle research. The following summaries provide details of the work and are intended to serve as a base for the integration of remotely sensed data into future research.

Reef zonation

Reefs are living structures, developing over a long period of time in suitable environments. As such all categories of reefs exhibit zonation patterns related to their stage of the evolutionary process and environmental factors. A most crucial factor in coral growth is the wind direction that governs the supply of energy to the organism. As reefs expand outwards the nutrient supply within the reef edge becomes limited.

This together with accumulation of sediment destroys living coral. The above is a very simplistic description but it demonstrates that reefs exhibit very strong zonation patterns. Typically a reef can be divided into an ‘outer reef zone’, ‘algal zone’, ‘coral zone’, and a ‘sand-rubble zone.

Remote sensing using sensors mounted on a satellite has potential to map the major reef zones. The data collected by the sensors in the 'visible light' range of the electromagnetic spectrum holds information about subsurface features to a depth of 20 metres in clear oceanic waters. Ahmad and Neil (1994) have demonstrated this capability by identifying 13 reef zones from Landsat Thematic Mapper data on Heron Reef (GBR). Further subdivision of zones according to primary productivity was also demonstrated.

Hill and Ahmad (1992) utilised satellite remote sensing to accurately map trochus shell habitat on reefs in the Torres Strait. The total area of habitat mapped at Yorke Island was within 2% of that derived from fieldwork and aerial photo interpretation. Ahmad and Hill (1994) also demonstrated that the methodology was transferable to similar environments allowing an inexpensive and fast survey of trochus shell habitat on neighbouring islands (fig 2).

Menges et al. (1997) used Landsat Thematic Mapper data to map turtle feeding areas in Patterson Bay, approximately 60km south-west of Darwin (fig 3).

The major importance of this reef environment is its significance to threatened species of sea turtle. The hawksbill (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*) frequent the reefs to feed on species of brown algae. The use of data in the visual range of the electromagnetic spectrum allowed the discrimination of six distinct reef zones. The algae, however, could only be mapped by addition of information from the Near Infrared (NIR) range. Although this is an unusual procedure because this wavelength is absorbed very rapidly by water, the study has shown that NIR can be used in marine applications provided that the cover type to be mapped is not submerged further than 50cm in clear water. If this condition is met, the ability to map algae and seagrass beds is greatly enhanced. A diagram showing the outline of the reefs and the areas identified as algae is shown below (fig 4).

Intertidal and subtidal zonation

The intertidal zone is the coastal habitat most affected by the water movement resulting from ebb and flood tidal currents (Levinton 1982). This water movement affects both sediment and biotic distribution. The subtidal zone is also subject to altering sediment regimes because of tidal mixing, mass transport of water and vertical mixing (Amos & Alfoldi 1979).

When using remote sensing techniques to map bottom habitats in the intertidal and subtidal zones the signal is confounded by the substrate type, water depth and water turbidity (Lyzenga 1978, 1981, Bierworth et al. 1993). Unless water depth and horizontal mixing is uniform across an image it is not possible to directly calculate the bottom reflectance (Quinn et al. 1985). Tidal, lunar and meteorological conditions present during imagery capture will also affect raw images so that interpretation of images must bear in mind the influence of these variables as shown in figure 5 (Carter et al. 1997).

There are a number of algorithms which have been designed for mapping water depth, bottom type and turbidity, however, these studies have largely investigated those parameters in isolation, and not considered the combined effects (Bierworth et al. 1993). Currently work is being undertaken to investigate the optimal processing algorithms for use in the variable coastal waters of northern Australia (Carter et al. 1997, Menges et al. 1997). This research will also suggest how the influence of tidal, lunar and meteorological conditions present during image capture affects results and interpretations, so that improved interpretation of results can be derived with each new coastal application of remote sensing.

SUMMARY AND RESOURCES

This paper has outlined GIS and remote sensing technology and provided some examples of the use of this technology in relation to turtle habitat. There has been relatively little published in this application of the technology to date and few references were found (Huang et al. 1995, Mosier 1994, Mosier & Blaine 1994).

The only significant internet site found which contained information of interest in this context was the Archie Carr Center for Sea Turtle Research (http://nervm.nerdc.ufl.edu/~accstr/accstr.html) at the University of Florida. Examples of the use of GIS and remote sensing for environmental purposes in northern Australia may be found in Carter et al. (1995) and Devonport and Riley (1993).

The contribution that GIS and remote sensing can make to the management and conservation of turtles in northern Australia may be summarised as follows:

- handle spatial data—store/retrieve/visualise/map
- identify patterns—migration/feeding/nesting
- look for associations—beaches/seagrass/algae
- monitor changes—in patterns/associations
- identify important areas—risk and/or suitability

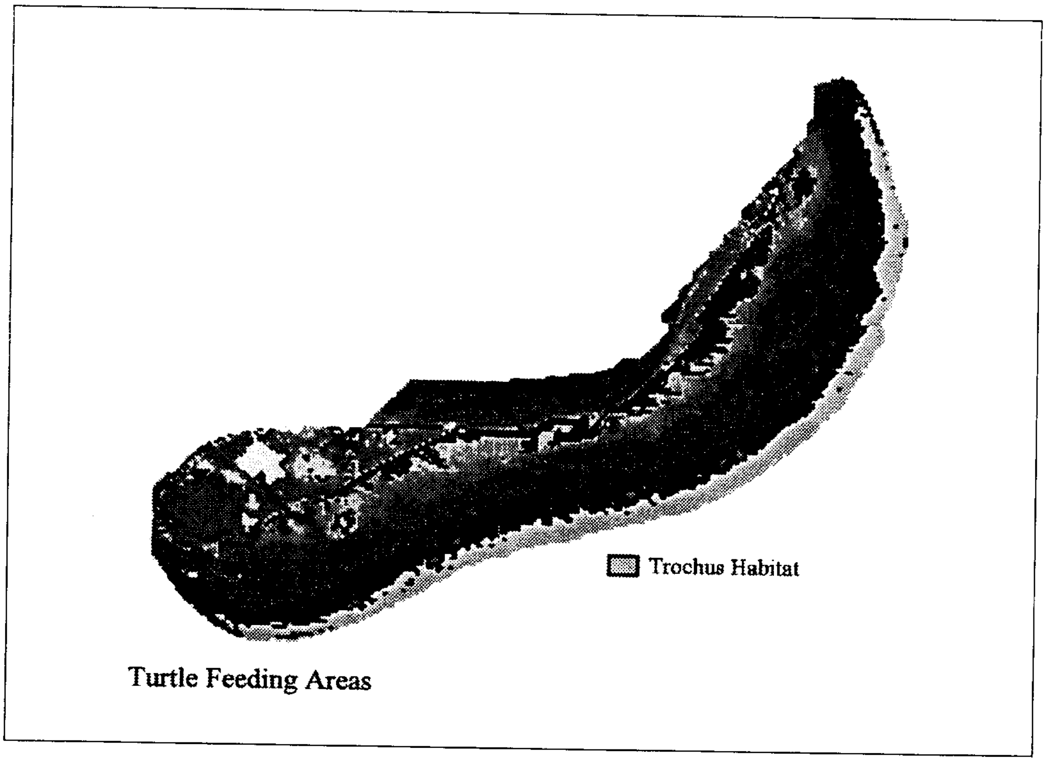

Figure 2 Yorke Island, Trochus habitat

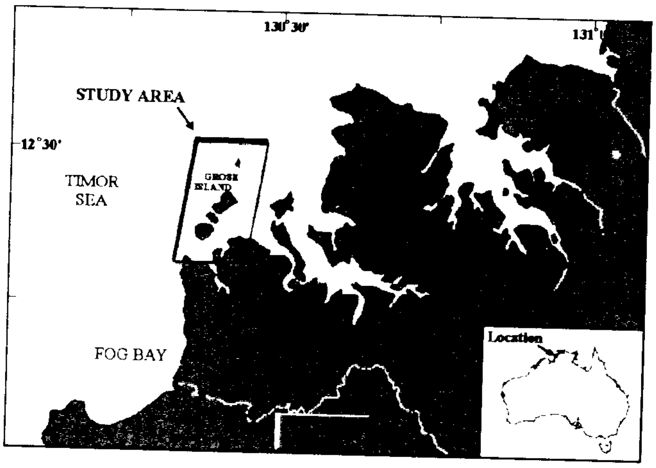

Figure 3 Geographic location of study area for mapping turtle feeding areas

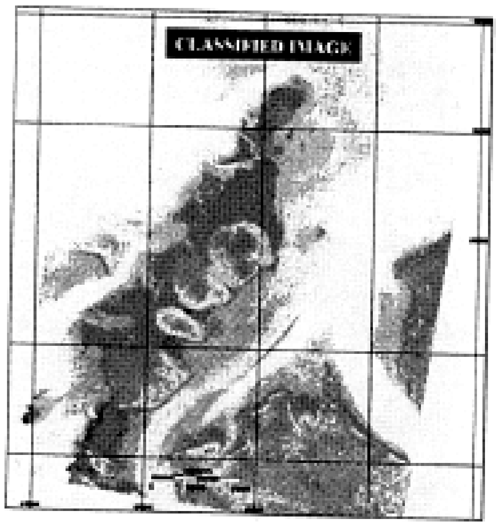

Figure 4 Classified image of study area, showing regions of algal growth in black

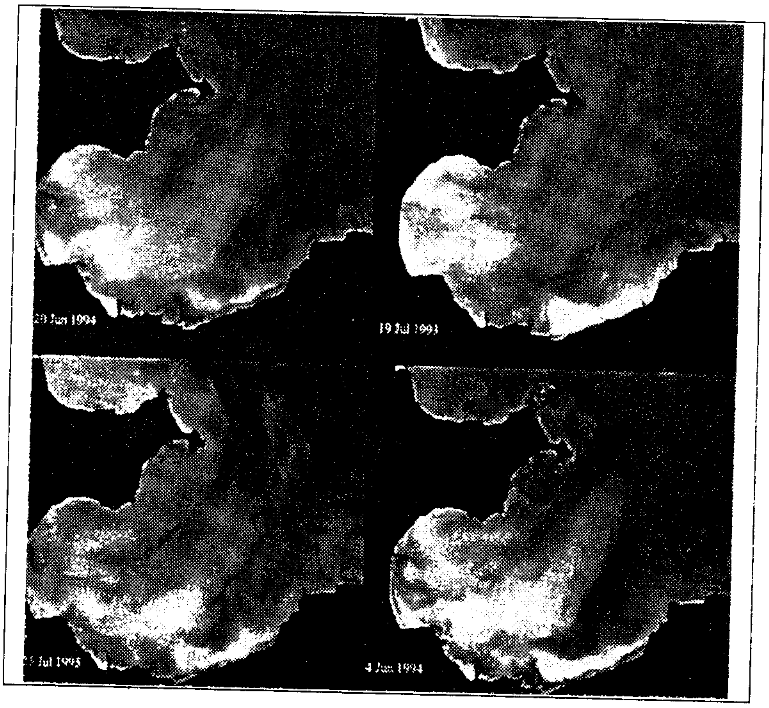

Image	Lunar phase	Tidal phase	Wind direction	Wind speed
20 June 1994	Neap	Low	O	O
19 July 1993	Spring	Outgoing	SE	1.0 m/s
25 July 1995	spring/neap	Outgoing	ESE	2.1 m/s
04 June 1994	neap	Low	SE	1.0 m/s

Figure 5 Subset of study area, showing differences between images

- educate—make information available/accessible
- manage—decision support/ evaluation/ conservation

Suggested outcomes for this workshop

- identify GIS aims/objectives for turtle management and conservation
- formulate strategies for data acquisition, integration, and distribution
- identify relevant research needs in GIS and remote sensing

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SEA TURTLE RESEARCH AT THE NORTHERN TERRITORY UNIVERSITY

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ABSTRACT

The history of sea turtle research at Northern Territory University is reviewed. Sea turtles feature in undergraduate teaching and postgraduate research. The sea turtle study group has been involved with collaborative projects with government departments and authorities and liaison with community groups interested in sea turtles and the marine environment.

KEYWORDS: Natator, Chelonia, Lepidochelys, Eretmochelys, Caretta, education, research, community liaison

INTRODUCTION

Six species of sea turtle live in the waters of the Northern Territory. The flatback (*Natator depressus*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) are known as nesting species. The loggerhead (*Caretta caretta*) does not normally nest on beaches of the Northern Territory. Surveys by explorers and navigators indicated, in part, the distribution of some species, but provided little information regarding the biology of the animals (Guinea 1994a). It was not until the more recent surveys of Cogger and Lindner (1969) and accounts of multiple strandings of sea turtles (Limpus & Reed 1985, Marsh et al. 1986) that quantitative data became available to the scientific community. Investigations into the biology of sea turtles started at the Northern Territory University (NTU) in 1986. The studies have been, and still are, aligned with the NTU mission of education, research, community liaison and interactions with government departments (fig 1).

METHODS

General methods

Standard methods are used in measuring, weighing and handling sea turtles and their eggs (Limpus et al. 1984). Turtles are marked with two individually numbered titanium flipper tags. Those animals caught within the conservation areas of Kakadu National Park and Ashmore Reef and Cartier Island Territories are tagged with 'CA' series tags and the resulting data sheets and databases returned to Environment Australia (EA), formerly the Australian Nature Conservation Agency (ANCA). Outside these areas turtles were tagged with 'T' series tags supplied by Dr Colin Limpus of the Queensland Department of Environment and Heritage and records returned to his program.

Education

Initially, aspects of sea turtle biology were incorporated into the undergraduate subjects of the Certificate of Environmental Biology at the Darwin Institute of Technology (DIT). Observations made on nesting seasonality of flatback turtles did not agree with those reported for this species in other parts of Australia (Limpus 1971). A study of the nesting biology of flatbacks started at Dundee Beach, Fog Bay, because of the convenient access and large number of turtles. Fog Bay in 1988 provided an ideal site for students enrolled in Marine Park Management to study the possible impacts of coastal development on the sea turtle nesting population. These studies expanded in early 1990 to include the immature green and hawksbill sea turtles feeding on the intertidal ironstone reefs.

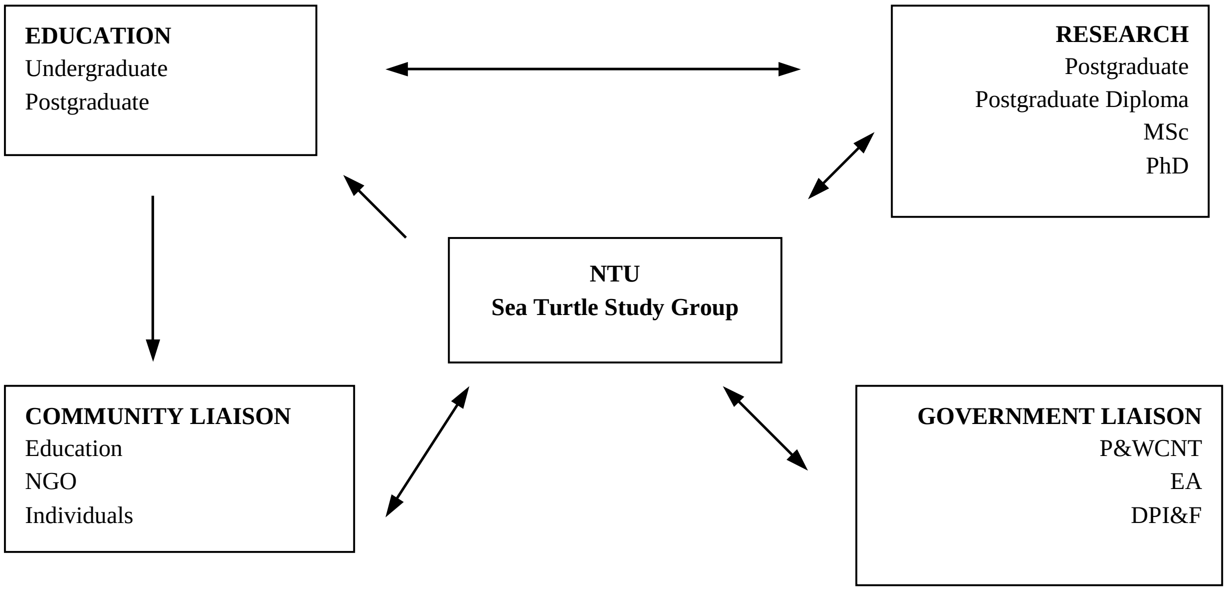

Figure 1 Interactions between the Sea Turtle Study Group at NTU, undergraduate, postgraduate students, government departments and the community

Research

Funds became available in 1988 to conduct regular monitoring of nesting sea turtles in Fog Bay. Monthly beach patrols enabled the collection of sand temperatures throughout most of the year and revealed the presence of olive ridleys feeding and nesting in the vicinity. By 1990, research activities included regular checks for sea turtle nesting on Bare Sand Island, an important sea turtle nesting area (Searcy 1909, Fry 1913). In addition, studies of the ecology of immature green and hawksbill turtles which feed on the surrounding reefs intensified. The beaches of Fog Bay and the islands to the north are now the study sites of two postgraduate students and have been used by another for field training for his studies in Kakadu National Park.

Government authorities

All aspects of teaching and research have been conducted with the appropriate permits supplied by Parks and Wildlife Commission of the Northern Territory (P&WCNT), Australian Nature Conservation Agency (ANCA) and Northern Territory Department of Primary Industry and Fisheries, Fisheries Division (DPI&F). Officers from a number of departments are members of the Animal Experimentation Ethics Committee which authorises the various procedures used in the investigations. Cooperative studies between NTU and government departments and authorities have been established as well as training courses for personnel involved in sea turtle research.

Community liaison

Interaction between NTU and the general community has progressed with the production of a leaflet on sea turtles for schools with the Northern Territory Department of Education (Michie nd). Oral presentations on sea turtle ecology have been given on behalf of non-government organisations for Sea Week and other community-based initiatives. An informal dialogue has been established with several Aboriginal organisations who have either requested information on some aspects of sea turtles, or from whom permission has been requested to visit traditional lands. In addition, dialogue has been established with numerous individuals who have an interest in, and a concern for, sea turtles.

RESULTS

Aspects of the biology and ecology of sea turtles remain an integral part of several courses conducted in the higher education section of NTU. Although some of the courses have been modified with time, an annual trip to the nesting beach at Fog Bay remains in the schedule for Field Technique courses. Results from the first four years of the teaching activities in Fog Bay are presented elsewhere (Guinea 1990, Guinea & Ryan 1990, Guinea et al. 1991; Guinea 1994a,b,c,d).

Postgraduate students have presented several theses on aspects of sea turtle biology and their inshore environment. Studies into the niche overlap and diet of loggerhead and olive ridley turtles on the feeding grounds at Fog Bay have been completed (Conway 1994). The spatial dynamics of macro-algae and corals in the intertidal zone in Darwin Harbour have been studied as a model for sampling in Fog Bay (Ferns 1995). The nesting ecology of flatback turtles at West Alligator Head and Field Island in Kakadu National Park has been studied and recommendations made to improve their survival status (Vanderlely 1997). Developments in the Northern Territory coastal net fishery have been reviewed with the aim of identifying target species and reducing bycatch, including sea turtles (Gillespie 1997). Reducing the accidental capture of sea turtles in fishing operations also featured in the strategies for implementing turtles excluder devices in the nets of the Northern Prawn Fishery (Wilson 1997).

Scott Whiting is presently studying the feeding ecology, demography and growth of immature green and hawksbill sea turtles on the ironstone reefs of islands north of Native Point in Fog Bay. Sean Blamires is presently studying the effects of predation on sea turtle eggs by goannas (*Varanus* sp.) on the mainland beaches in Fog Bay. (See papers by Whiting & Guinea and Blamires & Guinea in this volume.)

Collaborative activities with staff from government departments have focused on the accidental deaths of sea turtles from fishing activities (Guinea & Chatto 1992, Chatto et al. 1995, Guinea et al. 1997), consultancies (Guinea 1993 & 1995, Vanderlely 1995) and successful grant applications for 'Quail Island to Native Point Sea Turtle Refuge' and with P&WCNT and Dhimurru for 'Research and Management of Marine Turtles in Eastern Arnhem Land'.

Involvement with community-based projects has resulted in delivering several presentations to the public. Information has been sent to Aboriginal communities as requested so as to share the results of ongoing research.

DISCUSSION

Fog Bay has become a centre for comparative studies of sea turtle biology in northern Australia. As the area is readily accessible by road, sea and air, studies are conducted with a minimal amount of logistical support. Five different species of sea turtles are present in adequate numbers to provide statistically robust samples for population biology studies. The presence of subadult hawksbill sea turtles living in the area has been important in studying the population dynamics of this threatened species (Guinea & Whiting 1997, Limpus et al. 1997). Apart from research mentioned above, the area has become a reference point for genetic studies on green, hawksbill and flatback sea turtles (Broderick et al. 1994).

Fog Bay is within the proposed Beagle Gulf Marine Park. This marine protected area will be zoned for multiple use and most of the present uses will continue (Kelleher et al. 1995). Presently, tourism and fishing are the major industries in the bay. Future research by the sea turtle study group will continue to be collaborative with government departments. In particular, attention will be directed to assessing the impacts on sea turtle survival as the intensity of commercial and recreational activities increase in Fog Bay and nearby waters.

CONCLUSION

Sea turtle research at NTU may be classified into two broad areas:

- short-term studies designed to answer specific questions;
- long-term studies where the questions are open-ended and may lead onto other studies.

The short-term studies are suitable for individual research projects. Their duration may be from one to three years and fit neatly into postgraduate study programs. The long-term questions are usually those that are required for management. They require baseline data over extended periods, possibly decades. Each study, however, requires that the ecologies of the species and the respective age classes be known.

ACKNOWLEDGMENTS

I thank Geoff Tune and Arthur Georges who reported sea turtle nesting at Fog Bay in 1986. Col Limpus has provided tags, software, advice and encouragement throughout. Scott Whiting, Roger Vanderlely, Sean Conway, Laurie Ferns and Sean Blamires have provided valuable contributions to the project. Funds have been provided to the program by the Darwin Institute of Technology, National Estates Grants Program, Australian Nature Conservation Agency and the Japanese Bekko Association, and to individuals through Queen's Trust for Young Australians, Australian Geographic and Keep Australia Beautiful. To the above and to the numerous volunteers and students, I express my sincere thanks.

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Marine Turtle Monitoring in Gurig National Park and Cobourg Marine Park

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Abstract

Since the beginning of 1995 three marine turtle monitoring programs have been undertaken in Gurig National Park/Cobourg Marine Park. These programs consisted of an aerial survey of beaches for nesting turtle tracks in the Cobourg Peninsula region, ground based studies of nesting on the Black Point and Smith Point beaches, and a turtle tagging program on Greenhill Island. During the survey period, the islands east of Croker Island were the sites most used for nesting by all species of turtle known to nest in the region. In Cobourg Marine Park the mainland northern beaches play an important role for ***Chelonia mydas*** *(green turtles) and Greenhill Island for* ***Natator depressus*** *(flatback turtles). Green turtles nest predominantly on the beaches of Black Point and Smith Point. Predation on Black Point and Smith Point nests are predominantly by goanna (40.5%), dingo (14.0%), crab (3.2%) with the remainder not established (46%). During 1995–l997 a total of 187 marine turtles, mainly nesting female flatback turtles, were tagged at Greenhill Island. An extensive array of data relating to general biology was also collected over this time period. These preliminary studies provide a platform from which to design improved monitoring programs, which are integrated effectively with the other responsibilities of Park staff.*

KEYWORDS*:* nesting surveys, hatchling survival, nesting density cobourg peninsula

INTRODUCTION

Australia is one of a few countries where large numbers of marine turtles still occur. All six species of marine turtles from Australian waters are found in the Northern Territory (NT). These are *Chelonia mydas* (green), *Lepidochelys olivacea* (olive ridley), *Eretmochelys imbricata* (hawksbill), *Natator depressus* (flatback), *Dermochelys coriacea* (leatherback) and *Caretta caretta* (loggerhead) (Cogger & Lindner 1969, Guinea 1994a, Limpus 1995). The NT is significant for nesting green, flatback, hawksbill and olive ridley (Guinea 1994a, Limpus 1994, 1995).

Australian marine turtle research has received growing attention in the last 25 years. Much of this research is concentrated on the east and west coasts of Australia, though little research has been conducted in the NT. Currently the Northern Territory University (NTU) is researching the ecology and population dynamics of nesting flatbacks and feeding greens and hawksbills in the Fog Bay area. Environment Australia (EA) has a tagging program for its nesting flatbacks on Field Island, Kakadu National Park.The Parks and Wildlife Commission of the Northern Territory (PWCNT), NTU and Dhimurru Land Management Aboriginal Corporation are researching use of marine turtles as a cultural and subsistence resource by traditional owners on the Gove Peninsula, NE Arnhem Land. PWCNT is processing distribution data from widespread surveys of nesting marine turtles in the NT. Other basic data, such as recruitment and migration patterns, abundance and mortality, are largely unknown. Limited tag returns for animals marked in Western Australia, Indonesia and Queensland all indicate that Northern Territory waters are important for most marine turtle species by providing feeding grounds, nesting habitats or simply a corridor for the migrating animals.

In 1995, Gurig National Park rangers with approval from the Cobourg Peninsula Aboriginal Land and Sanctuary Board commenced a marine turtle research program. One year after its approval the program was extended for another four years. The primary aims were:

- collect preliminary baseline data to inform more coherent programs of research and conservation management;
- establish the feasibility of incorporating long-term monitoring programs in the work schedules of park staff.

Three programs were put in place:

- an aerial survey of Cobourg Peninsula region to determine (a) the significant breeding sites and (b) their peak nesting periods within the Cobourg Peninsula region;
- a ground-based survey on Black Point and Smith Point to determine (a) which species were nesting on Black Point and Smith Point beaches, (b) the peak nesting period and (c) predation of turtle eggs;
- turtle tagging program at Greenhill Island to elucidate flatback turtle movement and collect biological data regarding nesting turtles and nest success.

This paper presents a summary of the findings of the 1996 aerial survey of nesting sites in the Cobourg Peninsula Region and the Black Point and Smith Point ground surveys. Also, the preliminary analysis of tagging data collected during 1995–1997 is presented. A preliminary overview of nesting sites in the Northern Territory can found in Chatto (1998, this volume).

METHODS

Study area

The Gurig National Park/Cobourg Marine Park is located on the Cobourg Peninsula in the Northern Territory and is the most northern point of the Northern Territory mainland (fig 1). It comprises approximately 5000 sq km of land and sea and was the first site listed in the world as an internationally significant wetland on the Ramsar Convention on Wetlands of International Importance. Generally the northern coastline of the Park is characterised by isolated bays, rocky headlands and beaches. Intertidal and subtidal habitats consist of coral reefs, fringing coral and rocky reefs, sand and mudflats, with few areas of mangroves and seagrass communities. In contrast, the southern coastline and islands comprise mainly mangrove communities associated with large mudflats. These mangrove communities are interspersed with rocky headlands. Sandy beaches do occur in the southern area of the Park, but are mainly restricted to the associated islands.

Greenhill Island is the largest island in the Park and forms part of the Sir George Hope Island group in the southern part of the Park. The island's coastline is characterised by mangrove and mudflat habitat, rocky headlands, rocky and coral reefs and a 3.5 km sandy beach. The mangrove and mudflat communities occupy approximately two-thirds of the coastline, whereas the remainder of the habitats are found only on the western side of the island. The beach is backed by a 25–50 m strip of sand dunes. Benthic habitats in front of the beach to the north centre and south respectively are rocky reef, sand flats and coral/rocky reefs. Green turtles have been observed in the southern coral reef area and it is presumed to be a feeding area.

Aerial surveys

Aerial surveys were conducted over the beaches in the Cobourg Region, including Croker Island, and the neighboring Oxley, New Year, Darch, McClure, Templer, Lawson, Grant and Valencia islands in 1996 (fig 1a). The surveys were planned for every six weeks, weather and other duties permitting. The number of turtle tracks were counted and recorded for each surveyed beach. The number of turtle tracks found were divided by two to estimate the number of nesting attempts, as two tracks—one leading towards the nesting site and the other leading back to the sea—can be considered as one nesting attempt.

Ground surveys

Black Point and Smith Point surveys

Black Point and Smith Point beaches (fig 1b) were surveyed irregularly for nesting activity from 31 December 1995 to 27 November 1996. Seven kilometres of beachline were patrolled during the day and the number of new tracks and nests, hatched nests, predation and the likely predator was recorded. Predator tracks encountered at the raided nests were used to determine likely predator. The turtle tracks were marked by foot wiping. Turtle track-width was also measured to identify the species responsible for the track/nest. When an open nest was found, a maximum of 10 eggs were weighed and diameters measured, before replacing the eggs in the chamber and refilling the nest pit and egg chamber. If hatchling tracks were encountered and the nest could be located, the nest was opened, the clutch size was estimated from egg shells found in the nest, and the number of dead hatchlings, unhatched, undeveloped, yolkless and unfertilised eggs in the nest were recorded. From these data, nest success (any nest that produced a live hatchling) and hatch rates (the proportion of a clutch hatched) were determined.

Greenhill Island survey

For the period 14–25 August 1995, 1–20 July 1996 and 19 June to 12 July 1997 the 3.5 km beach (fig 1c) was patrolled continuously by 3 to 4 groups of 2 or 3 people for nesting turtles from dusk to dawn.

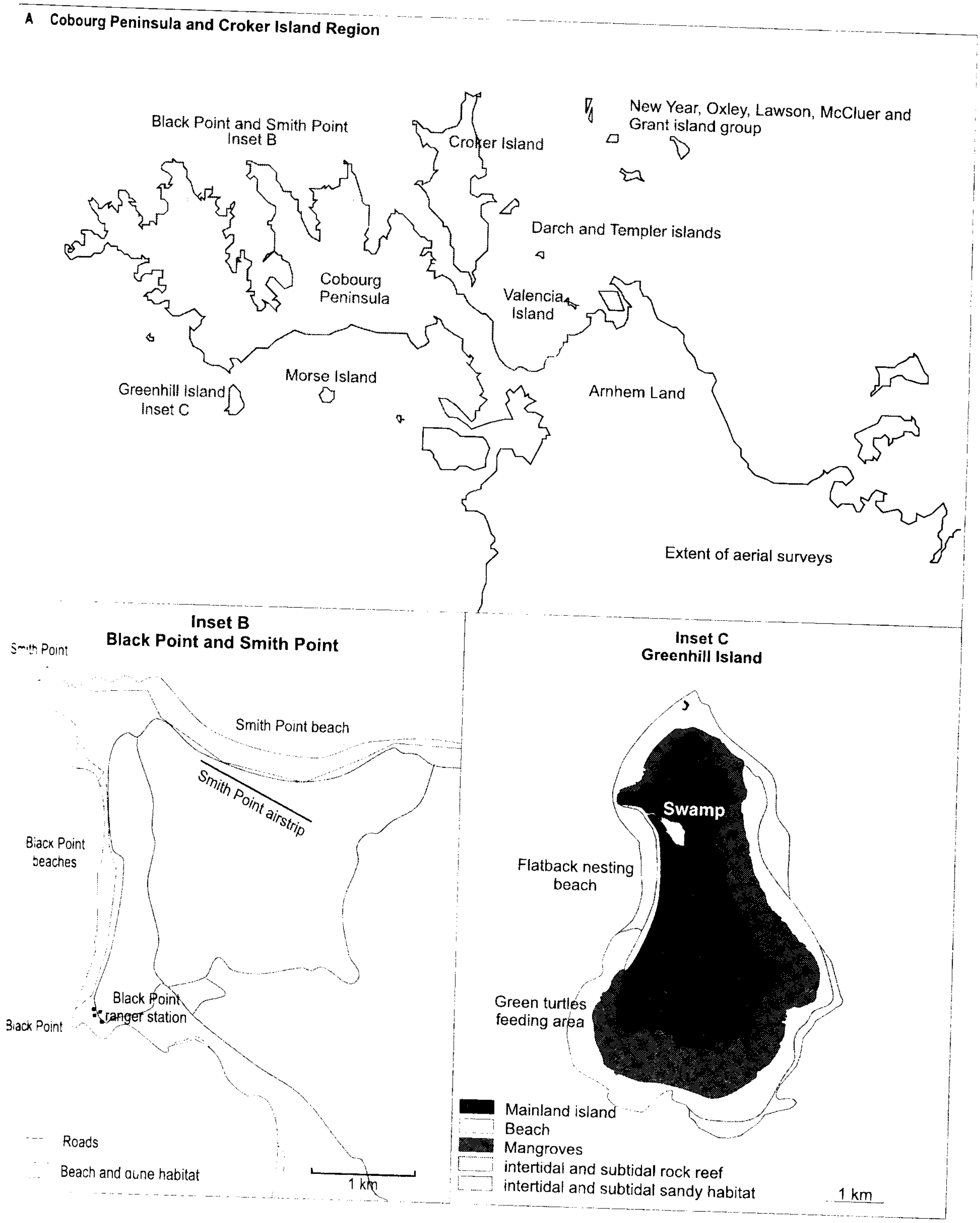

Figure 1 Locality maps showing the extent of a, the regional aerial surveys; b, the Black Point and Smith Point ground surveys; and c, the Greenhill Island surveys

The full length of the beach was surveyed, except for a 100 m stretch of beach on the far northern side of the beach. This stretch of beach was cut off from the rest of the beach by a corridor used by crocodiles to commute between the sea and a freshwater swamp located behind the sand dune system. This area was considered too dangerous to cross during the nightly tagging exercises. However, the unsurveyed stretch of beach was checked for turtle tracks the following morning.

Once a turtle was seen coming up the beach, the time taken for the various nesting activities was recorded (e.g. body pitting, chamber digging, laying and nest covering). Further, the number of eggs was counted during laying or after the laying event and 10 eggs were weighed and diameters measured. When possible the depth to the top and the bottom of the chamber was also recorded. Turtles returning to the sea were tagged with titanium tags in the axial scale on the trailing edge of both front flippers, weighed and curved carapace width (ccw) and length (ccl) measured. Turtle identification characteristics, e.g. carapace damage, were also recorded.

Every morning the beach was patrolled for hatchling tracks. Where hatchling tracks were encountered and the nest located, nest success and hatch rates were determined when possible as for the Smith Point and Black Point survey. Live hatchlings found in the nest were weighed and morphological characteristics were recorded. The hatchlings were released into the sea after sunset.

During the 1997 survey, a trial was conducted to determine if nests could be tagged to measure nest success and hatch rates for completed nests by tagged flatbacks. Whilst the turtle was laying the nest was tagged by leading one end of the flagging tape into the egg chamber. Once the turtle had left the nesting site, the flagging tape was wound around an obvious marker, which may have been a stick or grass pod, and the other end of the tape tag numbers, date and clutch size were recorded.

The end of the flagging tape was covered with sand to prevent fading by the sun. The beach was revisited 10 weeks later and the nest success was determined. Twenty-one marked nests could be located and were opened to determine hatch rate.

RESULTS

Aerial surveys

Aerial surveys were conducted in July, October and November (table 1). In the second half of 1996 the New Year, Oxley, Lawson, McCluer, and Grant Islands accounted for 61% of the turtle tracks counted; northern Cobourg Peninsula, 19%; southern Cobourg Peninsula, 6%; Croker Island, 5%; Darch and Templer Islands, 6%; Valencia Island and mainland Arnhem Land both accounted for only 1%. Within the Park, the northern area had three times higher track counts than the southern area of the Park.

Ground survey Black Point and Smith Point

Between 31 December 1995 and 27 November 1996, 246 turtle tracks were encountered. Frequency distribution for track widths is presented in figure 2. The mean track width was 98.5 cm (SD = 9.9 cm, N = 246).

Of the 246 turtle tracks there were 136 successful nesting events (55.3%), 51 no lay events (21.2%). The remainder were either not recorded (4.9%) or could not be determined (19.1%).

Of the 136 successful nesting events no predation was recorded for 44 nests (33.1%), 60 nests (44.1%) were predated and for the remainder 31 nests (22.8%) no information was recorded. The raided nests could be attributed to goanna (19.1%), dingo (6.6%) and crabs (3.2%). The predator could not be established for the other raided nests (46%). Losses were high (many/most eggs lost) when predated by dingo and goanna and low (few eggs lost) when caused by crabs.

Table 1 Number of turtle tracks encountered during aerial and ground surveys in July, October and November 1996 for the Cobourg Peninsula and Croker region

Region no	July	October	November	Total number of tracks	Percentage of total number of tracks
Southern Cobourg Peninsula	138	26	40	204	6
Northern Cobourg Peninsula	123	276	213	612	19
Croker Island	45	45	83	173	5
New Year, Oxley, Lawson, McCluer, and Grant Islands	401	905	655	1961	61
Darch and Templer Islands	80	59	57	196	6
Valencia Island	17		30	47	1
Arnhem Land mainland	33		13	46	1
Total	837	1311	1091	3239	99

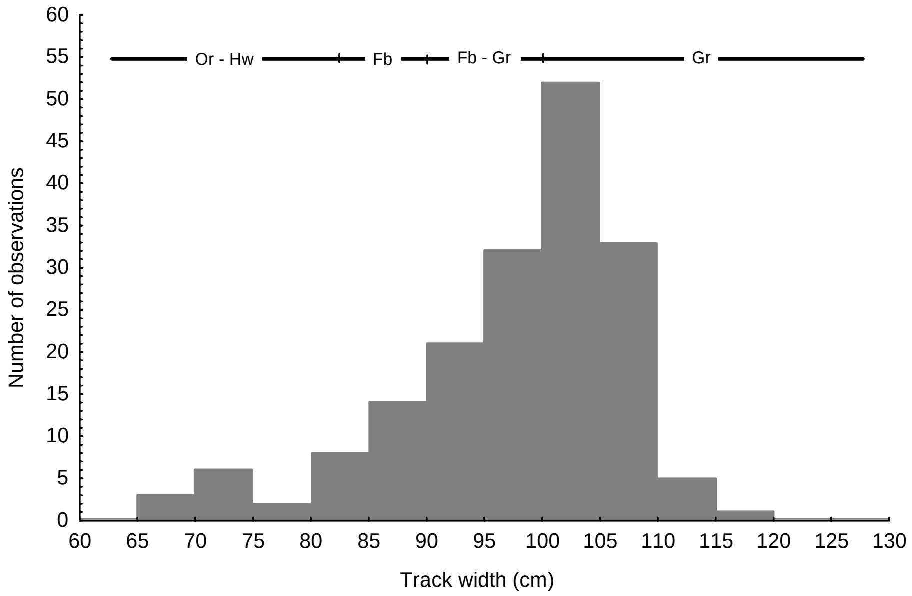

Figure 2 The width of encountered turtle tracks on the Black Point and Smith Point beaches. Track width ranges given for species of turtle are from unpublished PWCNT data and only indicate approximate ranges. Abbreviations: Or – Hw, Olive Ridley – Hawksbill group; Fb, Flatback; Fb – Gr, Flatback – Green overlap; Gr, Green.

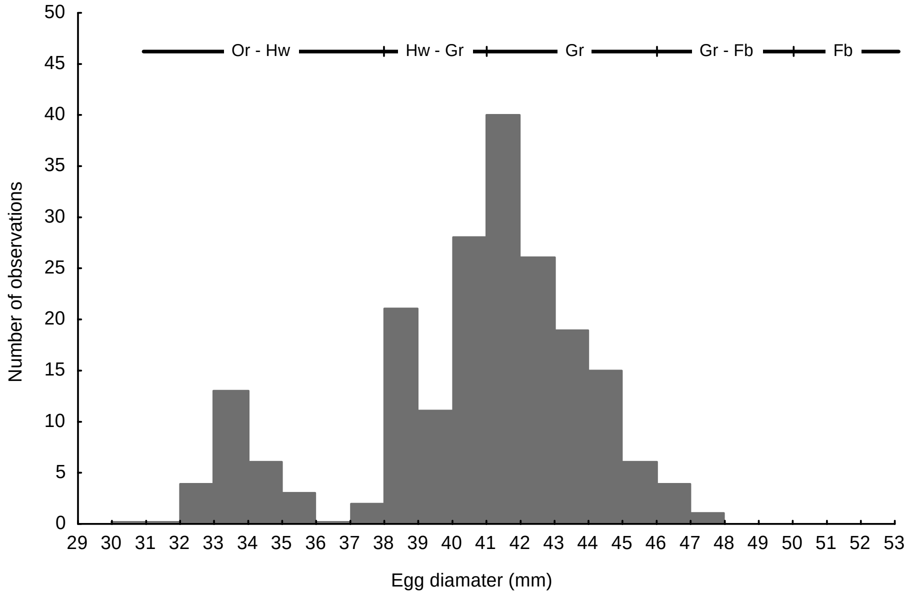

Figure 3 Egg diameter for turtles nesting at Black Point and Smith Point beaches. Egg diameter ranges given for species of turtle are from unpublished PWCNT data and are only indicate approximate ranges. Abbreviations: Or – Hw, Olive Ridley – Hawksbill group; Hw – Gr, Hawksbill – Green overlap; Gr, Green; Fb – Gr, Flatback – Green overlap; Fb, Flatback.

The degree of predation damage, measured as amount of eggs lost, was determined for 30 nests. Some eggs were taken from 15 nests; most eggs from 1 nest; and all from 14 nests.

Twenty-three clutches were examined for egg diameter. The number of eggs counted depended on the number of eggs that were available after the nest was predated. This varied between 1 and 10, with an average of 8.7 eggs per clutch. The egg diameter may be trimodal, one mode being at 33.5 mm, the second at 38.5 and the third at 41.5 mm (fig 3). For six of the 23 nests it was possible to determine the clutch size and hatch rate, with the range for clutch size and hatch rate being respectively 44–106 and 75–99%.

Greenhill Island Survey

A total of 187 turtles were tagged; 31 in 1995, 78 in 1996 and 78 in 1997. In the three years combined, 170 flatbacks (91%), three hawksbill, and three olive ridley (and 2 turtles for which species was not recorded), were tagged and released. The tagging effort was concentrated around the nesting period for flatbacks, which is mainly from June–July (Guinea 1994b). Although no nesting green turtles were recorded, nine greens were caught and tagged on feeding grounds, located on the southern rocky reefs of Greenhill Island in 1996 and 1997.

Renesting of flatback turtles within a survey period occurred in all three years; once in 1995, eight times in 1996 and twice in 1997. Mean renesting interval for 1995, 1996 and 1997 combined was 14.8 days (range: 9–17 days, mode and median: 16 days, N=11, SD=2.2 days). Re-migration of flatback turtles occurred with the three year program period: six nesting turtles were tagged in 1995 and recaptured in 1997; and six nesting turtles were tagged in 1996 and recaptured in 1997. No nesting turtles that were tagged in 1995 were recaptured in 1996; and no turtles that were tagged in 1995 were recaptured in 1996 and 1997. Mean re-migration period was 1.4 years (N=12, SD=0.5 yr, range 0.9–1.9 yr).

Mean curved carapace width (ccl), mean curved carapace length (ccl), weight and track width statistics are presented in table 2.

Nest characteristics

Nesting attempts and the proportion of successful nestings at Greenhill Island are presented in table 3. Figure 4 shows number of successful nestings in relationship to the nest position on the beach.

Turtle nests were mainly located between the high-water mark and the top of the first dune (81.2%); 3.6% of the nests were below the low water mark and 1.6% behind the first dune. The mean depth of the top of the egg chamber for flatbacks was 37.8 cm (SD=8.5, N=97). The mean depth of the base of the chamber was 60.4 cm (SD=9.1, N=98). For hawksbill, for which only one chamber was measured, the depth of the top of the chamber was 19.0 cm and the depth of the base of the chamber was 64 cm. No olive ridley chambers were measured in this period.

Table 2 Carapace dimensions (mm) weight (kg) and track width (cm) for species of turtles captured at Greenhill Island between 1995–1997

Species		Mean	SD	Minimum	Maximum	N
Flatback (nesting)	ccl	862.5	36.4	750	950	181
	ccw	719.8	39.4	584	885	180
	weight	67.8	8.5	50	90	107
	track width	88.5	7.9	7.4	11.3	59
Hawksbill [1] (nesting)	ccl	795	–	–	–	1
	ccw	680	–	–	–	1
	weight	40	–	–	–	1
	track width	78.0	–	–	–	1
Olive ridley [2] (nesting)	ccl	674.7	17.1	655	686	3
	ccw	685.7	35.8	665	727	3
	weight	–	–	–	–	–
	track width	–	–	–	–	–
Green [3] (feeding)	ccl	841.0	197.7	485	990	10
	ccw	776.5	186.2	440	925	10
	weight	82.1	46.5	15	119	7
	track width	–	–	–	–	–

1 Only one nesting hawksbill turtle was caught (1996); 2 No weight and track measurements were taken for the nesting olive ridley turtles; 3 Feeding green turtles were caught by rodeo jumping in 1996 and 1997; none of this species were found nesting

Table 3 Nesting attempts and percent successful nestings at Greenhill Island

year	species	Nest completed No	Nest completed unknown	Nest completed yes	Total nesting attempts	Percentage successful nests
1995	flatback	1	1	28	30	93
	unknown sp.		2		2	0
	total	1	3	28	32	88
1996	flatback		12	68	80	85
	hawksbill			1	1	100
	total		12	69	81	85
1997	flatback	4		71	75	95
	olive ridley			3	3	100
	total	4		74	78	95
1995–1997	total	5	15	171	191	90

Clutch size was determined for 141 nests. Flatback nests had a mean clutch-size of 52.2 (SD=10.7, N=137, range: 7–91); a hawksbill, which laid in 1996, laid 169 eggs and olive ridley, which nested only in 1997, had a mean clutch size of 113.7 (SD=31.8, N=3, range: 77–133). Only flatback eggs were weighed and their diameter measured: mean weight was 67.5 g (SD=7.6, N=776, range: 52–82 g) with a mean diameter of 49.3 mm (SD=2.0, N=806, range: 42.5–61.0 mm). Hatching rates for nests of tagged flatbacks were determined only in 1997: 94.1% (SD=7.2, N=21 range: 71.2–100%).

One olive ridley nest was opened, 42 of the 134 eggs were unsuccessful, giving a hatch rate of 67.9%. For either species no hatchlings were found dead in the nest.

Hatchling surveys

During the tagging periods (1995–1997) hatchlings emerged from 78 flatback nests of which 64 were located and examined for hatch rates. In total 4372 eggs were counted, of which 3958 hatchlings emerged from the nest, giving an overall hatch rate of 90.5%. Unfertilised eggs comprised over half of the unsuccessful eggs (5.5%), whereas unhatched-undeveloped eggs only accounted for 3.3% and yolkless eggs 0.4%. Twelve dead hatchlings were found in 9 nests. In total, 284 flatback hatchlings were found alive either at the top or the bottom of the nest, and 282 were weighed and measured. Flatback hatchlings mean weight was 33.6 g (SD=4.8, N=282, range: 22–49 g), mean ccl was 57.8 mm (SD=4.6, N=282, range: 42–70 mm) and mean ccw was 48.3 mm (SD=5.0, N=282, range: 31–60 mm).

Traditional harvest

Traditional owners of Cobourg greatly value the turtle for its cultural significance and its meat. Informal conversations with traditional owners and shell counts suggest that approximately 20 turtles and 20 nests are harvested per year. This approximation does not include harvest of turtle and eggs on Cobourg by Aboriginal people living on Crocker Island.

DISCUSSION

This paper presents some basic information on the use of Cobourg Peninsula and its surroundings by marine turtles for nesting and indicates that Cobourg Peninsula and nearby islands contains important nesting beaches for marine turtles.

Nest sites and relative nest densities

Aerial surveys show that nesting occurs on beaches located on Croker and neighboring islands, the northern coastline of Cobourg Peninsula, and on Greenhill and Morse islands south of the Peninsula. No nesting was identified on the southern Cobourg Peninsula mainland-beaches. Turtle track counts indicate that beaches on New Year, Oxley, Lawson, McCluer, and Grant islands (61%) and along the northern Cobourg Peninsula (19%) are important nesting locations. Within the Park, the northern beaches support more nesting than the southern beaches. Nesting densities (i.e. number of tracks per km beach) was not determined and therefore turtle track counts for an area might simply reflect the amount of beach that is available for nesting.

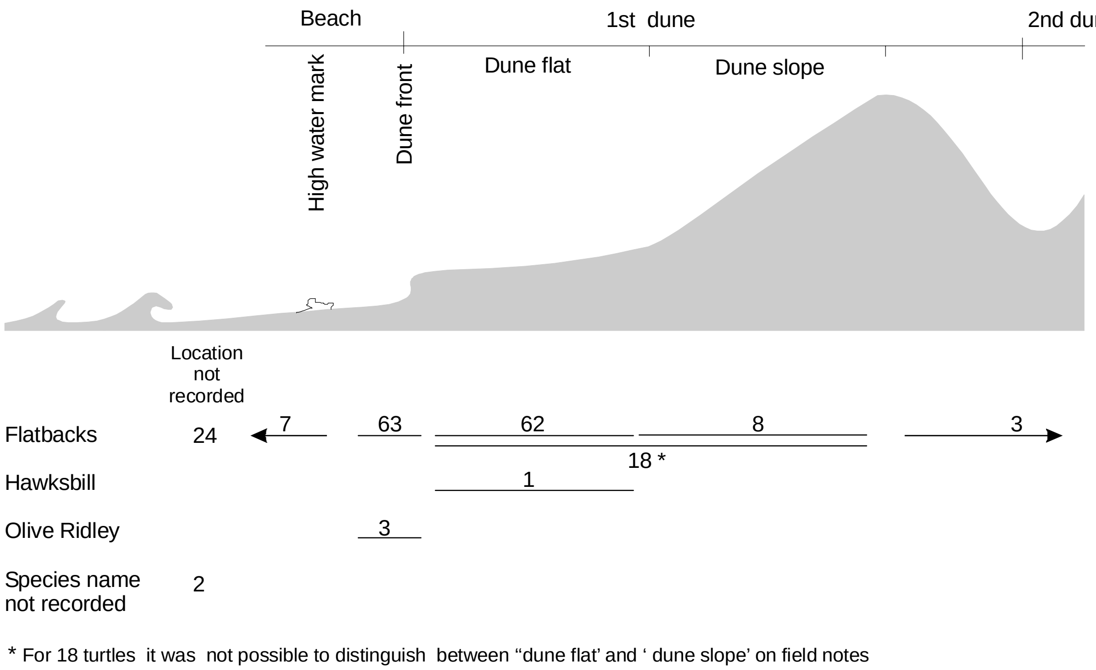

Figure 4 Nesting locations for species of turtles on Greenhill Island

Species nesting/use of habitat

Aerial surveys

Although species was not determined for these aerial surveys, Chatto (1998, this volume) mentions that Croker and neighboring islands are important for all species of marine turtles known to nest regularly on the NT coast (Chatto 1998, this volume).

Ground based surveys

The Greenhill Island tagging program clearly shows that the beach is mainly used by flatbacks, with the occasional olive ridley and hawksbill. The low numbers of tagged animals in 1995 may be attributed to the timing of the tagging program, which was conducted between 14–25 August and falls outside the peak nesting period determined by Guinea (1994b) for Fog Bay, which is in June–July.
Confirmation of species proved difficult for the Black Point and Smith Point survey, as the data were collected after the nesting had occurred. Positive confirmation can only take place if the turtle is caught while nesting or in some occasions the species can be deduced from track width, clutch size and egg size, or a combination of these characteristics.

Only 9 nests were positively assigned to species. Nevertheless, when examining the data available from the Greenhill tagging program and Black Point and Smith Point survey one can make some broad inferences. Figure 2 shows a bimodal distribution of track widths on the Black Point and Smith Point beaches: peaks are at 700–750 mm and 1000–1050 mm. Figure 3 indicates that few eggs found in nests on Black Point and Smith Point beaches have a diameter exceeding 45 mm. Greenhill Island data show that nesting flatbacks have a mean track width of 88.5 cm (SD=7.9, N=59, range 74.0–113.5 cm, 95% confidence limits 86.4–90.6) and a mean egg diameter is 49.3 mm (SD=2.0, N=806, range 41.5–61.0, 95% confidence limits 49.16–49.45).

This would suggest that there are no, or very few, flatbacks nesting on the Black Point and Smith Point beaches. In evaluating this suggestion it should, however, be recognised that the survey period at these sites was biased towards the green turtle nesting period. Of the nests that could be reliably assigned to species on Black Point and Smith Point beaches, those made by greens had an associated track width above 100 cm and egg diameters between 40 and 43 mm. Nests made by hawksbill or olive ridley were associated with track widths of 66–84 cm. Limpus (1971, 1995) reports mean egg diameters for greens, olive ridley and hawksbill as 44.1 mm, 38.8 mm and 35.3 mm respectively. The data presented here and in the literature would indicate that nesting at Black Point and Smith Point is dominated by greens, with a few olive ridleys or hawksbills.

Hawksbill and olive ridley nesting is negligible at Greenhill Island and low at Black Point and Smith Point. Numbers are too few to permit conclusions on preferred nest locations.

In summary, beaches around Black and Smith Points and islands along the northern coastline of the Peninsula have green turtles as the dominant nesting species with relatively smaller numbers of flatbacks, hawksbill and olive ridley. In contrast flatbacks nest predominantly on the islands south of the Peninsula with the occasional hawksbill and olive ridley. This implies little overlap in green and flatback nesting areas. Green turtles appear to prefer the oceanic beaches with a northerly aspect, whereas the flatbacks prefer more sheltered inshore island beaches. However, all conclusions from this study must be treated with some caution because full seasonal coverage was not achieved.

Breeding and feeding turtles

Nesting flatbacks characteristics, such as ccl, ccw, track-widths, clutch size etc, falls well within the range of measurements reported by Guinea (1994b) and Limpus (1971). Feeding green turtles were caught off the southern rock reefs by ‘turtle rodeo’ (figure 1c). Waters here are relatively deeper and more turbid than in eastern Australian sites where this technique is more commonly applied. However, the sporadic efforts produced some results. The ccl for tagged greens ranged between 485–990 mm. Although the total sample is small (N=10), there may be two size classes feeding on the reef: turtles smaller than 460 mm and larger than 700 mm, but invariably much smaller than females recorded nesting on the northern beaches (>1000 mm).

Nesting attempts

Determination of the number of visits to beaches which culminated in nest construction and laying by predominantly green turtles on Black Point and Smith Point proved difficult. For 24% of the nesting attempts either no data were recorded or outcomes could not be determined. Nonetheless, these indicate that at least 21% of visits to shore resulted in no nest, and the figure could be as high as 45%. No-nest visits by flatback turtles on Greenhill Island were a lower (10.5%) proportion of the total than at Smith Point and Black Point.

Nest success

Nest success (proportion of nests producing at least one hatchling) could not be determined for tagged flatbacks that nested at Greenhill Island. When the beach was revisited 10 weeks later, many of the marked nests could not be located and/or identified. The flagging tape used to mark nests was frequently disturbed by other nesting females, or was otherwise unusable in relocating marked nests. If nest success is to be determined in the future another method will have to be examined.

Hatch rates

Hatch rates within successful nests (presumed to be predominantly green turtles) for Black and Smith Points (88.5%) and Greenhill Island flatbacks (90.5–94.1%) are comparable with figures cited by Limpus (1971, 1995), at 83.6% for greens and 70–90% for flatbacks.

Breeding cycles

Renesting and remigration intervals for flatbacks on the southern Great Barrier Reef are respectively 13–16 days (range 10–23 days) and 2.7 years (range 1–5 yr) (Limpus 1995). The Greenhill Island tagging program having run for 11 to 24 days over three years, has understandably produced little information on these phenomena in northern waters. Nevertheless, data do suggest that there is a renesting intervals of approximately 15 days, which is comparable with renesting intervals found for flatbacks nesting at Fog Bay (Guinea, pers. comm.); and that flatbacks can remigrate in consecutive years.

Type of predators

At Black Point and Smith Point, 57.7% of nests were disturbed by predators, comparable to the 60% found by Guinea (1994b) for the Fog Bay area. Guinea attributed the 60% predation solely to goanna, whereas at Black Point and Smith Point it is attributed to goanna (40.5%), dingo (14.0%) and crab (3.2%).

During the tagging program on Greenhill no direct observations were made of predation by dingo and goanna on nests, though it has been observed that beach thick-knee feed on emerging hatchlings. Often a dense patch of beach thick-knee tracks can be used as a visual cue to indicate an area where a nest has recently hatched. No data have been collected to establish the level of predation on emerging hatchlings on Greenhill Island.

CONCLUSION

The studies of turtle nesting in the Cobourg Peninsula region reported here were designed as preliminaries to more coordinated and extensive studies funded in part by Environment Australia. A reassessment of priorities on the development of the National Heritage Trust resulted in withdrawal of funding and a cancellation of the major part of the program. Nonetheless, it has made a modest contribution to our understanding of regional patterns of nesting and habitat use. In addition to the information presented here, the tagging program at Greenhill Island provided other data such as egg sizes, egg chamber characteristics, morphological characteristics and weights for flatback hatchlings (not included in this paper), and nesting behaviour.

The Smith Point and Black Point survey provided information on the sources of predation losses and the proportion of nests raided. It also provided some methodological guidance by showing that assignment of species from track width, clutch size and egg diameter or a combination of these was problematic when relatively inexperienced observers attempt to apply these criteria.

Aerial surveys completed to date do not fully specify the locations of important nesting beaches in the Cobourg Peninsula region. Track numbers were recorded over long stretches of coast. Consequently, intensity of use cannot be calculated at a finer spatial scale, which might be desirable to identify (for example) readily accessible beaches that require special management attention. Because surveys were confined to the second half of the year the peak nesting periods also remain uncertain. Peak nesting periods at Black Point and Smith Point were not well established as the surveys were conducted irregularly, chiefly during periods of low Park visitation (wet season).

Although some useful information was gathered on rates of nest failure, understanding of egg loss to predators and harvest by humans is incomplete. Hatch rate data from Black Point and Smith Point beaches are entirely from disturbed (mostly partially predated) nests rather than those that were undisturbed.

In summary, the primary value of the current study is that it has provided a base from which to design more appropriate and achievable monitoring systems that provide information that can be used to reliably inform management prescriptions and monitor the outcomes of management actions, and has identified how park staff should be involved Park monitoring programs.

ACKNOWLEDGMENTS

Park staff at Cobourg Marine Park are greatly in debt to all people that have helped realise the current turtle research: Col Limpus for his expert advice before, during the set up of the Greenhill tagging program and supplying the tags and data sheets, Mick Guinea (NTU), Bob Prince (CALM), Department of Primary Industries and Fisheries (Fisheries Division), the army of volunteers that helped collect the data and kept us sane during the survey periods, ANCA/Kakadu rangers for their support during the tagging project and the Board and the traditional owners of Cobourg Peninsula for supporting the project.

The authors would like to thank Peter Whitehead for his critical reading of and comments on the manuscript.

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SUSTAINABLE HUNTING: IN SEARCH OF A SOLUTION

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ABSTRACT

This paper is a reflection of sustainable indigenous hunting of turtle and dugong by indigenous people within the Great Barrier Reef Marine Park, as seen by the indigenous Cultural Liaison Unit of the Great Barrier Reef Marine Park Authority (GBRMPA). Primary focus for discussion centres on the development of indigenous community-based management programs aimed at empowering communities for the management of resources within their traditional access area of the Great Barrier Reef Marine Park.

KEYWORDS: marine turtles, sustainable use, community-based management

INTRODUCTION

A system that is developed for the management of sustainable hunting of a critical resource must provide for adequate socio-economic security in order to achieve individual restraints from over hunting of that critical resource.

In general terms dugong and turtle fulfil varying needs, depending on how socially or economically isolated people are. Urban based use of dugong and turtle seem to be associated more with social and cultural events, whereas identified isolated Aboriginal communities' needs increase to an economic level of dependency upon resources simply because of limited access to basic provisions and services. However, this is not to say that people outside of these communities or people who are in urban settings do not hunt for economic reasons as well.

Social, cultural and economic values that indigenous people place upon resources such as dugong and turtle give strength to culture and demonstrate affiliation with tradition and traditional areas. However, these values also present a complex problem for the management of dugongs and turtles as resources.

Consequently, in relation to traditional hunting activities of dugong and turtle, there are a number of relevant factors which compound the issues of management and indigenous involvement. These factors are a result of the above mentioned values of indigenous people conflicting with conservation groups' calls to mitigate traditional hunting activities, applied pressure upon the resource from other sectors such as fishing, eg dugong and turtle getting caught in gill nets, and culturally inappropriate management programs of government.

Such a system must be compatible with the regional needs of individual communities, especially where communities have a socio-economic dependence upon the critical resource. GBRMPA is somewhat restricted in the area of providing communities with economic security. As a result GBRMPA is faced with the possibility of unbalancing the economic stability existing within communities by implementing constraints upon hunting through management or policy. Accordingly, indigenous communities' requirement of policies and mechanisms for the management for sustainable hunting need to be culturally appropriate, address the socio-economic impacts, maintain flexibility for the dynamics of indigenous society and, most importantly, be initiated, monitored and maintained by the communities themselves—empowering indigenous communities.

> Tragedy was said to result from individuals over-using resources, because without either private property or sufficient government protection there is no incentive to refrain from taking what someone else will take since no one is restrained. (Weiner 1991, 1)

Empowering indigenous people to develop solutions for addressing hunting is the key. Community empowered management regimes serve beneficial purposes such as giving recognition to communities and reinforcing self-determination, while the most effective results are direct benefits to the identified resource. These benefits include effective grass roots level management of the resource take and isolating the illegal hunting activities.

One such example of the type of effective management structure is Kuku Yalanji Marine Resource Committee. The Kuku Yalanji resource committee is a representative group of the traditional inhabitants which occupy the coastal hinterland of what is now know as Mossman (about 70 km north of Cairns). The primary purpose of the committee is to regulate the government permits issued for hunting of turtle within Kuku Yalanji traditional hunting area—permits which are administered by Queensland Department of Environment and GBRMPA (Britnell 1996). This process enables the community to monitor who receives permits. The committee meets on a regular basis depending on the season, but usually once or twice a month. Permit applications are assessed according to a set of criteria. The criteria vest control in the hands of the Kuku Yalanji via a management mechanism which is community driven. Not only do they regulate who can hunt, and when and where, their role also has had a major influence on illegal hunting and the education of the communities both indigenous and non-indigenous. An interesting component is that the Kuku Yalanji have stated strongly that no permits for the hunting of dugong be approved offshore from their traditional area. This is in response to the declining number of dugong in areas of the Great Barrier Reef Marine Park.

> The damage lies in the well intended efforts that wrongly assume the model to apply, and then assure that in fact it will, when it need never have been realised. (Weiner 1991, 1)

Other centres that have taken initiative specifically for dugong management within the GBRMPA area are indigenous communities at Mackay and Bowen where councils of elders have been established to regulate the permit system. However, they are not as defined as the Kuku Yalanji. The Durmbal Noolar Murree Corporation representing the people around the Shoalwater Bay region (which also happens to be an important dugong habitat) has taken the initiative to enter into a formal agreement to cease traditional hunting activities until the next survey is carried out and/or dugong numbers reach sustainable hunting levels. Each region has different traditions and cultural constraints, and mixed and diverse indigenous representative groups, issues and environmental concerns. Although the Kuku Yalanji model may not be duplicated anywhere else in the marine park area, the conservation of the turtle and dugong and the management of impacts represent the same collective goal of indigenous peoples.

This is evident through a program currently running called the Dugong Information and Education Strategy, Indigenous Communities. The program is a response to research findings that the numbers of dugong have declined by more than 50% (>80% in some local areas) overall in the southern Great Barrier Reef in the past five years. Under these circumstance there is pressure on indigenous people to cease traditional hunting activities. The program aims to educate indigenous people about the decline and to encourage involvement in management.

From Cooktown south, the GBRMPA has almost no option but to appeal to indigenous communities to stop hunting in order to protect the small populations of dugongs. Many communities have responded positively. However, it was made clear in all responses from communities, that if GBRMPA in its quest to reduce the level of mortality of dugong, does not deal equally with other impacts as intended for indigenous peoples, the consequences for dugong may be bleak.

Cooperative management between government and indigenous communities is appearing as a legitimate and perhaps the only effective management mechanism. Effective because as outlined in the Kuku Yalanji resource committee model it is controlled, monitored and enforced at a grass roots level. Government management agency enforcement can play an effective and productive part as a support but not necessarily as a solution. Prosecutions may only have limited effect on people and serve to slow an individual's activities, but will not address the dugong decline or help turtle research and management. While the merits of working with communities may effectively isolate individual offenders through a community monitored approach, the benefits of working with people far outweigh the difficulties associated with the 'big stick' approach. The benefits of working with the communities have already started to produce results in both Mackay and Mossman.

> Traditional and cultural experience and use rights of individuals are not a right to alienate or use resources in a way that is not assigned. (Weiner 1991, 1)

Often a situation like this presents individuals with an opportunity to make political statements about their rights or the impacts of commercial activities on the dugong and their habitats.

However, the education and information will help displace the levels of ignorance and complacency. The fact remains that for people to come up with a solution they first must know and understand the problem. The outcome of an education and information program will isolate the blatant and illegal hunters.

CONCLUSION

GBRMPA's approach to the management of hunting will govern the success of any management program. GBRMPA, also, must not be complacent in its dealings with indigenous peoples hunting activities.
In the areas of management practices and property rights (not an exclusive individual right but a common right), government actions are seen as trying to fix something that was not broken. However, what we should be recognising and strengthening are the already existing cultural and traditional practices.

The goals of GBRMPA and indigenous people are, in general terms, the same. It is the process to achieve the goals that is inconsistent. Although there have been changes in recent times, history indicates that 'blackman' lore has little credence as a base for research and management in a 'whiteman' management system.

To become established as effective management influences, community empowered management regimes need to have committed and skilled community members, while recognition, support and commitment from the government is crucial.

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Community Involvement in Managing Threatened Marine Turtles

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Abstract

Education, public awareness and community involvement are integral to achieving conservation of threatened species and ecological communities and sustainable use of natural resources, thereby maintaining Australia's rich biological diversity. Community networks are an excellent mechanism for facilitating good communication and coordinated action, especially at a grass roots level, in relation to particular species, environments and issues. Importantly, networks help to integrate diverse cultural and environmental considerations into recovery plans for threatened species.

KEYWORDS: education, community, awareness, involvement, networks, threatened species, recovery plans

INTRODUCTION

This paper emphasises the importance of community participation in preparing and implementing recovery plans for threatened species. It highlights the values of networks of community groups and individuals involved in conservation activities. Indeed, the turtle workshop brought together many key people involved in marine turtle research and management in Australia, providing an excellent basis for networking and, importantly, keeping up the enthusiasm through ongoing communication and cooperative action among participants. Moreover, the success of the recovery plans for marine turtles will reflect the degree of community participation and consultation during all stages of the recovery process.

DISCUSSION

The Endangered Species Program works cooperatively with State/Territory governments and other stakeholders to achieve conservation of threatened species and communities. The Commonwealth *Endangered Species Protection Act 1992* prescribes the process of preparing and implementing recovery plans as a key approach to securing the status in the wild of endangered and vulnerable species and endangered ecological communities.

Recovery teams are established for each species, or in some cases, groups of species, which have recovery plans in preparation or being implemented. These teams include specialist biologists and researchers, representatives from the relevant State/Territory conservation agencies, funding bodies and the Threatened Species and Communities Section (TSCS), significant natural resource managers (including local government) and a community representative.

Major responsibilities of the recovery team include preparing or updating the recovery plan, monitoring and assessing progress of each action, monitoring whether the recovery actions are consistent with the recovery plan objectives and revising these if necessary, commenting on drafts in progress and final reports, and assisting with press releases and other publicity. Ideally, the recovery team, through its community or other representatives, seeks input from, and provides feedback to, local communities throughout the recovery process.

Community networks are an excellent mechanism to facilitate good communication and coordination of recovery actions, especially at a grass roots level, about particular species, environments and issues. These may be formally established networks such as the Marine and Coastal Community Network, Threatened Species Network and Threatened Bird Network, or informal groups of interested individuals (Jelinek 1996, 16–17). On ground activities may include surveys and monitoring of species populations and habitat characteristics, revegetation, erosion control, fencing, feral animal and weed control, producing educational items or promoting conservation activities through the media.

Networks facilitate exchange of ideas and information such as research results, and promote local and traditional knowledge by establishing links between community groups, management organisations, industry groups and researchers. They encourage sharing of skills, resources, ownership and community support through carrying out and promoting management activities. Networks can also facilitate training volunteers about particular species, ecological communities or issues within a local, national and international context. Most importantly, networks help to integrate diverse cultural and environmental considerations, thereby developing trust, creating a team spirit among participants and promoting a long-term commitment to specific projects as well as the bigger picture of sustainable environmental management. *The Role of Networks* (Saunders et al. 1996) addresses these and a range of other issues and activities relating to community networks in conservation.

Many coastal indigenous and non-indigenous communities and community groups (eg Turtle Watch) are already actively involved in the management of marine turtles. In addition, large numbers of volunteers assist with turtle tagging and monitoring at organised venues like Mon Repos each turtle breeding season. Networking of these and other interested groups and individuals provides a valuable opportunity to assist and promote the preparation and implementation of recovery plans for the different species of marine turtles. Moreover, because most species of marine turtles migrate between countries, networking at a regional level is necessary to successfully implement cooperative international programs.

During 1995, the South Pacific Regional Environment Program (SPREP) implemented an extensive community awareness program about marine turtles. Australia's contribution included a detailed brochure and posters depicting marine turtle ecology from an Aboriginal perspective, with text in six indigenous languages and English. The Commonwealth's Endangered Species Program also funded representatives of Dhimurru Land Management Aboriginal Corporation, NT, to visit Mon Repos in Queensland to exchange information on turtle biology and management with scientists and local Aborigines, find out about turtles and ecotourism and, most importantly, to see the loggerhead (Garun) nesting. This was significant for Yolngu who until then believed that Garun laid its eggs underwater as they had never previously seen this species nesting on land. Video footage was taken of the Mon Repos visit and segments have since been used in Dhimurru's video on turtle management (DLMAC 1996) and the Endangered Species Program's Threatened Plants and Animals educational video (Jelinek 1996, 15).

The Year of the Sea Turtle project received widespread media interest and publicity throughout Australia and the Pacific region. The Maohi indigenous non-government organisation, Hiti Tau, held workshops on Mataiva; one of Polynesia's many remote islands, to identify key issues in relation to marine turtles and other local environmental, land rights and social issues. These workshops highlighted the importance of marine turtles to all aspects of Maohi culture and their aspirations for self determination. However, lack of a worldwide perspective on marine turtles, particularly migratory patterns, and the lack of information about and support for managing threats and local turtle populations, is of major concern to these people. Hiti Tau expressed great interest in exchanging knowledge about marine turtles with Australia's indigenous communities, obtaining information on sustainable traditional harvesting of turtle populations, undertaking cooperative training on turtle management and investigating opportunities to manage turtle populations through ecotourism activities which involve and benefit local communities.

Below are a few examples of recovery actions with a focus on community involvement, public awareness and education that could be considered in the recovery plans for marine turtles. Establishing a network of community groups and individuals actively involved in turtle management to liaise closely with the recovery team could be an effective way of successfully achieving these and other actions in the respective recovery plans.

- Facilitate community involvement in decision making and management through training, networking and communication activities. Examples of ways of achieving effective networking are:
  - organise field-based turtle workshops and training in different locations within Australia and the Indo-Pacific region;
  - include items in existing newsletters, or develop a special Turtle Network newsletter;
  - establish a special internet site that maintains current turtle research and management information, with links to other turtle sites;
  - establish a list server email discussion site and database of networkers.

- Share and disseminate traditional ecological knowledge and scientific information about marine turtles, migratory patterns and habitats to provide a framework for managing these species throughout Australia and the Indo-Pacific region.
- Focus community involvement to assist with coordinated monitoring of species populations and mortality, surveys of the species distribution, and carrying out habitat management and threat abatement activities.
- Complement turtle management activities with fulfilling traditional cultural responsibilities to 'looking after and care for country' and custodial responsibilities to Dreaming places.
- Adopt and promote approaches that ensure sustainable use of natural resources within a regional context through links with government and non-government organisations in the Indo-Pacific region.
- Ensure recovery actions reflect the strong relationship between indigenous peoples and the land and sea environments.
- Promote the ecological significance of turtles, aspects of turtle ecology, potential threats to the survival of turtles, the importance of particular habitats, and the cultural affiliation of Aborigines and Torres Strait Islanders with marine turtles, through local, national and international media items (newspaper press releases, magazine articles, TV and radio news or story items and special features on internet sites).
- Prepare multilingual educational materials about turtle management which reflect indigenous and non-indigenous perspectives, for example, local field guides, videos, brochures and portable displays.

CONCLUSION

Education, public awareness and community involvement are integral to the recovery of threatened species and sustainable use of natural resources necessary to maintain Australia's rich biological diversity. The recovery plans for marine turtles need to reflect community input and the cultural significance of marine turtles for indigenous peoples. In particular, greater public awareness, appreciation and support, through active involvement in decision making and implementing research and management actions, are essential outcomes of the recovery plans for marine turtles.

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The Dhimurru Miyapunu Project

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ABSTRACT

The Dhimurru Miyapunu (Sea Turtle) Project was established in the Gove region of north east Arnhem Land in 1995 in response to concerns from traditional owners about sea turtle numbers. Its broad aims are to gather data on sea turtle biology, distribution and abundance in the region as well as to quantify the indigenous harvest of eggs and turtles. This paper addresses the methods and results of the harvest monitoring program. Methods used to assess the harvest were ground surveys of selected beaches where eggs are regularly harvested, datasheets delivered to communities to record details of egg collection or turtle capture, regular monitoring of stock-piled turtle shells near hunting areas and interviews with hunters and traditional owners.

The datasheet method underestimated level of harvest of eggs and adults compared with other methods. Overall the harvest is predominantly of large adults, is female-biased and includes nesting females as well as turtles harpooned in the water. A preliminary estimate of the annual regional harvest is about 480 turtles but more data are needed. Eggs of all four species are collected and local collecting effort on some beaches can exceed 90%. However, data are inadequate to provide an estimate for the region and monitoring the egg harvest remains problematic.

KEYWORDS : indigenous harvest, Arnhem Land, marine turtles

INTRODUCTION

Efforts to conserve marine turtles in the Northern Territory are hampered by a lack of basic biological data, including baseline data on distribution and abundance. Australian populations are believed to be the most robust in the world but population declines in some Australian populations have been reported (Limpus 1995, Limpus & Reimer 1994). At present we have insufficient census data to determine the stability of NT populations and the identification and mapping of critical habitat is a high priority.

Of concern to both non-indigenous and indigenous Australians is the potential impact of indigenous harvests of turtles and eggs on marine turtle populations (Kennett et al. 1997, Kowarsky 1982). Currently, quantitative data on the size and extent of the harvest in the NT are limited and the issue of indigenous harvest must be viewed in the broader context of the many factors contributing to marine turtle mortality in the region. These include deaths in fisheries activities both within and outside Australian waters, destruction and modification of feeding and nesting habitat, entanglement of turtles in marine debris and the massive harvests of turtles and eggs throughout the Indo-Pacific region (Limpus & Miller 1993).

Six of the world's seven species of sea turtles occur in north-east Arnhem Land where they are collectively known as 'miyapunu' by the Yolngu, the traditional owners of the region. Miyapunu are an important natural and cultural resource to the Yolngu, who seek to manage their sea turtle populations to ensure the long-term sustainability of this resource (Kennett et al. 1997).

The Dhimurru Miyapunu (Sea Turtle) Project was established in the Gove region of north east Arnhem Land in March 1995 in response to concerns of traditional owners about turtle numbers. The project emphasises a 'two-way' approach to sea turtle research and management activities that emphasises the value of Yolngu traditional knowledge and practice while recognising that the adoption of modern scientific methods and techniques are essential. Generating community support and involvement in the project are primary considerations and this is reflected in the aims of the project and the activities undertaken so far (Kennett et al. 1997). The aims of the project are to:

- develop appropriate methodologies for recording traditional and contemporary Yolngu knowledge of sea turtle distribution, biology, utilisation and cultural significance:
- develop appropriate strategies for facilitating involvement of Yolngu in contemporary research and management;
- conduct field investigations of sea turtle distribution and biology;
- quantify the harvest of turtles and eggs by Yolngu;
- provide Yolngu with training and information about sea turtle biology and conservation issues and contemporary management of sea turtle resources;

The project is a collaborative effort between the traditional owners of the region (the Yolngu) and their resource management agency (Dhimurru Land Management Aboriginal Corporation), the Parks and Wildlife Commission NT and, most recently, the Northern Territory University. Field activities span coastal areas on the Gove Peninsula from Cape Wilberforce to Blue Mud Bay (fig 1).

This paper focuses on the harvest of adults and eggs by Yolngu and summarises methods and results to date. Other papers in this volume (N Munungurritj and D Yunupingu) provide details of other project activities.

METHODS

The following methods were employed to gather data on the size and composition of the harvest.

Oral interviews with hunters and traditional owners

Traditional owners and recognised turtle hunters were interviewed by Dhimurru personnel about the seasonality of hunting effort and the numbers and types of turtles hunted and eggs collected. Information was recorded during community visits by rangers, during field research activities involving Yolngu, and a community-based miyapunu workshop. Where possible information was checked against that collected under other monitoring activities outlined below.

Community-based monitoring using datasheets

A data recording kit was distributed to nine coastal communities in June 1995. The communities involved were Dhambaliya (Bremer Island), Bawaka, Miritjangay, Baniyala, Garrthalala, Dhalinybuy, Biranybirany, Dhaniya and Yirrkala (fig 1). The kit consisted of datasheets, pencils and erasers, a measuring tape, coloured flagging tape and plastic zip-lock bags to hold completed datasheets. The kit was developed in consultation with the communities and included a pamphlet written in English and Yolngu language that explained the purpose of the project and the sorts of questions the project was asking.

The datasheets were designed to be filled in each time a turtle was captured or eggs were collected and included information on the name of the hunter, month of capture, method of capture, sex and maturity of turtle, size of turtle and species of turtle. For eggs, the data included the date of collection, number of eggs in nest, species of turtle and a description of the tracks. On both egg and turtle datasheets, photographs of each turtle species with balanda (non-Aboriginal) and Yolngu names were provided and participants marked the correct photo. A map of the region was also included and hunters were asked to mark on the map the capture/collection location and write the Yolngu name for the locality.

Nesting beach surveys

Surveys of nesting beaches on a selected area of Cape Arnhem (Nanydjaka) were conducted. The aims were to examine the seasonal distribution of nesting activity, determine which species were nesting and whether or not the eggs had already been taken by egg collectors. Data on clutch and egg size were recorded opportunistically. Information on 4wd vehicle access, especially where vehicles were impacting on sea turtle nesting habitat, was also recorded. Surveys were conducted by driving a 4wd vehicle along beaches and the location of each nest was logged against the location determined from the vehicle odometer, a topographic map and/or information supplied by a Dhimurru ranger.

Species were identified by Yolngu rangers from tracks and, where possible, by examination of eggs.

Stock-piled turtle shells

The harvest of turtles was also monitored by counting turtle shells left on beaches. Sea turtles are often cooked in fires on a beach and the charred carapace is usually left near the fire. These cooking sites are often used on a regular basis and the shells accumulate. Hunters assist this monitoring program by stockpiling their shells in a central location within the community.

The Dhimurru Miyapunu Project

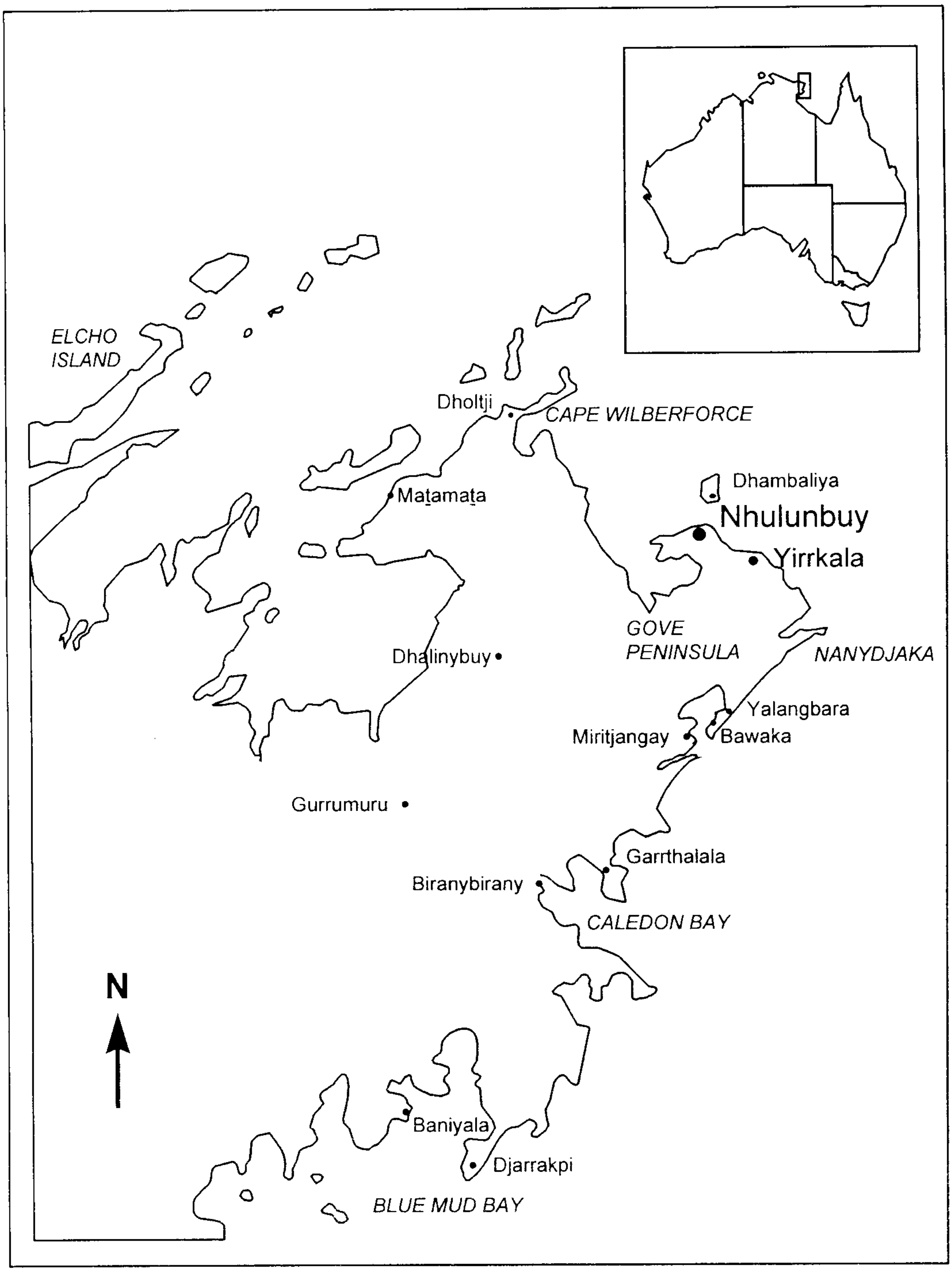

Figure 1 Map of Gove Peninsula and locations of coastal communities

Shell length (curved carapace length) is measured with a flexible cloth tape and shells are identified on the basis of shell characteristics. Harpooned turtles have a telltale hole or holes in the carapace caused by the harpoon point. Turtles without such holes are most likely to have been caught while nesting on the beach. Capture details, including the sex and date of capture, were confirmed when possible with hunters or other community members present at the time of the survey. Shells are marked or collected to avoid recounting on a later visit.

RESULTS AND DISCUSSION

The turtle (miyapunu) harvest

Size and composition

The datasheet method underestimated the number of turtles captured compared with data derived from measuring stockpiled shells (table 1, fig 2). Seventeen turtle capture datasheets spanning the period from July 1995 to August 1996 were returned from eight communities. In contrast, in September 1996, 47 shells were measured at four communities. These shells had accumulated since January 1996 at the earliest. It is possible that a small number of shells (<5) were recorded on datasheets then measured again in community visits. These shells were recorded from the same community (Bawaka) and were caught in the same period of months.

The harvest comprised 62 green turtles and 2 flatback turtles, with no other species recorded. The predominance of Green turtles reflects statements by Yolngu hunters that green turtles are the best eating and hence favoured target. Wakarratjpi, a senior custodian residing at Garrthalala, states that greens are the most common species caught and loggerheads are caught only about once every 2 years. Green turtles are the most common turtles hunted in most indigenous communities in Australia (Kowarsky 1982).

Table 1 Numbers and capture method of hunted turtles based on datasheet returns and stockpiled turtle shells at each of four coastal communities

Data source	Community	Number of nesting turtles	Number of harpooned turtles
Datasheets		6	12
Stockpiled shells	Bawaka	10	6
Stockpiled shells	Dhaniya	0	18
Stockpiled shells	Baniyala	0	9
Stockpiled shells	Garrthalala	2	1

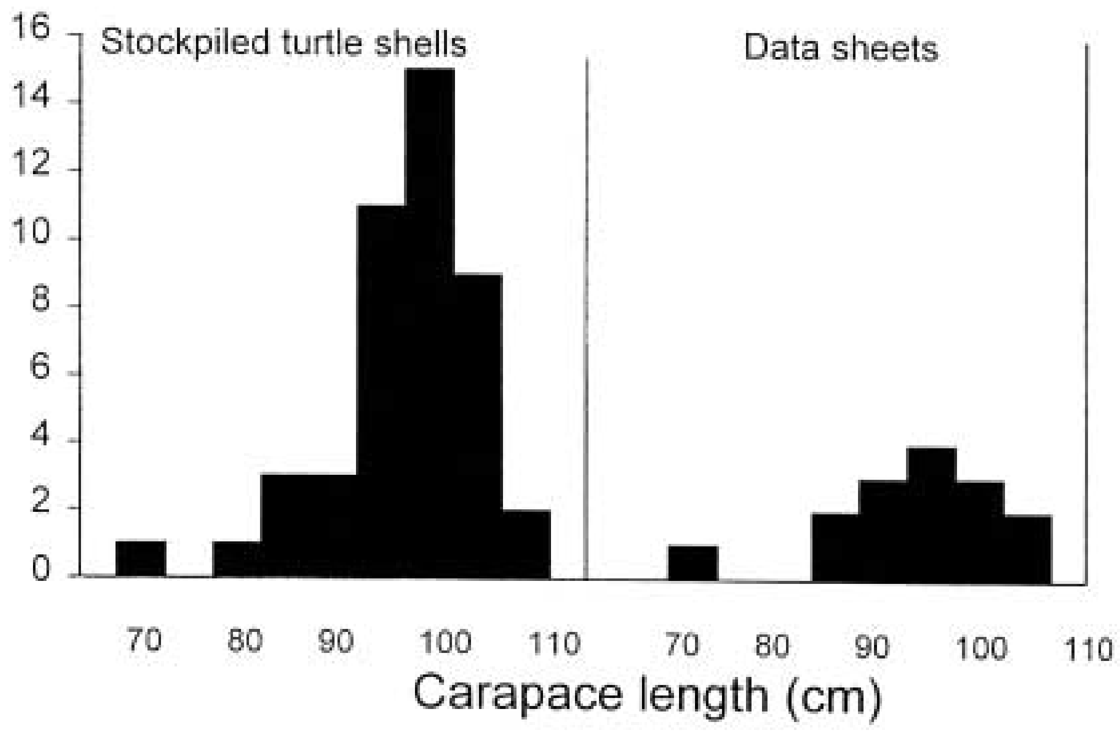

Figure 2 Size distribution of turtles hunted based on return of data sheets and on measurements of stockpiled shells

The two methods broadly agree on the size composition of the harvest (fig 2), with an overall size range of 67 to 111 cm with most turtles larger than 90 cm. Most turtles are likely to be mature adults because the size range of breeding females in Queensland is 91 to 124 cm, and males is 89.5 to 114.5 cm (Limpus 1993 & 1995). Both methods indicate more females than males are taken (datasheets 14F:3M; shells 15F:6M, chi-squared test for difference to an equal sex ratio, $p < 0.01$ and $p < 0.05$ respectively), although the sex ratio of the harvested population is unknown. The sex ratios for each method were not significantly different from each other (χ^2=0.8, $p > 0.1$). This apparent bias to females reflects the statements by Yolngu that females are preferred to males because they are larger, fatter and contain large numbers of ova (yellow eggs). When Yolngu are hunting turtles with a harpoon from a boat they may preferentially seek females. For example, 30 of the 42 turtles (71%) of known sex that were harpooned were females. The overall bias to females also reflects the large proportion of nesting turtles collected on the beach (table 1). This is a very easy way of collecting turtles when a nesting beach is accessible by vehicle and, of course, can only include females.

Not all communities take nesting turtles and this may be because access to nesting beaches is only possible by boat as in the case of Dhaniya, or that there are no nesting beaches nearby. Baniyala is located on the northern shores of Blue Mud Bay. Nesting activity on the shores near Baniyala is very low but the bay has extensive areas of turtle feeding grounds. No nesting turtles were captured at Baniyala (table 1).

Estimating the size of the regional turtle harvest

A preliminary estimate of the total harvest in the region can be made from counts of turtle shells and information from hunters. At Garrthalala, a traditional owner and a principal hunter estimates that about one turtle is caught per fortnight giving 25 to 30 per year (Nanikiya Munungurritj). At Dhaniya, 20 turtle shells accumulated over about 3 months hunting in miyapunu season. Miyapunu season refers to the best time to hunt turtles and corresponds with green turtle nesting activity. Assuming that this represents half of the miyapunu season (roughly July to December), then we estimate 40 turtles for the whole season and 20 turtles for the remainder of the year, giving 60 for the season.

At Bawaka, 20 shells accumulated over 9 months (January to September 1996), which roughly includes 3 months of miyapunu season and 6 months outside the season. Assuming that the estimated capture rate of 40 turtles in the season at Dhaniya is applicable to Bawaka (this is reasonable because the two communities are in close proximity, of similar size with close social links and hunt in the same area), then we estimate an additional 20 turtles for the remaining half of the miyapunu season giving 40 turtles caught for the year.

At Baniyala, hunters estimate 3 to 4 turtles per week, giving an annual take of 150 to 200. This far exceeds the take of other communities and is not supported by the number of turtle shells that were counted at Baniyala (nine total). However, there are a number of factors that make Baniyala different from other communities. It is the largest (100 residents), longest established and most permanent of the settlements. It is the furthest from Nhulunbuy and relies more heavily on bush foods than do the other communities. Baniyala is close to feeding grounds in Blue Mud Bay which probably support a relatively stable population of turtles and hence a reliable source of turtles throughout the year.

Other communities in areas where feeding grounds are smaller and where turtle abundances peak at nesting times when turtles congregate offshore, may have a more irregular supply of turtles. This is supported by statements of hunters at Bawaka and Dhaniya that they only catch about half as many turtles outside the Miyapunu season as in the season.

Based on an average of 60 turtles per year from the Dhaniya figures and that there are 8 permanent or semipermanent outstations where people regularly hunt turtles, then a preliminary estimate for the region is about 480 turtles per year. It must be noted that this is an extrapolation from an incomplete data set and must be regarded as a preliminary estimate only.

Implications and recommendations

It is not possible at this point to assess the impact of the harvest until we have more data on the size of the harvest and on the size of the harvested population. However, we can make a few points:

- The bias towards females, especially nesting turtles, is cause for concern. A harvest that targets breeding female turtles, hence the most 'valuable' members of the population in terms of its reproductive rate and ability to recover from harvest, will have a greater impact than a harvest that takes a random sample of turtles, where all size classes and both sexes have equal probability of being taken. Taking nesting females also reduces the reproductive effort of the population for that year. The consequences of taking a nesting female at the start of the season, when she potentially has another 5 to 6 clutches to lay are greater than if the females were taken at the end of the season. Raising awareness of the potential consequences of taking nesting females may be an appropriate management action by traditional owners and managers.

- The harvest includes predominantly adult turtles. Population models for sea turtles indicate that subadults and mature animals are most important to protect if a declining population is to recover. This reflected in the recommendation of Limpus (1995) that hunters should take turtles less than < 80 cm.
- The high proportion of green turtles in the harvest means that research on population dynamics of green turtles in the north east Arnhem region should be a priority in the context of understanding the potential impacts of the Yolngu harvest. Such a priority would be in keeping with research and management priorities regarding indigenous harvest identified by Limpus (1994). Equally important are additional data on the composition of the green turtle stocks in north-east Arnhem Land. For example, what proportion of the harvested stock are resident, i.e. feed and nest in the same region, what proportion remain in Australian waters and what proportion migrate to feeding or nesting grounds outside Australia? Such information is important in setting management priorities such as the scope of consultation with other turtle resource users that will be required to ensure the sustainable harvest of green turtles.
- Despite concerns about the level of harvest of adults in north east Arnhem Land, the data are insufficient to calculate quotas or devise regulations on turtle hunting by any management agency. Nor can the impact of other mortality factors such as fisheries activities or the harvest of turtles beyond Australian waters be quantified. Imposing regulations at this point in time will most likely generate understandable confusion and resentment amongst Aboriginal hunters and may seriously jeopardise the success of future research and management efforts involving Aboriginal communities. For example, the introduction of restrictions on hunting dugong and turtle on the east coast of Cape York Peninsula without proper consultation and based on inadequate information, generated considerable confusion and resentment amongst Aboriginal hunters and hampered research efforts in the region (Smith 1989). Similarly, statements to hunters by well-meaning ‘balanda’ about negative impacts of Aboriginal hunting on turtles may be interpreted by Yolngu as indicative of proposed balanda law.
- Turtles are a cultural resource as well as a subsistence resource. Continued access for harvest of turtles and eggs is likely to be an important component of cultural maintenance.

The egg (miyapunu mapu) harvest

A total of 45 nest datasheets were returned with the majority (91%) from nests collected within the Nanydjaka beach survey. Overall, the response to the egg harvest questionnaire was low (see below for a discussion) and the total of 45 nests almost certainly underestimates the egg harvest for both Nanydjaka and the entire region. Most datasheets relate to a period of the year when nesting activity by green turtles is low and hence the data almost certainly underestimate the importance of the green turtle egg harvest in the entire region.

The small sample size and limited geographic range of the survey limits data interpretation, however it is clear that Yolngu collect the eggs of all four species that nest in the region. Of 45 datasheets returned, 5 were for green turtles, 22 were flatbacks, 7 were olive ridleys and 11 were hawksbills. Loggerhead turtles do not nest in the region and leatherback turtles are extremely rare and their eggs are not collected. There is no evidence that Yolngu egg collectors show any preference for the eggs of a particular species, nor did Yolngu express any preference when questioned.

The results of the nesting beach surveys coupled with information from traditional owners indicate that there is regular visitation to Nanydjaka by Yolngu egg collectors and the rate of egg harvest is very high. In September and November 1995, 87% and 95% of nests were taken by egg collectors and eggs of all four species that nest at Nanydjaka were collected. These figures are based on two surveys of 11 km of beach.

This level of harvest at Nanydjaka is far in excess of the sustainable level of 70% of nests returning hatchlings to the sea suggested by Limpus (1995). Only 13% and 5% of nests were not taken by hunters and there are no data on the hatching success of these remaining nests. However, these data are ‘snapshots’ only and do not quantify the take as a proportion of eggs laid over an entire year. They also are derived from a small section of beach relative to the entire coastline of the study area. More frequent surveys of Nanydjaka and other representative areas need to be undertaken.

Given the obvious signs left by a nesting turtle, the skill of Yolngu hunters in locating nests and the eagerness with which eggs are sought, it is likely that similarly high levels of harvest also occur where there is regular vehicle access to nesting beaches.

Problems with monitoring the egg harvest

The overall response to the datasheet method was low with most sheets being completed by Dhimurru personnel on duty or during off-duty activities in the Nanydjaka area.

On several occasions Dhimurru rangers and I visited communities where eggs had recently been collected and were being consumed but for which datasheets had not been completed.

Eggs are usually collected at sites that are some distance from the community and often a proportion are consumed on the spot. On collection, eggs from many clutches may be stored for carrying in one container and on return to the community eggs are distributed amongst members, thereby mixing the clutches and making it difficult to fill in datasheets on return to the community. Egg collection is also done opportunistically so hunters often do not have the opportunity to prepare for data collecting by carrying datasheets with them. Unlike turtle shells, discarded eggshells do not last long enough to provide material evidence of egg collection activities. These reasons, coupled with the reasons for low response outlined above, mean that quantifying the egg harvest remains problematic.

ACKNOWLEDGMENTS

We thank the many Yolngu who assisted in the project and shared their knowledge of miyapunu. Without their help and input none of this research would have happened. Of especial note are the communities at Dhambaliya, Bawaka, Miritjangay, Baniyala, Garrthalala, Dhalinybuy, Biranybirany, Dhaniya, Yalangbara and Yirrkala. Thanks also to our Yolngu and Balanda colleagues at Dhimurru and the Nhulunbuy office of PWCNT for hosting visits by RK and making the project work. Financial support was provided by Environment Australia (Biodiversity Group), Parks and Wildlife Commission NT, Dhimurru Land Management Aboriginal Corporation, the North Australia Research Unit (Australian National University), the Northern Territory University and Nabalco Pty Ltd. NARU and NTU provided salary and office support for R Kennett.

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Cooperative Indigenous Community Management of Marine Turtles: a Case Study of the Arnavon Marine Conservation Area, Solomon Islands

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ABSTRACT

A case study of the development of the Arnavon Marine Conservation Area, which grew from recognition of the need to protect one of the largest hawksbill rookeries in the western Pacific. The paper documents the process and highlights the fact that successful marine turtle conservation in the Solomon Islands can only be achieved by co-operative community management by traditional owners and other resource users. It also highlights that development of successful community-based conservation areas and conservation strategies in Melanesia requires considerable time for consensus building, and effective input to co-operative management.

KEYWORDS: Arnavon Marine Conservation Area, Solomon Islands, hawksbill turtles, green turtles, marine resources, co-operative indigenous community management

INTRODUCTION

The nation of Solomon Islands lies to the west of Papua New Guinea, and east of Vanuatu (fig 1). The Australian mainland lies 1600 km to the south west.

The Solomon Islands population (around 380 000) is predominantly Melanesian (94.2%), with 3.7% Polynesian, 1.4% Micronesian (mostly Gilbertese resettled by the former British administration from Kiribati) and the remaining 0.7% of Chinese or Caucasian descent (SIG 1989). Much of the population lives in rural areas in small settlements and villages along the coastal fringe. The majority of people engage in a traditional subsistence lifestyle heavily reliant on slash and burn agriculture, wild food collecting and fishing. Solomon Islanders' reliance on marine resources is reflected by one of the highest per capita seafood consumption in the world. The annual subsistence fisheries catch (including marine turtles) is probably in the order of 10 000 tons/year (Skewes 1990). Fisheries also provides a source of income for many coastal dwellers. Due to the isolated nature of communities and irregular shipping services many communities relied previously on income from storable marine products such as trochus, beche-de-mer, blacklip and goldlip oyster shell and until 1993, hawksbill turtle shell (bekko). Between 1983 and 1990 over 18,650 kg of bekko was exported from Solomon Islands (Leary 1993). In 1990, Solomon Islands was the second largest exporter of bekko to Japan (Canin 1991). During that year, 56% of turtle shell exported for which the origin of capture was known came from the vicinity of the Arnavon Islands (Leary 1993). It is estimated that roughly 1300 turtles were killed commercially in this area alone. It was also estimated that as much as 50% of the eggs from the nests on the islands might have been harvested by local communities for food.

From 1973 to 1982, the Fisheries Division of the then Ministry of Natural Resources undertook an extensive turtle research/survey project throughout Solomon Islands and found the Arnavon Island Group to be by far the most significant rookery. Vaughan (1981) gave an annual estimate of 560 hawksbill and 45 green turtle nests per year for this group. This made the Arnavon Group one of the most important hawksbill rookeries in the world (low-density nesting being the norm for hawksbills). Only the Seychelles, with over 600 nests per year (Marquez 1990), has more.

THE ARNAVON ISLANDS—TRADITIONAL LAND OWNERS AND RESOURCE USERS

The Arnavon Island Group lies in the Manning Straits, and stretches from 7°24'S to 7°30'S at approximately 158°E. The Group is approximately equidistant from the north-western tip of Isabel and the eastern end of Choiseul (fig 1). It is composed of three main islands (Kerehikapa, Sikopo and Maleivona or Arnavon Island) and 9 smaller islands, coral atolls and sandbars. The total area of the Group is only 2.89 km^2.

The ownership of the Arnavon Islands is a complex question. The British Colonial administration of the then British Protectorate of Solomon Islands alienated this land and registered it as government land, considering it to be 'uninhabited and with no traditional landowners'. Most of Solomon Islands, on the other hand, remains under or was returned to customary traditional ownership at the time of independence in 1978. The traditional ownership of this land is still disputed by two different tribes, the Volikana tribe of southern Choiseul (the majority of whom reside about 85 km from the island group in the vicinity of Posarae village) and the Sinagi tribe (the majority of whom reside in the vicinity of Kia village on (Santa) Isabel Island about 48 km from the islands). The land, however, remains as government registered land.

The Sinagi people visited the islands to fish, harvest megapode eggs, and dive for trochus shells. At times of feasts or church celebrations they also used to dive for and catch nesting turtles. As many as 20 hawksbill turtles would be harvested for feasts or special occasions (Leary & Biliki 1993). The Volikana, on the other hand, are now Seventh Day Adventists and did not catch turtles in the area because of religious taboos on eating them. They did, however, collect turtle eggs and fish in this area. All members of both the Volikana and the Sinagi tribes have access or usage rights to the islands which are governed by their own two different sets of traditional law, but the Chiefs of either tribe may place restrictions on harvesting species or visiting the islands. In customary law, access to land or reefs by non-landowners requires permission from the tribal Chief. For both these tribes, the waters around the Arnavon Islands only represents a small proportion of their traditional 'sea country'.

A third group of people—not traditional landowners—was the primary resource user of the area. This is a large Gilbertese community resettled by the British Colonial administration from the Gilbert and Ellis Islands (now Kiribati) in the late 1960s. This community lives approximately 26 km away on the island of Waghena. The Gilbertese community visited the islands regularly and harvested turtles for both subsistence and commercial sale of bekko, as well as other sedentary marine resources such as trochus and beche-de-mer.

PAST MISTAKES

A wildlife sanctuary was established in 1979 over the Arnarvon Islands by an international conservation group working with Isabel Provincial Government in recognition of the significance of the Arnavon rookery, but as a result of a dispute with customary land owners, the project facilities were burnt to the ground, and the project was abandoned in 1982.

The Wildlife Sanctuary was established without informing or involving the landowners or nearby communities, and this was a major factor in its subsequent failure. Other factors which contributed to the failure of the project were:

- failure to recognise traditional landowners rights to the island group;
- failure to consult landowners and nearby communities in the formulation of the ordinance legally establishing the sanctuary;
- development of inappropriate restrictions and legislation which failed to take into account customary usage rights and the Solomon Island lifestyle;
- failure to inform and involve local communities adequately in the activities of the project.

The legislation for the Arnavon Wildlife Sanctuary protected all resources on the islands, and even prevented landing and camping on the islands in the case of bad weather and rough seas. The legislation did not take into consideration traditional owners, and in fact the Volikana were not even consulted or informed when it passed into law. The underlying reason for the failure of the sanctuary was lack of involvement of the traditional owners which resulted in it being seen as a set of government rules imposed without regard for the traditional landowners' interests.

DEVELOPMENT OF A COMMUNITY CONSERVATION AREA PROPOSAL

Despite an ever increasing hawksbill turtle shell (bekko) export trade after the abandonment of the Arnavon Wildlife Sanctuary in 1982, no further monitoring of the turtle population was carried out until 1989 when the Environment and Conservation Division and Fisheries Division undertook a survey of turtle nesting beaches in Isabel Province.

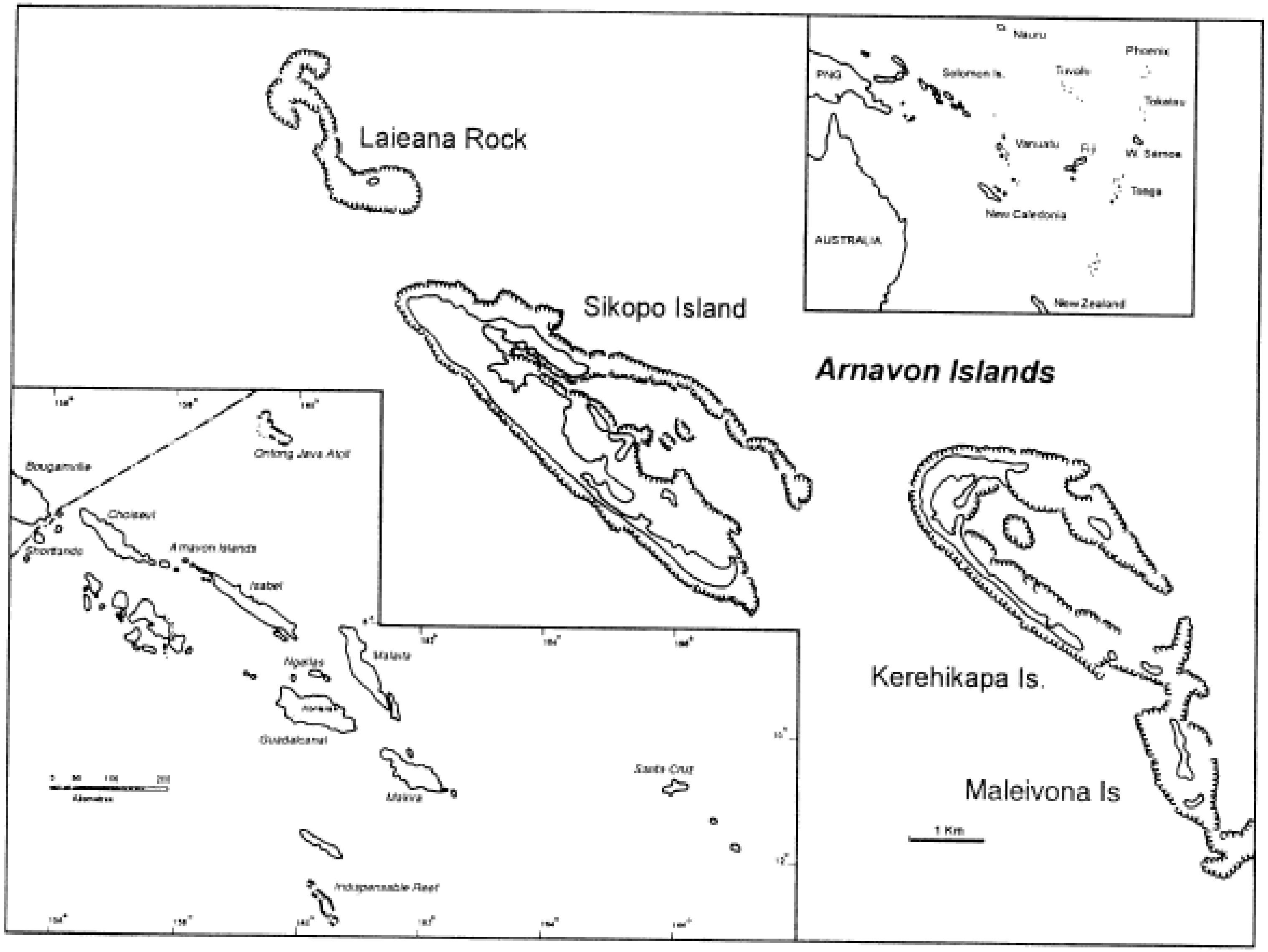

Figure 1 Location of the Arnavon Islands, Solomon Islands

Qualitative data collected through systematic interviews with local residents (Leary & Laumani 1989, Leary 1990) indicated a decline in the number of hawksbills nesting in Isabel Province compared with Vaughan's data (Vaughan 1981). The most notable decline was for the Arnavon Islands, where local landowners estimated only 120 to 200 clutches were laid per year (Leary & Laumani 1989). Landowners attributed the decline to the high harvest level for the bekko trade and to loss of suitable nesting beach from storm surge wave action and particularly from cyclone Namu in 1986.

Serious concerns were expressed about the decline of the hawksbill turtle population by both landowners and government officials. This led the then Ministry of Natural Resources (now the Ministry of Forests, Environment and Conservation) to seek further funding for a turtle tagging and nest monitoring program through the Regional Marine Turtle Conservation Program of the South Pacific Regional Environment Program (SPREP), to obtain more quantitative data on the nesting turtle population.

Nest monitoring of the Arnavon Group during three months of the peak breeding season in 1991 suggested a serious decline in the nesting population with only 11 turtles tagged. The 1992 results, however, suggested that this decline was not as serious as first thought (27 turtles tagged). During both these surveys landowners from both Kia and Posarae were involved in the tagging, and much awareness activity was undertaken with the communities. Posters, T-shirts and information leaflets were also produced.

Landowners and government saw an urgent need for the establishment of some kind of conservation status over the Arnavon Group if this important nesting rookery was to be maintained. Initially the motivation of the two landowning groups may have been merely to keep the Waghena community out of the islands, and to prevent them from depleting what they saw as their resources. Nonetheless, this concern led to a proposal for the establishment of the Arnavon Marine Conservation Area by the Environment and Conservation Division (ECD) in 1991. The ECD sought assistance from The Nature Conservancy (TNC) to implement this project. TNC opened its Solomon Island Program Office in August 1992. Since then it has been working co-operatively with the ECD, traditional owners and other local communities to implement this project.

Local communities initially participated in the turtle program by returning tags of turtles killed for food or turtle shell. By the end of 1992 when a third of the tagged turtles were known to have been killed, most of them being captured just off the islands by Waghena fishermen, it was obvious that the Waghena community needed to be involved in the turtle project in a more substantial way, even though there was initial resistance to this notion by both the Volikana and Sinagi tribes.

In recognition of traditional ownership claims (unacknowledged by government) and in light of the failure of the Arnavon Wildlife Sanctuary, the guiding philosophy of the project became the involvement of traditional resource owners and other local communities and resource users. This has been achieved and will be maintained through traditional owner and community involvement in all project activities. This includes the gathering, sharing and assessment of all information, the preparation and approval of a plan of management, the training of personnel for the 'hands on' management and monitoring (both biological and socio-economic), and the implementation of the management of the conservation area by local communities.

CONSULTATIONS AND BIOLOGICAL SURVEY

Extensive community consultations and awareness activities revealed local community concern that other resources may have been seriously depleted. Landowners expressed concern that no sedentary marine resources or turtles would be left for their children and that the megapode population would be exterminated by overharvesting. The landowners requested an ecological survey of the area to assess the status of the resources and to identify and provide advice on the management of the resources.

The survey team included a marine ecologist, two fisheries biologists, a botanist, a terrestrial vertebrate ecologist, and two landowner representatives from each of the three communities. The survey found that sedentary marine resources had been over-harvested. Trochus populations, blacklip pearl shell, goldlip pearl shell and beche-de-mer (sea cucumber, particularly 'white teatfish') had all been seriously depleted by commercial exploitation (Leary 1993). Eggs of the incubator bird (*Megapodius eremita*) also appear to have been overharvested.

The survey results were analysed and then discussed at community workshops. A local drama or 'akson' group, 'Isi', performed humorous plays about the plight of the turtles and the marine resources of the Arnavon Islands. They also undertook awareness performances about turtle biology and sustainable marine resource management. Household surveys were conducted around the same time to ensure that all stakeholders were informed and to make a better assessment of the communities' use of resources and the potential socio-economic impacts of development of a conservation area (Leary & Mahanty 1993). The consultation process found that most of the communities were extremely receptive to the development of the conservation area, but wanted to ensure that they had a controlling voice on whatever rules were to be established and the day-to-day management of the conservation area.

MANAGEMENT STRUCTURE AND RULES OF THE CONSERVATION AREA

A steering committee was established late in 1993, and subsequently became the Arnavon Marine Conservation Area (AMCA) Management Committee. It was composed of two representatives from each community who were elected for a three-year term by the communities. In 1997, at the time of writing, the representatives were Chief Leslie Miki and Mr Nelson Bako from Kia, Mr Rence Zama and Mr Elijah Pita from Posarae, and Mr John Rabaua and Mr Bwereti Eribati from Waghena. In addition, the committee has a representative from each of Isabel and Choiseul Provincial Fisheries Divisions, the Ministry of Forests, Environment and Conservation, the Ministry of Agriculture and Fisheries, and TNC.

The AMCA Management Committee meets four times a year (one meeting in each of the communities and a fourth at the AMCA Field Station). After the meetings the community representatives provide feedback to their community and also bring community issues or concerns to the next Management Committee meeting.

The AMCA Management Committee was instrumental in developing AMCA's rules and its plan of management, and overseas the day-to-day running of the project. The rules and the plan of management were developed through a process of consensus building, the community representatives undertaking extensive community consultations before a set of rules was agreed upon. There were some differences of opinion between communities about the rules and initially old group rivalries led to suspicion about the commitment of others. However, through a process of 'customary negotiations' and dispute settlement, a consensus was finally reached. This process took almost two years. The traditional landowning groups saw the process as a means of legitimising their involvement (in the eyes of the government) in the management of what they still see as their land and 'sea country'. They also saw it as a means of ensuring, through protection of the main nesting beach in the area, that they and future generations of their children would still be able to eat hawksbill and green turtles, although they would no longer catch them near the Arnavon Islands.

The management rules came into force in 1995 (although not legally gazetted until late 1996) and will be reviewed in 1998. Currently they are as follows:

1. Closure to the commercial and subsistence harvest of all marine turtles inside the 82.7 km^2 Arnavon Marine Conservation Area.
2. Marine invertebrates including beche-de-mer, trochus, blacklip, goldlip, green snail and giant clams closed to harvesting for three years to allow stocks to recover. (After 3 years, the monitoring program of these resources, conducted by the conservation officers from each community and scientists, will reassess the status of the stocks and the results will be presented to the Management Committee and the communities. If stocks have recovered sufficiently, the area will be opened to limited harvesting which may include a management regime of alternative years or areas of open and closed access.)
3. A six month closed season on megapode egg harvest from January through June each year. There is a complete ban on the killing of megapode birds within the conservation area.
4. A ban on the use of scuba and hookah gear for the harvest of any marine resources in the area.
5. Line fishing for reef fish is permitted for subsistence use. All commercial fishing, net fishing and any other methods are banned for the harvest of these resources throughout the conservation area.
6. Commercial shark fishing is not permitted. Subsistence shark fishing is allowed but is limited to 2 sharks per canoe per visit to the area.
7. Visitors arriving on the island group must notify the resident conservation officers. Camping is not permitted on the islands. Visitors must stay in the guesthouse adjacent to the field station.
8. Subsistence use of all other resources while visiting the islands is allowed, but resources can not be taken away. Commercial use of all resources throughout the entire conservation area is banned unless specified in the management rules.
9. There is a complete ban on hunting and killing of pigeons for any purpose within the conservation area.
10. There is a complete ban on the cutting of live vegetation from the conservation area.
11. There is a complete ban on the harvesting of milk fish from the lagoon areas.

The Arnavon Marine Conservation Area was finally officially opened in August 1995 with the above rules gazetted under the Isabel Province Conservation Areas Ordinance and the Isabel Province Marine and Freshwater Ordinance late in 1996. Under the Solomon Islands constitution, ownership of plants and animals is not vested in the crown as it is in Australia, but in the traditional owners. The ordinances empower landowners to make rules regarding the management and protection of their resources. The rules that they make have the backing of the legal system, and fines and imprisonment may be imposed for breaches of the rules. Solomon Islands does not yet have national conservation or protected areas legislation. These Isabel Provincial ordinances were an innovative step by the Isabel Provincial Assembly to recognise traditional landowners' desire to sustainably manage and protect their resources from both outsiders and from over-exploitation by their own people, particularly where traditional authority and 'tambus' (traditional laws or restrictions) are breaking down. The ordinances may be used to reinforce customary (traditional) laws by giving them legal status, or to create new rules for the sustainable management of resources or for the total protection of areas.

The successful establishment of the first Marine Conservation Area in Solomon Islands took seven years from initial discussions by the first author in 1989 with local communities to the gazettal of the rules. Perhaps the most outstanding lesson from this process was the need to allow adequate time for the local communities to gain a sense of ownership of the project and to become true partners in the Marine Conservation Area. The continuing success of the AMCA depends on continuing community ownership of the project.

DAY TO DAY OPERATIONS OF THE CONSERVATION AREA

Due to the isolated nature of the Arnarvon Group, all three communities felt that it was necessary to have a presence on the islands to enforce the rules, and also to continue monitoring nesting turtles and other resources. A field station has been established on Kerehikapa Island in the Arnavon Group. The field station includes accommodation for three staff and a guesthouse for visitors (traditional owners, tourists and visiting researchers), and is built largely from local bush materials (collected away from the Arnavon Group). Each community selected two conservation officers to work for the Arnavon Marine Conservation Area. The conservation officers work in groups of three (one from each community) and work a rotation of one month on the islands and one month off.

During their off-island time, they work within their own communities to raise awareness about turtles and turtle conservation, sustainable marine resource management and ACMA's activities, and to further develop a sense of ownership of the Conservation Area by the three communities. They also collect information on traditional harvest of turtles and eggs away from the island group. A newsletter is also in the process of being produced which will go to the community schools, church groups, local councils, and women and youth groups in all three villages.

During the conservation officers' time on the islands they undertake a monitoring and tagging program of turtles and turtle nest monitoring, monitor other marine resources, monitor sand migration, conduct vegetation surveys, monitor megapode nesting behavior and activity, assist visiting researchers, patrol the islands to deter poachers and keep a daily record of all their activities. They receive extensive training ranging from outboard motor maintenance to scuba diving and marine resource monitoring techniques.

The number of turtles successfully nesting on the islands seems to be increasing, probably because turtles are no longer intercepted close to the nesting beach by hunters. The full effects of the harvesting pre-1993 probably will not be felt for some years. There are still occasional poaching incidents on the island and some turtles are still being intercepted after they leave the AMCA, but the number appears to be lessening as awareness of turtle conservation grows, and community ownership of the Arnavon Marine Conservation Area strengthens.

One concern which has been expressed is that a large proportion of the turtles nesting are untagged (and therefore likely to be first time nesters at that island) and that there have been few tagged turtles re-nesting between seasons. It appears that even wider control of hawksbill turtle hunting outside of the conservation area (perhaps even a complete ban on hawksbill hunting in the Solomon Islands, which would be extremely difficult to enforce) may be necessary if this rookery is to survive in the long term.

FISHERIES CENTRES

A recent extension to the AMCA project has been the establishment of Fisheries Centres to purchase deepwater fin-fish in Sire (Posarae) and Waghena through funding provided by the Biodiversity Conservation Network program. (Kia's Fishery Centre had been recently rebuilt under EC funding.) The proposal to develop Fisheries Centres arose out of the recognition that conservation objectives can be best achieved when community needs are being adequately met. The Fisheries Centres provide all three communities with the opportunity to earn income from sustainable fisheries operations which are linked to the conservation initiative.

The Fisheries Centres include ice-making machines, water tanks, eskies and 4 wooden fishing boats and outboard motors. Fishermen training sessions have been run in each of the communities. The Centres have been operating and buying fish since December 1996. Monthly purchase of fish for each Centre is currently 2 to 3 tons from Sire and 4.5 tons from

Waghena. A 10% royalty is paid out of the profits from the Centres towards financing the operations of the AMCA. Other avenues of raising revenue to allow the AMCA to be self-funding are still being explored. It is hoped that eventually the AMCA will be totally self-supporting and not dependent on donor or government funding.

CONCLUSION

The road to the establishment of the Arnavon Marine Conservation Area has been a long and not always easy one. There has been a tendency for the communities to blame each other for any problems or failings, or breaking of management rules, but as John Rabaua (a Management Committee representative from Waghena) pointed out, '[it] is individuals that do these things and not communities'. Through this project, the ties and trust between the three communities have strengthened, and it is evident that with time and patience three communities of totally different culture and language can work co-operatively to sustainably manage turtles and marine resources.

AMCA's progress is an achievement of which the communities are justifiably proud, and this is evident from the Arnavon Marine Conservation Area logo that includes symbols depicting each community's culture inside a hawksbill turtle.

ACKNOWLEDGMENTS

Funding for the AMCA is gratefully acknowledged and has come from a variety of sources. Major donors include MacArthur Foundation, South Pacific Regional Marine Turtle Conservation Program (SPRMTCP) through the South Pacific Regional Environment Program (SPREP), South Pacific Biodiversity Conservation Program (SPBCP), JUSCO, a Japanese toy manufacturer, Embassy of Japan in the Solomon Islands, Canon Equipment, Keidanren Nature Conservation Fund and the Biodiversity Conservation Network.

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Nhaltjan Nguli Miwatj Yolngu Djäka Miyapunuwu: Sea Turtle Conservation and the Yolngu People of East Arnhem Land

Nanikiya Munungurritj

Dhimurru Land Management Aboriginal Corporation
PO Box 1551, Nhulunbuy, NT 0881

As you can see, Dhimurru Land Management Aboriginal Corporation works within the area of northeast Arnhem Land (see fig 1 in Kennett, this vol).

We have got quite a big area where we monitor turtles. Around from Nhulunbuy right across to Baniyala. This is the main area where Rod Kennett and I have travelled, talking to people from various outstations.

One particular area that we monitor very closely in our turtle research is Cape Arnhem. This area has been used by non-Aboriginal people and Aboriginal people as well, using car tracks where our turtles come up and lay eggs. It is a really unique area that we want to maintain. And what we want to do in the long run is look after all our turtles, along with the help of Parks and Wildlife. Also we get a bit of help from Nabalco and the help of the communities along the coastline (plate 1).

What Dhimurru has said, in the background of Dhimurru, is to work very closely with Parks and Wildlife, and with traditional Aboriginal people who live along the coastline. Most of our outstations are along the coastline, which myself, old man Djalalingba and Rod Kennett have travelled, talking to various people. What we want to do is look after these turtles. Not just for the benefit of us, this time, but for our children's children. Turtle is an important food for Aboriginal people. Most balanda (non-Aboriginal) scientists, along with the traditional owners of this land, could learn and work in relationships together.

This time now, it's a breeding season and turtles are coming in from various areas. Where they migrate from we don't know. But through working with Dr Rod Kennett we have learnt something that Aboriginal people never learnt in the past.

That's a loggerhead down at Mon Repos, where old Djalalingba and a couple of our Rangers went (plates 2 & 3). In the past we heard that loggerheads lay eggs under the sea. That is the story that the old people told us. But now, since Djalalingba and the other rangers went to Mon Repos, they have found out something that the Aboriginal people didn't know about: where the loggerheads go down to Queensland to lay eggs.

There are six species of these turtles that Aboriginal people, Yolngu people, have given names. And all these, miyapunu, we call them, they have got different names.

That green turtle is called *dhalwatpu*. But when we cut all this *miyapunu*, every bit of him in the meat, they've got various names. Sometimes our clans and our groups sing all these turtles. That is why it is really important for us to learn all these things. The Aboriginal people have already known all these things in the past and as it passes through generation after generation. That's why we want all the people, people like old Joe Djalalingba, to sit around with us and tell us all these stories. So that we can have all that information to pass onto the next generation.

I want to carry on with all the names and the details of the particular turtles, because we give them maybe three or four names. I will just give you the common ones. The other turtles are *garun*, the loggerhead turtle, *yimurra* or *garriwa*, the flatback turtle, *Wurrumbili*, that's the leatherback which we don't see much around here but I think they breed around the other areas of the Pacific. Some of the old people, they call it *wurrumbili* and they call it a friend of the whale, because this is the biggest turtle. And there is *muduthu*, the olive ridley turtle.

On the outstations, we get the school children involved with doing the information sheets (see datasheet, fig 1).

I.D NUMBER ________________

DHIMURRU - CCNT MARINE TURTLE RESEARCH PROJECT

INFORMATION SHEET - MIYAPUNU

COMMUNITY

WHO CAUGHT THE TURTLE?

WHEN WAS THE TURTLE CAUGHT?

CIRCLE THE MONTH

JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY

AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

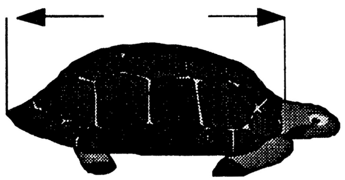
HOW WAS THE TURTLE CAUGHT?

IS THE TURTLE MALE OR FEMALE?

CIRCLE ONE

DARRAMU MIYALK YUTA YAKA MARNGI

HOW BIG IS THE TURTLE?



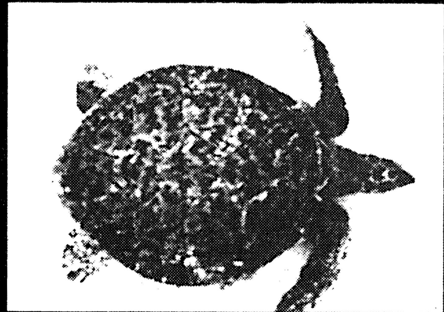
COLLECT THE TURTLE HEAD

TAKE THE PLASTIC TAPE OFF THIS SHEET AND TIE IT TO THE TURTLE HEAD. PUT IT IN THE PLASTIC BAG.

GIVE THE TURTLE HEAD AND INFORMATION SHEET TO LAYNHA AIR

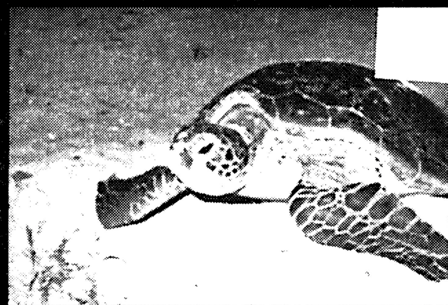

Wurrumbili - Leatherback Turtle


Muduthu - Olive Ridley Turtle


Guwarrtji - Hawksbill Turtle


Garun - Loggerhead Turtle


Garriwa - Flatback Turtle


Dhalwatpu - Green Turtle

WHERE DID YOU CATCH THE TURTLE? PUT AN 'X' ON THE MAP TO SHOW WHERE YOU CAUGHT THE TURTLE. WUKIRRI YOLNGU WÄNGA YÄKU

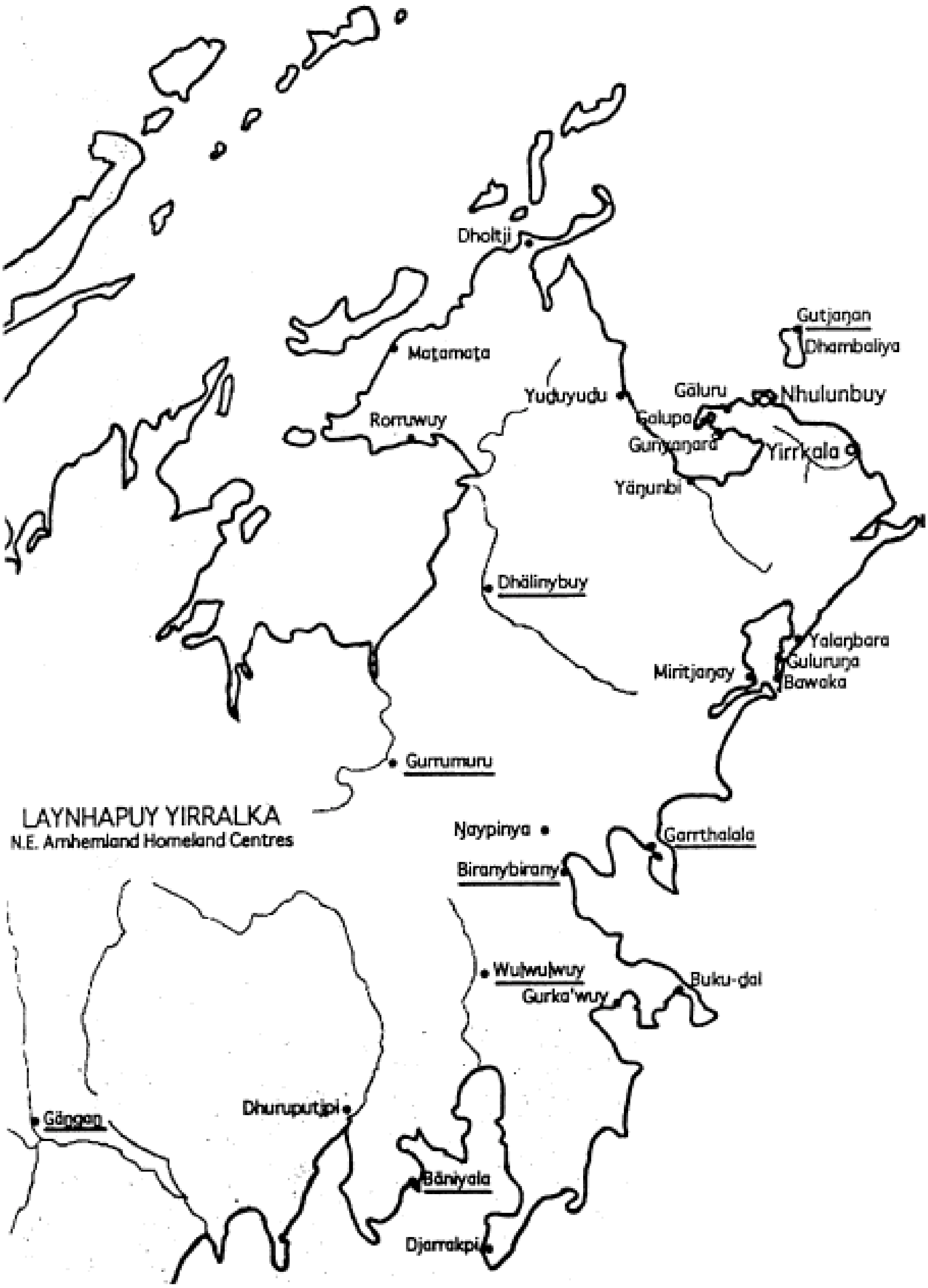


Plate 1 Rangers from Dhimurru vehicle and Parks and Wildlife Commission NT work closely together. Here they are conducting a beach patrol at Cape Arnhem to monitor turtle nesting activity. (photo: Rod Kennett)

Plate 2 A Garun (loggerhead turtle) nesting on the beach at Mon Repos. The visit to Mon Repos Sea Turtle Study Centre was the first time that a Yolngu person had observed Garun nesting. (photo: Dhimurru Land Management Aboriginal Corporation)

Plate 3 Grant Gambley, Dhimurru trainee ranger, holds some Garun (loggerhead turtle) eggs. The visit to Mon Repos Sea Turtle Study Centre was the first time that a Yolngu person had seen Garun's eggs. (photo: Rod Kennett)

Plate 5 Dhalwatpu (green turtle) tracks on a beach—one turtle track is two (photo: Ian Morris)

Plate 4 Dhimurru rangers, Botha Wunungmurra and Djawa Yunupingu, and PWCNT ranger Darren Larcombe tag a Garriwa (flatback turtle). (photo: Rod Kennett)

We teach so that they can feed information back to Dhimurru. How many turtles they catch at each outstation and how many eggs they collect. So that the school children will learn and they will know that these turtles are not just for us, or for this generation, but for the generations after.

There was a workshop that Dhimurru Land Management did on research about *miyapunu*. We talked about issues. How Yolngu people look after the turtles. We got a bit of information from Dr Kennett about balanda technology of how to look after the turtles. These are very serious issues, where flatbacks, olive ridleys, hawksbills and green turtles come in to nest.

Plate 4 shows one of our tagging trips, up around Cape Arnhem. There are a couple of Rangers there, tagging a flatback.

As you know, at this time, there is two-way learning. That two-way learning, everybody can learn. Non-Aboriginal people can learn, the Yolngu people can learn, even the nation can learn. Because if you understand that picture (see plate 5), one turtle track is two. There is one coming in, one going out. That represents the two knowledges that we can share between us.

That is all I wanted to show you and I hope you really appreciate it

Metals and Arsenic in a Green Turtle *Chelonia Mydas*

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ABSTRACT

*The metal and arsenic concentration is reported for pectoral muscle, liver, kidney, intestine and fat from a green turtle (**Chelonia mydas**) collected from the McArthur River region in the south west corner of the Gulf of Carpentaria, Australia. The concentrations are considered to be background with the turtle feeding on seagrass which has low concentrations of metals and the region is considered to be a pristine environment. The liver had high concentrations of cadmium and copper which may indicate the presence of metallothionein-like proteins similar to those of other vertebrates. The metal and arsenic concentrations were below the Australian Food Standards Maximum Permitted Concentrations except for cadmium in liver.*

KEYWORDS*:* *Chelonia mydas,* heavy metal concentration

INTRODUCTION

There are few reports of metals and arsenic in sea turtles and this is largely due to their protected status. All species of marine turtles are listed as endangered or vulnerable under the International Union for the Conservation of Nature and Natural Resources (IUCN 1996). They are also listed under Commonwealth of Australia legislation (*Endangered Species Protection Act 1992*). Therefore the killing of specimens for any form of analysis is banned.

Sea turtles and their eggs have been analysed for a range of metals, arsenic (As) and selenium (Se) (Davenport & Wrench 1990, Edmonds et al. 1994, Sakai et al. 1995, Stoneburner et al. 1980). However, the significance of the concentrations of these elements reported is largely unknown. Due to their protected status there has not been opportunity to gather sufficient data to allow interpretation of the reported metal concentrations—particularly in terms of what can be considered as background concentrations and what may be harmful or toxic concentrations.

A study by Thomas et al. (1994) has identified the presence of a metal-binding metallothionein protein in the liver of the red-eared turtle (*Trachemys scripta*) which would indicate that turtles might have an ability to regulate or detoxify heavy metals. Metallothioneins have been isolated from a range of vertebrates and are involved in detoxification of heavy metals.

The few reports on metals that do exist are from opportunistic collection of animals that had been killed due to entanglement in nets or died of other 'natural' causes. Davenport and Wrench (1990) reported the metal, arsenic (As) and selenium (Se) concentrations in the liver, pectoral muscle and blubber of a male leatherback turtle *Dermochelys coriacea* (L) in the United Kingdom. The concentrations were not regarded as elevated with zinc having the highest concentration in the liver of 2.62 ± 0.18 µg g^{-1} dry weight. Aguirre et al. (1994) also reported the concentrations of a range of metals, As and Se in the liver and kidney of the green turtle *Chelonia mydas* from Hawaii. The concentration of copper in the liver was more than 3 orders of magnitude higher and the concentrations of cadmium and zinc were at least an order of magnitude higher than that reported by Davenport and Wrench (1990) in a leatherback turtle. These differences may be due to differences in the diets of the two species or other interspecies differences; however, due to the limited data these types of interpretations cannot be made.

Sakai et al. (1995) investigated the relationship between the heavy metal concentration in the eggs and adults of loggerhead turtles (*Caretta caretta*) to develop a non-killing method for heavy metal monitoring in turtles. They concluded that the heavy metal concentrations in the yolk of eggs collected randomly from a clutch provide an estimate of the heavy metal concentration in the nesting female turtles. This method may provide a mechanism for obtaining more significant datasets on heavy metals in female turtles.

As part of a study of metals in biota in the south west corner of the Gulf of Carpentaria, tissue samples were obtained from a green turtle (*Chelonia mydas*) collected by the local Aboriginal community (Yanyuwa).

MATERIALS AND METHODS

Samples

An adult, female green turtle (*Chelonia mydas*) was caught by Yanyuwa Aboriginal people using a harpoon. It was caught in August 1992 approximately 5 km east of Cora Point near the mouth of the McArthur River in the south west corner of the Gulf of Carpentaria (UTM coordinates 684500E and 8251100N). The curved carapace length and curved carapace width were 101 cm and 72 cm, respectively.

The turtle was butchered by the Yanyuwa within one hour of capture and samples of pectoral muscle, liver, kidney, intestine and fat were collected in clean zip-lock plastic bags. The samples were immediately placed on ice and frozen within 3 hours of collection.

Sample preparation

All tissue samples were rinsed briefly in high purity water, lyophilised and homogenised. The lyophilised samples were pre-digested overnight at room temperature in concentrated AR grade nitric acid in 50 ml digestion tubes. The tubes were then heated to 130°C for 12 hours, cooled and filtered prior to metal analysis.

Samples for arsenic analysis were pre-digested overnight at room temperature in a nitric-perchloric-sulfuric acid mixture (three acid digests), then heated in steps to 300°C. The digest was then cooled and filtered prior to analysis.

Metal and arsenic analysis

The nitric acid digests were analysed for cadmium (Cd), copper (Cu), manganese (Mn) and zinc (Zn) by inductively coupled plasma – atomic emission spectrometry (ICP-AES, Perkin Elmer Pasma 400). The nitric digests were analysed for lead (Pb) using a Varian SpectrAA40 atomic absorption spectrometer with electrothermal vaporisation (Varian GTA95 furnace).

The three acid digest was analysed for arsenic (As) using the hydride generation technique and mercury (Hg) was determined using the cold vapour technique with a Varian SpectrAA40 atomic absorption spectrometer and Varian vapour generation unit (VGA76).

Quality control

Standard reference materials, International Atomic Energy Agency (IAEA) No. MA-B-3/TM fish tissue and National Bureau of Standards (NBS) No. 1566a oyster tissue, were used to determine the accuracy and precision of the analyses.

RESULTS AND DISCUSSION

Heavy metals and arsenic concentrations in tissues from the green turtle are shown in table 1. The results for the standard reference materials show that the analytical methods used provide quantitative recoveries for the elements analysed (table 2).

Table 1 Concentrations (mg/kg dry weight) of metals and arsenic in pectoral muscle, liver, kidney, intestine and fat from the green turtle *Chelonia mydas*

Sample	As	Cd	Cu	Pb	Mn	Hg	Zn
Muscle	1.51	<0.6	1.4	0.35	<0.2	<0.02	28.0
Liver	0.42	11.3	204.0	0.45	3.6	<0.02	87.0
Kidney	0.60	0.7	3.0	0.19	0.5	<0.02	76.0
Intestine	0.35	<0.6	3.0	0.12	4.2	0.06	73.0
Fat	<0.12	<0.6	<1.1	0.18	<0.2	<0.02	26.0
DL*	0.12	0.6	1.1	0.08	0.2	0.02	0.5

* DL = detection limit calculated back to the original sample

Table 2 Metals and arsenic concentrations (mg/kg dry weight) in IAEA MA-B-3/TM fish tissue and NBS 1566a oyster tissue

Sample	As	Cd	Cu	Pb	Mn	Hg	Zn
			Fish tissue				
Result	1.78	<0.6	3.3	5.38	2.2	0.435	104.0
Certified	2.11	nc*	3.1	4.62	2.6	0.510	109.2
			Oyster tissue				
Result	11.27	4.70	68.0	0.34	11.4	0.053	911.0
Certified	14.00	4.15	66.3	0.37	12.3	0.064	830.0

- nc = not certif

The concentrations of Cd and Cu in the liver are highly elevated compared with the other tissues. These high concentrations may be due to the presence of metal binding proteins, similar to metallothioneins, which have been identified in the red-eared turtle *Trachemys scripta* (Thomas et al. 1994). Thomas et al. (1994) found that 42% of the body burden of Cd was found in the liver and was associated with a metallothionein-like protein. Metallothioneins sequester potentially toxic metals, such as cadmium, resulting in the subsequent detoxification of the metal.

The concentration of zinc is evenly distributed throughout the tissues due to it being an essential metal in most animals. Aguirre et al. (1994) reported the heavy metal concentrations in the livers and kidneys of 12 green turtles, juvenile males and females, from the Hawaiian Islands. They found that arsenic and lead were in very low concentrations in both the liver and kidney, being below the method detection limit (MDL) of 0.6 mg/kg wet weight for arsenic and below the MDL for lead, although the MDL for lead was not reported. These results are in agreement with the results of the present study especially as the concentrations reported in this study are on a dry weight basis. The comparable wet weight concentration is approximately 25% of the dry weight concentration. The range of cadmium, copper and zinc concentrations reported by Aguirre et al. (1994) is shown in table 3.

Table 3 Range of concentrations (mg/kg wet weight) cadmium (Cd), copper (Cu) and zinc (Zn) in the ivers and kidneys of 12 green turtles reported by Aguirre et al. (1994)

Sample	Cd	Cu	Zn
Liver	0.39–26.0	1.3–189.0	15.1–45.8
Kidney	4.72–70.2	1.1–10.5	12.5–38.1

The concentration of zinc in liver and kidney in this study is within the range reported in table 3, allowing for the difference due to wet and dry weight concentrations. However, there are significant differences in the cadmium and copper concentrations in the liver and kidney in the present study compared with the range of concentrations reported in table 3. Table 1 shows that the concentration of cadmium in the liver was more than an order of magnitude higher than in the kidney, whereas Aguirre et al. (1994) reported higher concentrations of cadmium in the kidney than the liver (table 3). These differences may be due to age. Aguirre et al (1994) used juveniles (maximum carapace length of 69.0 cm) compared with the adult in the present study (carapace length 1.01m), and/or the health of the turtles. Aguirre et al. (1994) reported that 10 of the turtles in their study were afflicted with green turtle fibropapillomas (GTFP). The differences cannot be fully explained as there are not enough data to establish baseline concentrations or normal ranges of background concentrations.

As with any animal the diet will influence the levels of chemical species that are found in tissues. Green turtles are herbivorous, consuming algae and seagrass. The green turtle used in this study was in an area of extensive seagrass beds and its stomach and intestine was packed with partially digested seagrass leaves. The dominant species was *Syringodium isoetifolium* which in the McArthur River region has metal and arsenic concentrations (mg/kg dry weight) in the ranges: As: 1.6–2.7; Cd: 0.36–1.1; Cu: 2.0–4.8; Pb: 0.20–0.97; Zn: 5.0–27.8 (Parry & Munksgaard, unpublished data). This region is considered pristine with no anthropogenic sources and therefore these metal concentrations in the seagrasses are considered to be background concentrations. The metal and arsenic concentrations in the muscle, kidney, intestine and fat of the green turtle (table 1) are within the range of concentrations found for the seagrass they were feeding on in the McArthur River region. However, the cadmium and copper concentrations in the liver are one and two orders of magnitude higher than the seagrass concentrations, respectively. This is further evidence for a storage and detoxification mechanism in the liver involving metallothionein-like proteins.

The Yanyuwa people hunt turtles as a source of food and generally cook the turtle whole in its shell, eating muscle and the organs. The concentrations of arsenic and metals in the turtle in the present study were all at least a factor of two lower than the Australian Food Standards Code (1996) for Maximum Permitted Concentration (MPC) in food, except for cadmium in the liver. The MPC for cadmium in liver is 1.25 mg/kg edible portion (wet weight basis) and the concentration in the turtle liver on a wet weight basis was approximately 3 mg/kg. The results presented here are from only one animal and therefore it is not possible to say whether the concentration of cadmium in the liver of this turtle is within a normal range or whether it is at the upper end of concentrations for green turtles from the McArthur River region. It is this lack of data that continues to hamper any critical assessment of metals in marine turtles.

The increased coastal development in the Gulf of Carpentaria, especially mining related activity, increases the potential for marine environmental impacts from metals. Therefore it is imperative that monitoring programs for heavy metals in marine biota, including turtles, are established. The difficulties in obtaining significant sample sizes for turtles have been discussed in this paper. The monitoring of heavy metals in seagrasses from the turtle feeding grounds would provide an indicator of potential metal uptake by green turtles, however, studies of turtles are still required to determine how or if they accumulate heavy metals from seagrass and if they do whether they have mechanisms to regulate the metal concentrations in various organs.

ACKNOWLEDGMENTS

Members of the Yanyuwa Aboriginal community provided tissue samples for analysis. McArthur River Mining Pty Ltd provided funding for the baseline study.

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Marine Turtle Conservation: the Links Between Populations in Western Australia and the Northern Australian Region. People and Turtles

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ABSTRACT

Results from the Western Australian Marine Turtle Project (WAMTP) indicate that populations of loggerhead and green turtles nesting in Western Australia include many individuals that disperse widely to feeding grounds around northern Australia and into Indonesian waters as well. These turtles generally share their home feeding grounds with turtles that nest elsewhere in the Indo-Pacific region. Tag returns indicate that green turtles are an important food resource (including commercial trade) in the region. Loggerhead turtles are also hunted but tag recoveries are more likely to result from incidental capture in fisheries.

Limited work with nesting flatback turtles indicates that they also disperse widely to feeding grounds and a tag return from near Melville Island, Northern Territory, was recently recorded. Like loggerheads they are more likely to be caught incidentally in commercial fisheries than hunted for food.

Eggs of all species are taken for food.

There is currently no comprehensive dataset on indigenous turtle harvests in northern Australian waters. However, it is clear that a green turtle hunter in the west Kimberley region of Western Australia may be hunting the same breeding stock that is shared with Aboriginal people in NE Arnhem Land or even the Gulf of Carpentaria. Because the impact of indigenous hunting on a single genetic (breeding) stock of turtles is spread over a broad geographic range, the involvement of indigenous Australians is vital to calculating the combined catch of turtles from that stock. These data are necessary for the sustainable management of turtles.

Currently some northern Australian fisheries have better data relevant to sustainable management of turtles, where joint management of resources is required, than do turtle hunters, or government conservation agencies. This latter deficiency is understandable but needs to be redressed soon. The regional arrangements for management of the Northern Prawn Fishery that have allowed for collection of data on turtle bycatch by fishers, as well as for integrated management of that fishery, provide a good basic model to consider implementing for conservation purposes.

KEYWORDS: nesting, migrations, feeding grounds, indigenous harvest

INTRODUCTION

The marine turtle populations of the northern Australian region comprise a significant conservation resource on a worldwide scale. These turtles also comprise a source of food that has been exploited by indigenous coastal dwelling people of the region from pre-historic times. Apart from this context of now accepted knowledge, however, the population structure of the regional turtle species populations involved, and identification of the common stock interests of those people utilising turtles for food within the region, could only be discovered by the application of modern scientific method.

In this paper I present and discuss information derived from work undertaken within the broad framework of the Western Australian Marine Turtle Project (WAMTP: see Prince 1993, 1994) over the past ten years that shows: how conservation and sustainable exploitation of these marine turtle populations must be managed on a regional scale to fully succeed; and how the interests of indigenous Australian coastal people wishing to maintain established hunting practices and cultural traditions focussed on marine turtles form part of this whole. Data derived from a commercial fishery operating at similar regional scale are discussed further, and the management format involved suggested as a basic model suitable for our purposes.

THE WESTERN AUSTRALIAN MARINE TURTLE PROJECT

Work of the Western Australian Marine Turtle project (WAMTP) commenced in late 1986. Some preliminary investigations of marine turtle resources and their nesting areas in Western Australia had been undertaken on a local scale prior to this time, eg, Johannes and Rimmer (1984) for North West Cape nesting beaches, and Morris (unpubl. data) on beaches used by turtles nesting in the Dampier Archipelago (noted in Morris 1990; see also Groombridge & Luxmoore 1989). Capelle (1979, reported by Kowarsky 1982) had also attempted to discover the extent of Aboriginal harvest of green turtles in the Kimberley, but, essentially, the nature and extent of the marine turtle populations of the Western Australian region remained practically unknown, as indicated in the review of Limpus (1982).

The fact that Western Australia had legally permitted, under provisions of then existing State Fisheries legislation, a relatively large commercial green turtle fishery to continue operating off the western Pilbara coast through the 1960s until closure in the early 1970s, without any substantial knowledge of biology of the stocks being exploited, was of residual concern for marine wildlife conservation. Kimberley coastal Aboriginal people had also expressed particular interest through 1984–85 in further involvement in management of the turtle populations of value to themselves, based on their previous participation in work commissioned by Applied Ecology Pty Ltd, and consistent with the desirable participatory approach to achievement of sound sustainable management of continuing indigenous wildlife harvests, as indicated by Prince (1988). The apparently precarious and declining status of the Malaysian nesting leatherbacks at that time also provided further incentive for the work to begin.

With major operational support primarily obtainable from the Australian National Parks and Wildlife Service (ANPWS; lately the Australian Nature Conservation Agency [ANCA], now merged into Environment Australia) through both the States Cooperative Assistance Program (SCAP) and the Contract Employment Program for Aboriginal Nature Conservation and Resource Management (CEPANCRM), the new Western Australian Department of Conservation and Land Management (CALM) was able to proceed with implementation of the integrated work that has been focussed through the WAMTP. This work aimed at obtaining biological data on the marine turtle species populations present in and dependent on resources of the Western Australian region, including aspects of their natural history, population dynamics, and the interrelationships between different within species population units that might be involved, so that conservation status could be properly assessed and monitored. These data would also provide the basis for planning and implementation of necessary conservation measures, having regard to both local and regional perspectives (Prince 1993, 1994). The primary work of the WAMTP is not yet complete, but results now available are providing the background information for preparation of a formal Western Australian Wildlife Management Program for marine turtles (Mettam, Raines & Prince, in prep.).

For the purposes of the workshop, the results obtained from tagged turtle dispersal and capture reports, and the population genetics analyses including western Australian and northern Australian nesting turtles, are the most relevant data.

SETTING THE SCENE FOR MANAGEMENT

Green turtles *(Chelonia mydas)* are the species generally most favoured by indigenous hunters worldwide, but turtles of all species may be captured and eaten, and eggs of all are taken. Within Australia, generally, only Aboriginal and Torres Strait Islander people are now legally entitled to capture and utilise marine turtles.
Other Australians may, in going about their legal daily business, also incidentally capture and,

perhaps, accidentally kill turtles. Other activities of all sorts flowing from the ordinary daily life and the location of any of these people can also affect the health of the waters in which the turtles live, and thus the health of the turtle populations too.
All of these factors must be taken into account when we aim to achieve a sustainable ongoing association of people and turtles, however each of us might view the particular value of the wildlife.

RESULTS FROM THE WAMTP: DEPENDENCE, DISPERSAL, POPULATIONS AND FATE OF TURTLES

The main foundation work of the WAMTP has concentrated on discovery of the individual turtle species major nesting locations in the western Australian region, and inception and maintenance of a suite of long-term population studies based on tag and release, and ongoing monitoring, of individually identifiable nesting adult female turtles, complemented where possible by collaborative genetic studies aimed at helping define the appropriate regional management units for conservation (eg, Norman et al. 1994, Coates et al. 1994, Broderick et al. 1994).

Turtles bearing the external flipper tags used by turtle research workers to identify each individual from a tagged turtle population are recognisable by other people. Providing that other people seeing, finding, or catching these turtles tell the project managers of their discoveries, very important information can be obtained on the distribution of feeding grounds occupied by turtles from particular nesting populations, the types of encounters providing these observations, and the subsequent fate and uses of the turtles involved.

The main body of data I have relevant to the workshop discussion is derived from the green turtle population studies of the WAMTP.

Beginning late 1986, 11 471 nesting adult female green turtles have now been tagged and released, having been sampled from among the turtles attending major nesting beaches in the Western Australian region. Principal study sites have been West Island in the Lacepede Islands group (west Kimberley), the mid-west coast beaches of Barrow Island (offshore Pilbara), and the west coast beaches of North West Cape plus some from South Muiron Island (Gascoyne coast). As is common with other tagged turtle studies, most of the green turtles tagged and released have since gone unreported by anybody. There are a variety of reasons why this may be so—some observations are provided in other papers in this volume. I will concentrate on the records of turtles found at locations other than their nesting beaches.

Of the 5171 adult female green turtles (*C. mydas*) tagged and released from the Lacepede Islands, 66 have been reported from other locations, with the majority of reports (60 = 91%) detailing capture for human use. **Captures** reported to date from remote locations (fig 1) include: **within Australian waters**, ex Western Australia—2 from Exmouth Gulf region, 27 from west Kimberley locations (most from around Bardi community, One Arm Point via Broome), 1 from NW Kimberley, and 2 from far N Kimberley: ex Northern Territory—5 from Bathurst and Melville (Tiwi) Islands area, 3 from Cobourg Peninsula, 9 from around Croker Island and adjacent mainland, 3 from South Goulburn Island, 1 from Milingimbi, 1 from Elcho Island, 1 from Yirrkala area, 3 from Numbulwar/Rose River area, and 1 from Borroloola; ex Queensland—3 from Wellesley Islands area. One other WA-tagged green turtle (not individually identifiable, due to omission by the reporters to make a record of the tag number data from the turtle before releasing it from their fishing lines) has been reported from near Weipa. This was most probably a Lacepede Islands nesting turtle. **External captures** of four Lacepede Islands nesting green turtles have been reported **from Indonesian waters:** 3 from the southern Aru Islands area, and 1 other taken by Bajo people from SE Sulawesi (exact capture location unknown).

We have proportionally fewer (18) remote capture records for the Pilbara–Gascoyne region tagged nesting green turtles (4088 tagged from North West Cape + Muiron Islands; 2212 from Barrow Island). The explanation considered most probable is a lesser level of human presence and related activities focussed on turtle capture in the areas to which these turtles disperse. Only eleven (= 61%) of the reports were from capture for human use. The dispersal data include a report of one Barrow Island nesting green turtle taken in Indonesian waters east of Timor; the 17 others (including both Barrow Island and North West Cape/Muiron Island nesting turtles) cover a wide range of Western Australian coastal locations, ranging from south of Shark Bay northward to the NW Kimberley region.

Fewer loggerhead turtles (*Caretta caretta*), flatback turtles (*Natator depressus*) and hawksbill turtles (*Eretmochelys imbricata*) have been tagged than have green turtles because they are less abundant in WA waters and because less effort has been spent on these species. Nevertheless, the limited dispersal data we have obtained for flatbacks and loggerheads also reinforce the need for a regional focus for conservation and management of human interactions in each case, although the main interaction between turtles and people differs from that found for the green turtle.

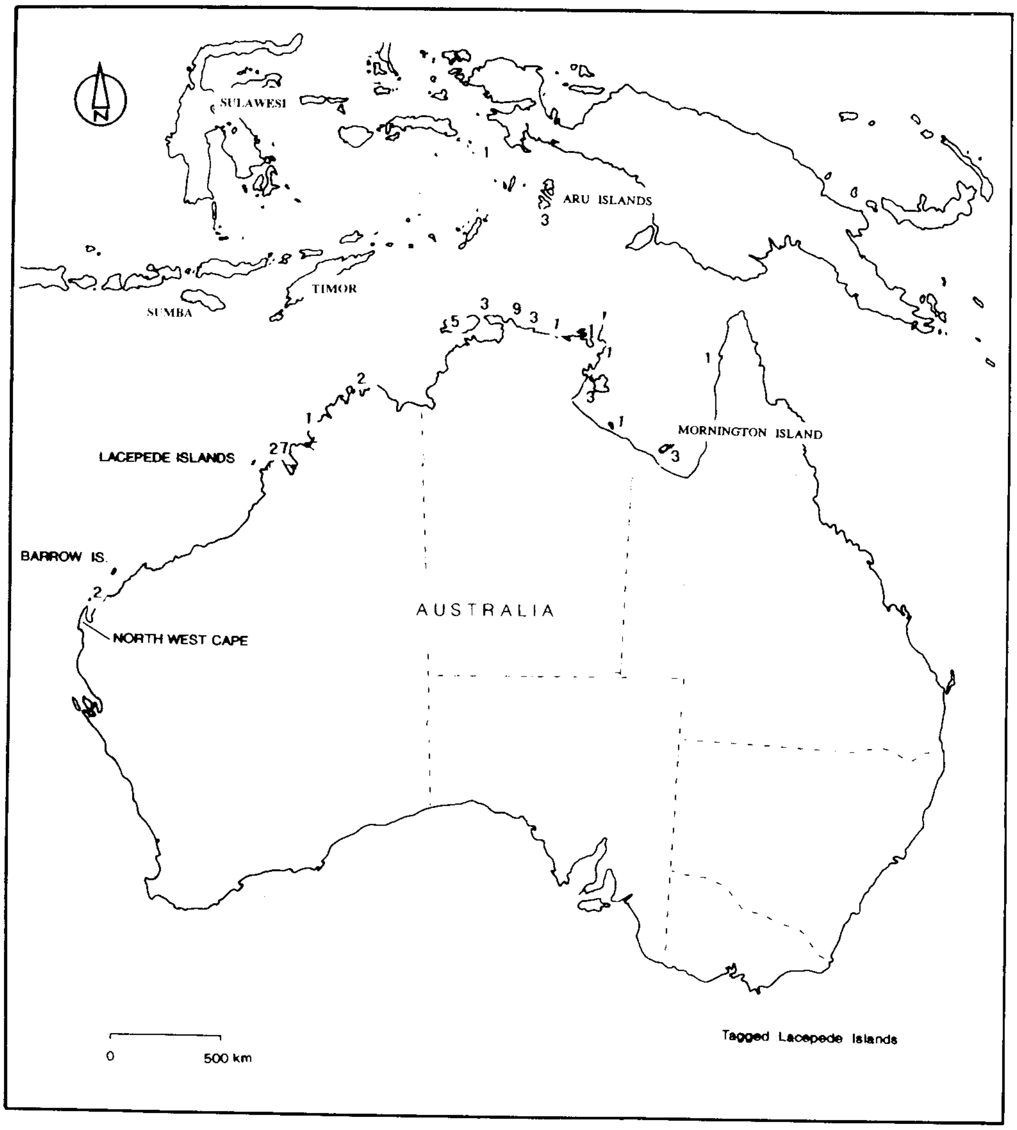

Figure 1 Dispersal of tagged adult female green turtles from the Lacepede Islands breeding beaches

Loggerhead turtles

Over three nesting seasons to date, starting 1993/94, we have tagged and released 1776 adult female loggerhead turtles from the Dirk Hartog Island, Shark Bay, nesting beaches. Forty-five per cent of these are 1996/97 season turtles. Twelve of these loggerhead turtles have been reported at sea so far, including one from among the 1996/97 group. Eleven of the twelve have been caught in prawn trawls within the Shark Bay fishery, and subsequently released, but the twelfth was found dead on the coast north of Broome, WA. One of the trawled turtles is known to have survived.

We have one other independent tagging record showing that a single loggerhead found and tagged in 1991/92 on its feeding ground near the Montgomery Islands, WA, attended the Dirk Hartog Island rookery in 1995/96.

None of these Dirk Hartog Island nesting loggerheads were deliberately captured for human use. All locations are also within Western Australian coastal waters, but the extremes of these locations span 10^{o} latitude (*c.* 1800 km separation at sea).

Seven hundred and thirty-six adult female loggerhead turtles have been tagged and released from beaches on South Muiron Island and the adjacent North West Cape, with the majority (639) being from South Muiron Island, and most turtles tagged and released from 1990/91 through 1993/94. None of the relatively few North West Cape nesters have been reported at sea, and only four of the South Muiron Island nesters, but this latter group of four has included one individual captured in a shark fishery operating in the Java Sea (Indonesia), another taken for use at Maningrida, NT, and two others captured and released from the Shark Bay trawl fishery.

Flatback turtles

Even smaller numbers of nesting flatback turtles have been tagged and released in comparison with the loggerheads, and only three at sea locations reported to date, but these data also demonstrate the wide area dispersal of turtles to living areas in contrast to use of restricted nesting beaches. The captures comprise: two turtles (from 560 tagged and released to date) using the mainland nesting beaches south west of Cape Thouin, WA, found at separate locations—one off the De Grey River mouth, and the second near the Montalivet Islands off Montague Sound, far north Kimberley region of WA (*c*. 1000 km distant); the third turtle (from 181 tagged and released to date) was tagged and released from Rosemary Island in the Dampier Archipelago, and captured inside Exmouth Gulf, WA. All captures have been by Western Australian prawn trawl fisheries. One of these three turtles is known to have survived capture and release back to sea.[2]

Hawksbill turtles

We have also tagged and released around 1050 adult female nesting hawksbill turtles from Rosemary Island (most from 1990/91 on), and another 304 from Varanus Island in the Lowendal Islands group (main work starting 1986/87). None of these turtles have been reported from discovery at sea, although many have been seen renesting at these two locations since their first tag and release.

Other species

Two other species of marine turtles are found in Western Australian coastal waters, but neither of these has confirmed breeding presence within Western Australia. Thus, populations of olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*) turtles found feeding in Western Australian waters are dependent on breeding locations elsewhere. There is only limited known breeding presence of either species in northern Australian waters (eg, Guinea 1990, Harris 1994, Limpus & McLachlan 1994), so it is probable that many of these turtles seen in our waters are part of international migratory populations.

DISCUSSION

I have not subjected the data above to more complex analysis, because they are sufficient to illustrate the two main points of interest to us here: 1) the interactions between each of the turtle species and people and their activities are not uniform, 2) but where there is evidence of particular interaction between people and turtles, this is most likely to occur at a wide regional scale, and this scale may transcend national and international political boundaries.

We should remind ourselves now that most of the turtles presently at sea are not individually identifiable, and that I have presented WAMTP data resulting only from the intersection of some form of localised human activity with the distribution of some of the surviving tagged turtles at sea, and the subsequent reporting of that event by the person(s) involved. There are two consequences:

- all the captures made are most unlikely to have been reported;
- the observational data we do have are further biased because we have had no control over, or any detailed knowledge of, the concurrent distribution of tagged turtles at sea and the particular activities that resulted in formal reports.

Other studies can provide a different focus, and further help us appreciate the necessary scope of management.

Poiner et al. (1990) studied the interaction between the northern prawn fishery (NPF) and turtles at sea. The NPF operates in northern Australian waters extending from Cape Londonderry, WA (127^{o}E), to Cape York, Qld (142^{o}E). Most fishing generally occurs in waters >10m depth, with about 25% of trawls in depths >40m. Based on data collected between 1979 and 1988, Poiner et al. (1990) concluded that the NPF caught an average of 5730 (± 1907) turtles per year up to 1987, with an average loss by drowning of 344 (± 125). Fishing effort reductions introduced for the NPF after 1987 reduced these estimates to 4114 (± 1369) turtles being caught, with 247 (± 90) drownings. Poiner and Harris (1996) further examined the interaction of this fishery with turtles in more detail in 1989 and 1990. Estimated total turtle catches were again in the range 5000–6000 per annum, with about 14% drowned, and another 25% injured or comatose. The individual species being captured and the estimated mortality rates for each present quite a different picture in contrast to the tagged turtle data from the WAMTP

[2] A flatback turtle tagged while nesting at the beach on Mundabullangana Station (c. 50 km west of Port Hedland, WA) in December 1996 was captured in a NPF prawn trawl north of Melville Island late April 1997. This is the first record of a WA nesting flatback found outside WA waters.

captures at sea. The majority (average 59%) of turtles being captured in the NPF were flatbacks, but the drowning mortality rate (11%) for these turtles was the lowest for all species recorded. Olive ridley and loggerhead turtles were the next most frequently caught (range *c*. 5–15% of captures), but drowning mortality of the loggerheads being caught was much higher (range *c*. 19–33%, *cf* 8–19%). Green turtles comprised less than 10% of captures, with drowning mortality of *c*. 10–15%. Very few hawksbill turtles were captured, but these had drowning mortalities ≥ those for the loggerheads.

Using the data above, Poiner and Harris (1996; see table 8) derived some estimates of the likely abundance of the different species of turtles on the grounds fished by the NPF, the number of drowning deaths by species of turtle, and the apparent annual mortality rates of each turtle species within the trawl-fished populations for a substantial part of the northern Australian coast spanning three of the separate Australian States and Territories. They also noted that the fishery did not sample the turtle populations in the waters <10m depth, that the relative abundance of turtle species in these shallower waters could differ from that on the trawl grounds, especially for green turtles and the sub-tidal seagrass banks on which they may feed, and that comprehensive data on turtle mortality due to other fishing activities in the general region were scarce, but, where information was available, catches for human use were apparently much greater. The most recent relevant data for the Australian region are from Torres Strait, where catches of as much as 5000 to 6000 turtles per annum may be common (see Johannes & McFarlane 1991).

Further information from the long-term marine turtle studies focussed on the turtles breeding in Queensland waters has shown that turtles from those locations also have living areas within the Gulf of Carpentaria, and further afield along the NT coast, and westward into Indonesian waters of the Maluku/Irian Jaya region (Limpus et al. 1992; see also fig 2, p157 in Limpus & Parmenter 1988). Turtles breeding in Indonesian waters may also be found in Australian coastal waters (unpubl. data; C Limpus, pers. comm.). There is an apparently substantial turtle harvest continuing in Indonesian waters (Greenpeace International 1989; HA Reichart, unpubl., cited by Poiner & Harris 1996).
Unfortunately, there are as yet no comprehensive contemporary data providing an overview of recent and current turtle harvests from northern and north-western Australia. These are the harvests of greatest significance to the members of the coastal Aboriginal communities in this region.

The local stocks of turtles from which each community obtains these harvests are probably a complex mix of individuals from a number of different breeding populations. The mix of turtles of any species being caught might also differ from that actually present on the reefs and in the surrounding waters, and local indigenous catch may or may not reflect close interaction with the catch being extracted by the commercial fisheries operating offshore. Whatever the true relationships are in these respects, Australian conservation authorities and the Aboriginal people with a cultural and nutritional interest in continuing harvests are in a poor position to advance towards better management of the marine turtle resources without acquisition of quantitative data on the harvests at a similar regional scale as a first requirement.
More complex issues of catch sharing, and catch quotas if necessary, might then be dealt with as part of the process leading to socially acceptable and equitable sustainable management of these turtles at the necessary regional scale. The cooperative NPF management arrangement may be an appropriate basic model suitable for the purpose of achieving more effective Australian regional marine turtle conservation.

ACKNOWLEDGMENTS

This paper is a report from the Western Australian Marine Turtle Project. Major financial support for the work has been provided by the Western Australian Department of Conservation and Land Management; the Australian Nature Conservation Agency (now incorporated into Environment Australia) via the States Cooperative Assistance Program, and also CEPANCRM which aided Aboriginal community involvement in the west Kimberley work; and the World Heritage Management Program; with additional assistance provided from industry by West Australian Petroleum Pty Ltd, Woodside Offshore Petroleum Pty Ltd, Apache Energy, Arrow Pearl Co Pty Ltd, Hamersley Iron Pty Ltd, Robe River Mining Co Pty Ltd, BHP Iron Ore and Coates's Wildlife Tours, and from the community by the North West Cape conservation group CARE, the Kwinana-Rockingham-Mandurah Branch of the Western Australian Naturalists' Club, and the Vitenbergs family. The seasonal fieldwork on nesting beaches could not have been done without the substantial help of many volunteers. Dispersal data obtained have been provided by the many turtle hunters and others who have taken the care to ensure that their finds have been reported.

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Marine Turtle Conservation and Management in Northern Australia: Briefing Paper

Bill Risk and Robert Browne

Larrakia traditional owners

FOCUS: TO ESTABLISH A TURTLE AND DUGONG CONSERVATION MANAGEMENT OMMITTEE AND PLAN[3]

- A management committee be established to develop and administer a strategy to deal with turtle and dugong conservation issues. The committee should be comprised of key Aboriginal representatives, Parks and Wildlife NT and Environment Australia and could also include research marine enforcement and fisheries agencies.
- Aboriginal customary law dealing with turtle and dugong harvesting should be a fundamental component of this strategy and be reflected into statutory law. For example:
  - Aboriginal and Torres Strait Islander people form other area intending to hunt turtle or dugong in Larrakia sea country must seek permission through this committee.
  - Harvest restrictions such as gun prohibition, controls over sex and minimum size and regulations involving geographical and seasonal closures be put in place so that all Aboriginal hunting continue to occur in a manner approved by traditional owners.
  - Mechanisms be in place to allow the free handover of turtle and dugong bycatch from commercial fishing operations to traditional owners.
- In areas surrounding Darwin, patrols should be operated by Parks and Wildlife and the police with paid Larrakia representatives to monitor harvest by Aboriginal communities and to document the illegal turtle egg harvest by non Aboriginal people particularly in areas of Bynoe Harbour such as Quail and Indian Islands. Greater penalties need to be introduced for these illegal activities.
- Larrakia involvement in research and management activities need to be carried out to monitor and control goanna numbers on islands within Bynoe Harbour to reduce turtle eggs predation.
- Larrakia strongly support recommendations from Manguyga ga Rulpapa and traditional owners from Cobourg Marine Park and Borroloola regions calling for all incidental dugong and turtle by catch to be handed over to traditional owners and for bycatch reductions devices to be made mandatory on all prawn vessels from 1999 following a period of research and trial.

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3 Northern Land Council 1997 Manbuynga ga Rulyapapa, Northern Land Council, Darwin, http://www.ozemail.com.au/~nlc95/Mgr.htm

MARINE TURTLE BYCATCH IN THE NORTHERN PRAWN FISHERY: SCALE OF THE PROBLEM AND DEVELOPING SOLUTIONS

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ABSTRACT

Prawn trawling in the Northern Prawn Fishery is one source of mortality affecting marine turtle populations. From 1996, the Australian Fisheries Management Authority implemented a turtle monitoring program through the commercial logbook completed by fishing vessels. Preliminary analysis of this logbook information shows that at least 1493 turtles were inadvertently captured during trawl operations and at least 85 of those drowned during 1996. These data underestimate actual captures and mortality due to non-reporting by 26% of vessels and some misreporting by others. These estimates are lower than 1989/90 CSIRO estimates, but may be partly explained by a 30% reduction in fishing effort since 1990. Refinements to the logbook monitoring program are being developed in response to inadequacies identified in this study. Fishery management measures directed at turtle conservation are also discussed.

Keywords: marine turtles, bycatch, management, prawn trawling, Northern Prawn Fishery, Australia

INTRODUCTION

The Northern Prawn Fishery (NPF) extends from Cape York in Queensland to Cape Londonderry in Western Australia, encompassing the Gulf of Carpentaria, the northern coast of Arnhem Land and Joseph Bonaparte Gulf. NPF trawlers target banana and tiger prawns, but also retain by-products such as bugs, scampi and scallops. Trawlers also inadvertently catch turtles during trawl operations. There are concerns about the sustainability of some marine turtle populations in Australia due to increased mortality from habitat degradation, traditional harvesting, feral animals, boat strikes and entanglement or ingestion of debris. The incidental drowning of turtles in trawl nets is an additional source of turtle mortality.

CSIRO has conducted several studies of turtle captures in the NPF using research vessel trawls and volunteer commercial fishers who, after training in turtle identification and data collection, monitored turtle catches during prawn trawl operations (Poiner et al. 1990, Poiner & Harris 1994, 1996).

Information reported in these studies was collected prior to 1991 when more than 200 trawlers worked in the fishery. However, since this time the number of vessels has dropped to only 128 through an industry funded buy-back and fleet adjustment program. Also both the number of fishing days and the areas closed to fishing have been increased by management in order to preserve prawn nursery grounds, protect spawning prawns and prevent fishing on low-value, small prawns. These changes have resulted in a 39% reduction in the number of days trawled in the NPF. To date, the effects of these fleet size and effort reductions on turtle captures have not been fully analysed.

The Commonwealth Director of National Parks and Wildlife received a nomination for prawn and scallop otter trawling to be listed as Key Threatening Processes under Schedule 3 of the *Endangered Species Protection Act 1992*. This nomination listed loggerhead, green, leathery, hawksbill, Pacific ridley and flatback turtle populations to be threatened by prawn and scallop trawling. At the time of writing, this nomination is being assessed by an Endangered Species Scientific Sub-committee on behalf of the Minister for the Environment.

In 1995, a Draft Regional Strategy on research and monitoring for sustainable management of marine turtles was developed (Limpus 1995). This document identified priority areas for research and monitoring, including quantifying the size and distribution of turtle mortalities attributable to trawling; determining the impact of trawling on turtle habitat; and developing methods to reduce turtle catches.

This paper describes the measures the Australian Fisheries Management Authority (AFMA) has implemented to update estimates of turtle mortality due to prawn trawling in the NPF and address some of the priority research and monitoring needs identified in the 1995 Draft Regional Strategy.

METHODS

AFMA is working with the industry to determine the catch of turtles in the NPF (Sachse & Robins, 1997a). In 1996, vessel skippers were asked to report details in their logbook on every turtle captured. They recorded the number of turtles caught on each day, the species of each turtle and its condition when released.

Fishers used diagrams of the turtle shells to identify each species. However, the skippers were given only basic training on species identification so identifications may be unreliable. To verify identifications, in the 1997 season AFMA issued every boat a disposable camera for the fishers to photograph each turtle. This will not only provide a check on the species breakdown but further assist with training skippers in identification. Results of this initiative to obtain species verifications will be available next year. The logbook has also been modified to make it more user friendly for recording the necessary data.

RESULTS

Numbers of turtles caught

Data were collected from 95 of the 128 trawlers that operated during 1996. These data have not yet been verified for accuracy. In all, 1493 turtle captures were reported from 1 April to 30 November 1996. Actual data were extrapolated by multiplying these results by 134.7% to account for the 33 vessels that did not report bycatch, providing more realistic estimates (table 1).

Of the turtles captured, 841 turtles were returned to the sea alive, 85 were dead and 567 turtles were recorded with an ‘unknown condition of release’. The large number in the latter category was partly due to the logsheet not providing a clear format for recording this information, and partly due to the difficulty that untrained personnel had in determining the condition of a turtle.

The data show the rate of drowning in 1996 was about 6%. This was lower than the estimated mortality rate (14%) from data collected by trained volunteer fishers in 1989 (Poiner & Harris 1996), but consistent with a 6% direct mortality estimated from research survey trawls (Poiner et al. 1990). Poiner and Harris (1996) found that 21% of turtles were comatose when bought aboard but over half of these regained consciousness after about 30 minutes of rest. The variability in estimates may be partly attributed to the inability of the crew to distinguish between comatose and dead turtles.

Table 1 Numbers of turtles incidentally captured and released from NPF trawlers

	Actual data	Estimate	% of total
Total captures	1493	2011	100.0
Released alive	841	1133	56.3
Released—‘unknown condition’	567	764	38.0
Drowned	85	115	5.7

Species of turtles caught

Preliminary analysis of logbook records showing the reported species composition of the NPF turtle bycatch is shown in table 2. These data vary from earlier CSIRO reports of the species composition of the turtle bycatch. It is probable that training of vessel crews was insufficient to identify species with certainty, and these data are unreliable. There is a tendency with inexpert observers to classify turtles as green turtles where doubt exists (Aubrey Harris, pers. comm.). This may explain the large proportion recorded as green turtles. It is hoped that species can be verified from photographs during the 1997 season, allowing greater confidence in species composition data in future.

Table 2 Reported capture of turtle species during 1996

Species	Captured	Drowned
Flatback	448	20
Green	368	17
Pacific ridley	349	27
Loggerhead	185	8
Hawksbill	62	6
Leatherback	15	0
Unknown	66	7

When are turtles caught

Few turtles are captured during the banana prawn season, which lasts from April to early May, as banana prawns are mainly landed during the day with short shots (from a few minutes up to an hour). The tiger prawn season, from mid May to late November is when most turtles are caught. When targeting tiger prawns, the trawlers operate at night with shots lasting about 3 hours. The chance of drownings is also increased with this type of operation. Further analysis of turtle bycatch patterns in time is yet to be undertaken.

Where are turtles caught

Turtle captures are distributed throughout the fishery. The rate of turtle captures in different areas is related to the amount of fishing effort. The largest turtle bycatches were in the Weipa, Mornington Island and Vanderlin Islands regions where fishing effort was also highest.

DISCUSSION

Scale of the problem

Allowing for non-reporting by 33 vessels and for a 39% reduction in the number of fishing days between 1989 and 1996, captures of turtles in the NPF are less than previously reported by Poiner and Harris (1996) (table 3). Although Poiner and Harris's estimates have wide confidence limits due to the small number of vessels involved (7 in 1989 and 11 in 1990) and limited sampling, it is likely that the logbook data contain negative bias due to some misreporting.

AFMA recognises the need to verify logbook records of turtle captures. To do this, several approaches are being developed by the NPF Fishery Assessment Group. These include use of independent observers, using only reliable logbook respondents, and inter-boat comparisons.

Table 3 Comparison of estimates made by Poiner and Harris in 1989, 1990 and this study. The Poiner and Harris estimates have been scaled to account for a 30% reduction in the number of days trawled by NPF vessels.

	Poiner and Harris (scaled estimates)		This study
	1989	1990	1996
Fishing days[1]	27049	25746	16635
Estimated captures	3357	3195	1939
Estimated drowned	346	575	115

1 Only fishing days targeting tiger prawns are used in this comparison as few turtles die during banana prawn trawling. Data from Kovacevic and Sachse (1990, 1991) and Sachse and Robins (1997b).

Lower direct mortality rates due to drowning could also be partly explained by the same wide confidence limits that apply to capture rate estimates. However, we believe that it also reflects the success of an education campaign to train trawler crews in turtle recovery procedures. These procedures ensure that the turtle's lungs are drained of water by raising its rear flippers about 20 centimetres off the deck, as well as keeping the animal aboard until it has fully recovered. Many skippers are surprised that such a simple technique can bring an apparently dead turtle back to life so quickly.

Post-release mortality of turtles has not been studied to date and is not known. Trawlers are now actively participating in turtle tagging projects and it is hoped that tag returns will improve estimates of post-release mortality.

DEVELOPING SOLUTIONS

Three main reduction methods were suggested in the Draft Regional Strategy (Limpus 1995):

- use of turtle exclusion devices (TEDs) in trawl nets;
- implementation of seasonal and area closures to avoid times and sites of high turtle abundance;
- limitation of trawl duration to minimise drowning risk.

AFMA has facilitated large research programs on the development of alternative trawl gear to reduce turtle bycatch. The main thrust of this research is development and testing of TEDs most suited to the NPF. Researchers from CSIRO, Queensland Department of Primary Industries (QDPI) and the Australian Maritime College (AMC) are all actively involved. The initial research phase, funded by the Fisheries Research and Development Corporation, has yielded encouraging results. Several TED designs have been shown to eliminate turtle bycatch under research conditions (Brewer et al. 1997). However, at some locations clogging of the TED grid bars occurred, causing significant losses of prawns. Lost income due to this problem is offset to some extent by the improved quality of the catch which is landed without damage and efficiencies in the sorting and processing required. Consequently, there is growing support for TEDs by members within industry. From May this year, CSIRO, QDPI and AMC are making trial TEDs available to NPF vessels through a 'TED library'. There has been a positive response to this initiative.

To date, AFMA has resisted legislating for mandatory use of TEDs in the NPF. This decision draws upon the experience in the Gulf of Mexico shrimp trawl fishery where legislation without sufficient prior research created massive non-compliance problems and mistrust of regulatory authorities (Margavio et al. 1996). However, we accept that after the current research, development and voluntary use phases, it may be appropriate to formally include TED use in management arrangements for the fishery. To this end, AFMA and NORMAC (the management advisory committee established to provide management advice to AFMA for the NPF) are in the process of developing bycatch action plans. These plans are likely to include an implementation timetable for TEDs.

There are seasonal closures in the NPF from 15 June to 1 August and from 30 November to 1 April. These closures already avoid peak nesting periods and there is limited scope for greatly restricting the fishing season further.

There are extensive area closures in inshore waters of the NPF to protect seagrass beds—the nursery habitat for juvenile tiger prawns. These closures help reduce the catch of green turtles that feed in seagrass areas. As more data are collected, we may be able to identify areas and times of high turtle density. Once identified, discrete closures could be usefully incorporated in the management arrangements for the fishery to reduce turtle bycatch. The vessels in the NPF fleet will each be equipped with a satellite-based vessel monitoring system (VMS) next year. This technology will provide AFMA with greater real-time resolution of fleet activities, and also give greater ability to monitor and enforce closures in this remote part of Australia.

To date, limiting trawl duration has not been considered a practical method of reducing turtle mortality. Trawl duration during banana prawn fishing is short and little turtle mortality is attributed to this activity. Tiger prawn trawling consists of trawls or 'shots' of about 3 hours on average. Reducing these times may result in fewer turtles drowned in trawls, however, such a measure would create disruption to operations with high rates of non-compliance. AFMA's ability to enforce such a measure in the NPF would be limited. Therefore, AFMA's preferred approach at this stage is to encourage implementation of TEDs and examine the possibility of specific turtle closures. With further monitoring we will develop a clearer picture of the success of these mitigation methods.

CONCLUSIONS

Following this preliminary analysis after one year of monitoring turtle bycatch using NPF logbooks, the following conclusions can be drawn.

- The response rate was high (74%), therefore logbooks are a means of collecting turtle bycatch information.
- The large number of vessels in the NPF that return information through logbooks will provide wide spatial and temporal data for northern Australia, unlikely to be otherwise available.
- There is some (yet to be quantified) level of under-reporting, therefore estimates derived from logbook data should be treated as minimum estimates. Methods to determine the extent of any under-reporting are currently being developed.
- Untrained vessel crews may not be able to recognise species of turtles with accuracy, therefore species data are probably unreliable. This inadequacy is now being addressed by issuing cameras to vessels to photograph captured turtles.

AFMA is contributing actively to turtle conservation through:

- research aimed at reducing turtle bycatch;
- reviewing management arrangements with a view to minimising turtle bycatch;
- educating trawler crews to minimising turtle drownings;
- refining a logbook based monitoring system for turtles inadvertently captured by NPF trawlers.

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WHERE DO THEY GO? IMMATURE GREEN AND HAWKSBILL TURTLES IN FOG BAY

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ABSTRACT

Green and hawksbill sea turtles feed on the shallow algal covered rocky reefs in Fog Bay. For both species the size class structure is predominantly juvenile. The absence of larger turtles supports the theory of developmental migration, by which turtles, as they mature, move into different feeding habitats.

Keywords: green turtle, hawksbill turtle, juvenile, size structure, developmental migration

INTRODUCTION

Several conceptual models of the life cycle of sea turtles are presented in the literature (Limpus et al. 1984, Lanyon et al. 1989, Musick & Limpus 1997). The shallow water feeding stage is broken into several sub-stages through which turtles migrate as they grow and mature (Carr 1980).

Although the idea of developmental migration has become popular (Musick & Limpus 1997), the extent and duration of these migrations remain unknown. Some populations may not migrate at all after they settle into a feeding area at the juvenile stage (Musick & Limpus 1997), while other studies indicate that both small (Limpus 1978, Guseman & Ehrhart 1990) and large scale shifts in foraging habitat may occur (Limpus 1992).

This paper discusses developmental migration in relation to the juvenile turtles in Fog Bay.

METHODS

Study site

The Fog Bay study site is situated approximately 100 km west of Darwin (fig 1). Eight islands sit on an ironstone base forming an archipelago that extends 15 km from the mainland. Green and hawksbill turtles feed on the intertidal algae which grow on the 23 km^2 of rocky reef which join the islands and the mainland.

General methods

Research into the feeding ecology of green and hawksbill turtles began in Fog Bay in 1990 when substantial numbers of both species were caught on the intertidal ironstone reefs. In the early years of the study, turtles were tagged opportunistically due to other time commitments, but since 1995 catch effort has been increased.

Three methods of capture were used: rodeo jump, beach jump and netting. In the rodeo jump method turtles are chased with a speed boat and captured by hand when a diver leaps onto the back of a swimming turtle (Limpus & Walters 1980). In Fog Bay the turbid water conditions restrict this technique to water depths of less than 2 m. In the beach jump method turtles are captured by walking along the reef and diving on turtles in the shallow water that washes over the reef with the rising tide. Netting was trialed as a catch method in 1997. The net has a length of 50 m and a mesh size on 16 cm (6.5 inches). The net is placed in selected channels along which turtles leave the reef on the falling tide. The research team uses a 4 m (12 foot) aluminium dinghy with a stern steer 25 HP Johnson outboard motor. Gloves, full-length wet suits and booties are used as standard protection for personnel.

Turtles were tagged on the trailing edge of both front flippers using titanium turtle tags (Stockbrands). Curved carapace length ($CCL \pm 0.5$ cm) was recorded for each turtle (Limpus et al. 1984).

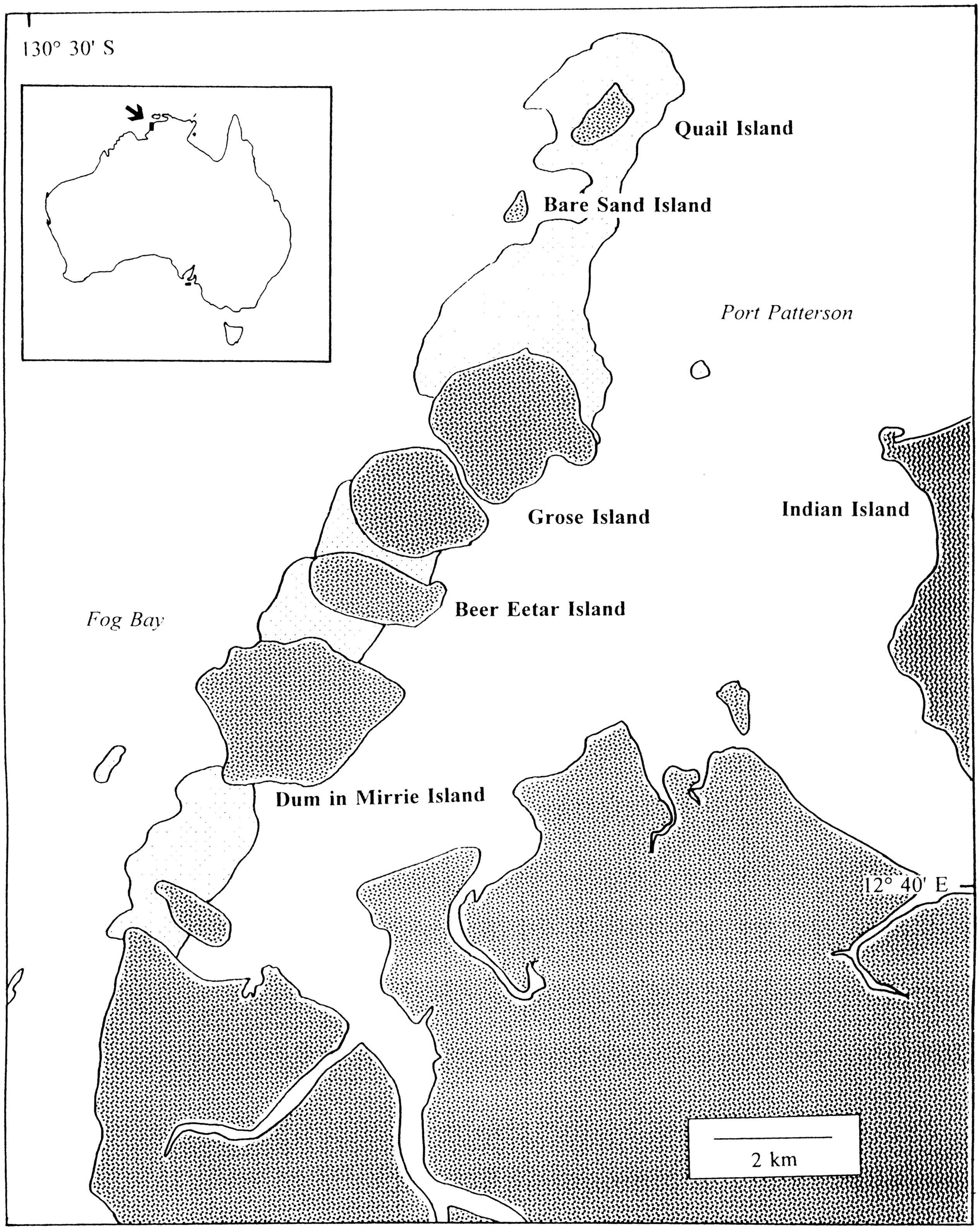

Figure 1 Fog Bay. Insert: Location map of Fog Bay. Main map: dark stippled area represents the mainland and islands; light stippled area represents intertidal reef flat.

RESULTS

Three hundred and thirteen green turtles were recorded from 320 captures and 178 hawksbill turtles were recorded from 210 captures.

Species composition

Green turtles are more abundant than hawksbill turtles in the shallow feeding area of Fog Bay: 65.5% greens and 34.5% hawksbills. However, the species composition varied between catch sites within the reef. Hawksbill turtles comprised more than 60% of the catch in some areas.

Size class structure

Almost all hawksbill and green turtles captured in Fog Bay were of juvenile size classes (green, mean CCL ± sd = 47.7 ± 8.13 cm, range 33.7–103.8 cm, n=259, fig 2; hawksbill, mean CCL ± sd = 49.3 ± 11.44 cm, range = 26.3–75.5 cm, n=187, fig 3). Although some larger adult sized turtles from each species were captured, they comprised only a small percentage. Green turtles entered the feeding ground at around 38 cm and disappeared at around 60 cm (fig 2). Hawksbill turtles were found over a greater range of size classes: 28 to 65 cm (fig 3).

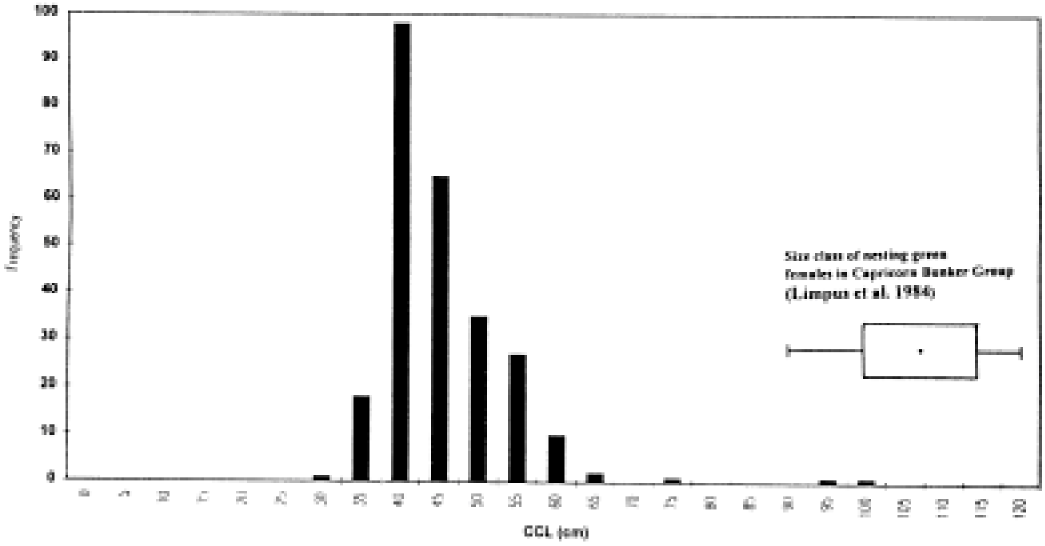

Figure 2 Size class structure of green turtles captured in Fog Bay shows an absence of adult sized turtles. Box represents mean, standard deviation and size range of adult female green turtles nesting on Heron Island (Limpus et al. 1984)

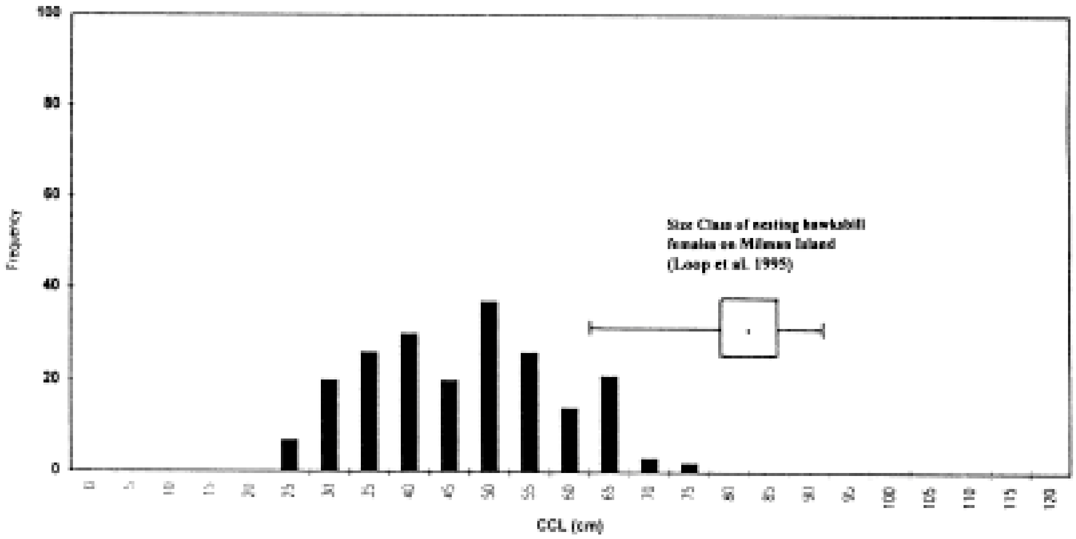

Figure 3 Size class structure of hawksbill turtles captured in Fog Bay shows an absence of adult sized turtles. Box represents mean, standard deviation and size range of adult female hawksbill turtles nesting on Milman Island (Loop et al. 1995)

DISCUSSION

Where do the turtles go once they reach the larger size classes? Only a small percentage of the green and hawksbill turtles captured in Fog Bay were larger than their respective minimum breeding size (Limpus et al. 1984, Loop et al. 1995). The few individuals in the adult size range may have been sexually immature (Colin Limpus, pers. comm.). Other Australian feeding populations of green turtles e.g. Shoalwater Bay (Musick & Limpus 1996), and hawksbill turtles eg Southern Great Barrier Reef (Limpus 1994), comprise a mixed distribution of size classes.

The absence of larger size classes from the intertidal feeding area in Fog Bay may indicate emigration from the area. This would be consistent with the concept of developmental migration in which different size classes utilise different feeding habitats. Larger turtles may feed in deeper water just outside the reach of the present capture methods or they may move to feeding habitat many kilometres away. In Fog Bay, the theory that a localised shift in foraging behaviour may be occurring is supported by observations of larger sized hawksbills more than 20 km offshore and in waters of 30 m depth. Also larger sized green turtles are more commonly sighted in deeper waters than in the shallows of the reef.

To answer the question of the missing size classes we hope to:

- increase catch effort in those areas where larger turtles 'seem' more abundant;
- trial different catch techniques in habitat which is not conducive to catching turtles with standard techniques (deeper water);
- obtain any tags from beach washed, trawled or hunted turtles so that movements and growth data can be obtained.

ACKNOWLEDGMENTS

Funding was provided by National Estates Grants Program and the Queens Trust for Young Australians. Assistance in the field by Colin Limpus, Diane Fontannaz and numerous volunteers is gratefully acknowledged.

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An Overview of the Sea Turtle Research in Park and the Surrounding Area

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ABSTRACT

In 1995 a joint 5 year turtle monitoring project between Kakadu National Park (Parks Australia North) and Gurig National Park (Parks and Wildlife Commission of the NT) was proposed. The project has been in progress for two years and it is hoped that the respective management authorities will agree to its continuing for the remaining three years. The data collected by this project once combined with some of the work done previously will start to give a better understanding of marine turtles in the area. As the work on Greenhill Island is the subject of a later presentation this report will concentrate on the work done within Kakadu National Park.

KEYWORDS: Marine Turtles, Kakadu National Park, tagging program, Gurig National Park

INTRODUCTION

The turtles

Of the six species of marine turtle occurring in Australian waters at least 5 have been recorded in the waters around the Kakadu coastline—the flatback (*Natator depressus*), green (*Chelonia mydas*), Pacific ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*). There are reports of green, Pacific ridley and hawksbill turtles nesting along the Kakadu coastline and they certainly have known nesting areas nearby in Arnhem Land. However, the only species recorded as nesting in the recent monitoring studies has been the flatback.

The fact that marine turtle populations worldwide are declining dramatically is well documented. Anecdotal evidence suggests that the same is true for the local Van Diemen Gulf populations. Various reasons have been put forward to explain the drop in numbers. In Kakadu, heavy pressure on turtle eggs from predators especially the goanna is one explanation that has been advanced. At this stage, however, there are not sufficient data to accurately assess whether the drop in numbers is real, perceived, or even cyclic and natural. This study hopes among other things to add to the information on these issues to enable a more accurate assessment and in the long term the introduction of appropriate management strategies.

The Aboriginal perspective

Sea turtles have been a major food resource for Aboriginal people in this area for many years and as such are an animal group that the traditional owners of Kakadu take a particular interest in. Evidence of the long association between Aboriginal people and the sea turtles is shown by the collection of a bark painting depicting a sea turtle from Field Island in 1884 by a passing ship (Records of the South Australian Museum 1957). In the local area, turtles are actively hunted for their meat, however, the flatback is not as favoured for its meat as the green turtle and therefore not subject to the same hunting pressure. Flatback eggs are collected opportunistically in the area but the frequency of egg collection is not high.

The study area

Kakadu National Park includes almost 20 000 km^2 of the Alligator Rivers Region in the tropical north of Australia. The Park is world renowned for its magnificent wetlands, rock art, escarpment and associated waterfalls and its pioneering system of joint management with the Aboriginal traditional owners.

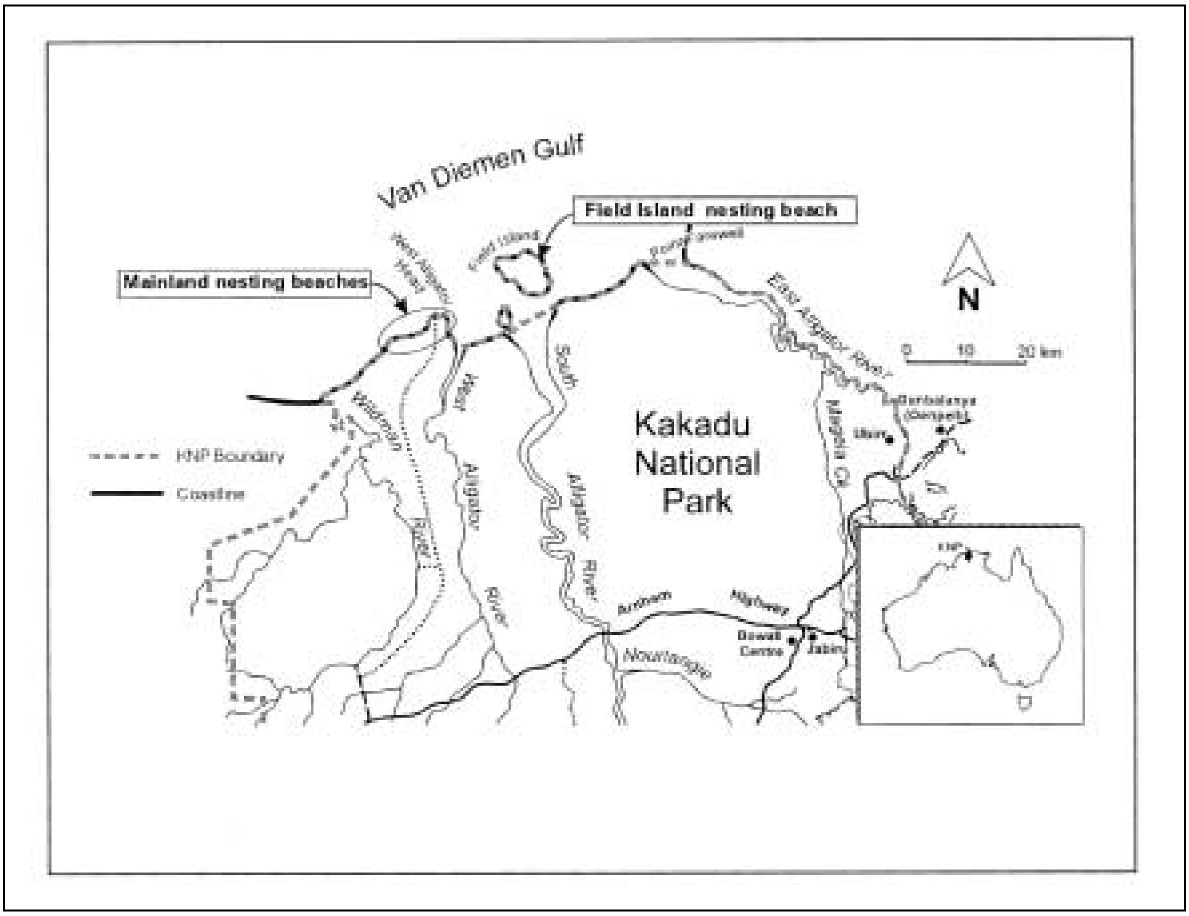

Figure 1 The study area

Kakadu has approximately 70 km of coastline as well as two small islands (Field and Barron) but apart from a small and dedicated band of the fishing fraternity its coastline is unknown to all but a few of the ~ 250 000 people visiting annually. Most of the coastline is dominated by mangrove tidal mudflats and the principal geographical features are the four major rivers—Wildman, West Alligator, South Alligator and East Alligator—that enter the sea at this point. There are, however, some small stretches of sandy beach essential for nesting turtles within Kakadu notably Main or Pocock's beach (5 km in length), Middle beach (1 km), Sandfly beach (0.8 km) at West Alligator Head on the mainland, and the small beach on Field Island (250 m).

The project

In 1995 it was proposed that a 5-year turtle monitoring program be undertaken in cooperation with Parks and Wildlife Commission of the NT who were conducting a similar exercise on Greenhill Island. Approaching the program as a joint operation allowed resources to be pooled and a more regional picture of marine turtles within the Van Diemen Gulf area to be obtained. The Kakadu and Greenhill Island populations of flatback are two of the few populations to be extensively studied in northern Australian waters. Therefore, despite the current study being very much in its infancy, it is a significant and one that needs to be built on.

Project aims

- determine the diversity of species nesting and feeding along the Kakadu coastline;
- conduct a 5 year tagging program to obtain more information on the population dynamics and nesting behaviour of marine turtles in the Kakadu region particularly as evidence points to a dramatic decline of the local and global turtle population;
- obtain more information on the predation of turtle eggs particularly by the goanna;
- assess methods of intervention which aim to increase the level of egg survival through protection from predators such as the use of hatcheries;
- provide training and staff development in another area of natural resource management and monitoring consistent with the Plan of Management;

- increase the Park's coastal presence in line with concerns expressed by local staff and traditional owners.

METHODS

The nesting beaches in the area are surveyed at every opportunity and any nesting activity is recorded to give an indication of the spread of the nesting season and to identify its peaks. Any nests that have been destroyed by predators are also recorded to get a measure of predator impact.

The major part of the survey is concentrated into a two to four week window during the peak nesting season over June, July and August. A team of researchers is on site each day over this period and every turtle that comes to nest is caught and processed. Where possible, random surveys are made for short periods either side of this 2 to 4 week period to add to the data collected and increase the chance of recording recaptures of turtles returning to lay again.

The data collected from the nesting turtles—such as weight, carapace length and width, clutch counts and egg measurements—are the same used by virtually all turtle researchers and in this case the methodology and data sheets are taken directly from the work of Col Limpus in Queensland.
The level of goanna predation was investigated by surveying the beach each morning while looking for hatchling activity and recording how many of the nests laid previously had been opened by a predator that would usually be a goanna. Care was taken to stay off the beach for the majority of the day to minimise the influence of human presence on any of the predators' behaviour.

It was not thought necessary to sacrifice any live young to determine the sex ratio of these hatchlings as there were sufficient hatchlings found dead in the nest for this purpose. The histological examination of these specimens has not yet been completed.

RESULTS

This paper does not claim to present proper analysis and comparison of scientific results—the level of data collected thus far still needs to be built on and properly analysed. Rather it is a discussion paper giving a brief history of the work that has been done in this area in the past, an update on what is happening at present and what is planned for the future. Some areas in which ideas from other experienced researchers in this area would be welcomed are also identified.

At this stage information on marine turtles in the area has come from a combination of personal observations by local residents, some minor early tagging work in 1990/91and the study done over approximately 2 months in each of 1993 and 1994 by R Vanderlely (1995) which was largely confined to the mainland beaches. This is now being added to by surveys by Park staff in 1995 and 1996 which it is hoped will continue annually until 1999.

Until the present monitoring program the only sustained program had been by Vanderlely (1995). The present program has taken up where this study left off and concentrated on Field and Greenhill Islands. In combination the two studies will give a much better picture of marine turtles in the Van Diemen Gulf area looking at three major and quite distinct nesting sites.

The chronology of turtle research in the area, 1987–88

The first records of more than a passing interest in turtles in the area were in 1987 and 1988 when South Alligator District staff in Kakadu expressed interest in undertaking some monitoring work and received advice from Col Limpus on the matter. A local resident, Mr John Grice, was also demonstrating considerable interest and provided local information and observations over this initial period.

1990–91

Twelve flatback turtles were tagged on Field Island during 1990 and 2 on Sandfly beach by District staff and Mr John Grice. No other species were recorded on either of the beaches. Of the 14 tagged turtles 5 were recaptured at later dates, 4 on Field Island and 1 on Sandfly beach.

1993

Eleven flatback turtles tagged on mainland beaches by R Vanderlely.

1994

From records provided by R Vanderlely, 35 turtles were recorded coming ashore on the mainland beaches over the July–August survey period. Of these, 13 were recaptures and 7 were missed and not tagged. On Field Island for the same period 62 turtles were recorded coming ashore to lay. Of these 12 were recaptures and 6 were missed and not tagged.

Field Island 1995

Thirty-four flatback turtles were handled over a 12 day period in early July. Three turtles tagged during this period returned to lay a second time over this period, 2 returned 8 days after the first laying event and one within 4 days. There were 2

other recaptures—one first tagged on the 14 July 1990 and for the second no records were available.
A two-hour survey of part of the Field Island reef system at low tide counted 20 green turtles and 2 hawksbills. The reef system in the area is obviously an important feeding area for these species as well.
Goanna predation was monitored over this period. Only 2 nests from approximately 40 laid were interfered—12 eggs were taken from one and 6 to 8 taken from another. Between 6 and 13 July, 4 nests produced a total of 220 hatchlings—an average of 55 per nest.

Field Island 1996

Thirty-six flatback turtles were handled between 27 August and 3 September; there were 5 recaptures. One turtle had not laid and returned within 3 days. Hopefully details on these will be found when the full tagging details of previous studies are analysed. No surveys of goanna predation or hatching events appear to have been carried out.

DISCUSSION

Standardising tag series and databases

It would be helpful to standardise tag systems and databases to introduce conformity at least for the studies done in the NT. Each time that sets of tags are ordered there is this dilemma of which of at least 3 tag series to work with. There are occasions where for the same tagging exercise more than one tag series is used. A central database which everyone can access but which still protects the individual researcher's own data would also be an advantage.

Assessment of predation on eggs

Exactly what to do about the reported level of predation on nests particularly by goannas is a management dilemma. The levels of predation reported by Vanderlely (1995) and others certainly seem to be beyond what the population can sustain. There are definitely periods when every nest laid the previous night has a goanna feeding on it the next morning. On the other hand there are also periods as described in the results section where predation of the nest is minimal, raising the possibility that levels of predation could in some cases be cyclic.

The initial response to reports of heavy goanna predation in the area was that the goannas should be culled and all the eggs moved into protective hatcheries. However, goannas are native animals and any reduction in their numbers, particularly in a national park, needs to be carefully considered, as does the use of labour intensive hatcheries.

Hatcheries

If some sort of human assistance is necessary to increase the viability of the population by protecting the eggs in hatcheries several factors need to be considered.

In 1994 on Field Island several hatchlings were not able to escape from a hatchery and perished which caused some concern. While every effort needs to be made to ensure that any human intervention in a natural process is not to the detriment of the animal concerned, this incident also needs to be put in the context that mortality of hatchlings is naturally high. On occasions hatchlings can perish by becoming entangled by vegetation and debris while trying to make their way from the nest to the sea. The level of mortality in this case was probably no more than would be naturally caused by such entanglement. Nevertheless several tests were done to determine the optimum size of mesh that maximised the ability of hatchlings to escape but minimised the opportunities for predators to enter. Several mesh sizes were tested by placing a panel of the mesh in the sand between some hatchlings and the water and then releasing hatchlings that had been processed and observing their progress through the mesh and down to the water.

Hatcheries are extremely labour intensive so alternative measures should be investigated. One possibility on beaches that have a low density of turtles coming in to lay may be to use squares of mesh 3m x 3m that could be placed flat over the nest and pegged. Predators such as goannas often will not dig up a nest if they area forced to approach it from anywhere but directly above. The same principal is used on rabbit proof fences where a skirting of mesh is laid from the base of the fence along the ground away form the upright fence for a short distance.

Operational health and safety procedures

In 1996 during the turtle monitoring exercise on Greenhill Island there was an incident involving a crocodile and a member of the monitoring team. As a result Kakadu Park management is obligated to formalise some operating procedures that address safety while working in crocodile areas. There is a definite need to be safety conscious during such field exercises but equally the danger of introducing or having imposed a set of procedures that are so restrictive that they have a negative impact on the exercise needs to be avoided. Certainly any people involved in turtle and other research in crocodile areas who work for a government department will almost certainly find this is a requirement in the future. It would therefore be advantageous for this forum to produce a set of operating guidelines that everyone is happy with that considers the safety of those involved while at the same time still allowing useful research or monitoring to continue.

ACKNOWLEDGMENTS

Several people have provided invaluable assistance in the setting up and running of this project and this is gratefully acknowledged. Dr Col Limpus of the Queensland Department of Environment and Heritage who has been available for advice from the inception of this project including the early attempts in 1988 and has also provided Kakadu personnel with training at Mon Repos.

Mick Guinea from the Northern Territory University and Bob Prince from CALM who also gave advice and came to Field Island during the first monitoring exercise in 1995 to give on site advice.

John Grice, resident of Sandfly Beach, who particularly in the early attempts at starting the program assisted staff and provided valuable local knowledge.

Roger Vanderlely, whose masters thesis is the only other substantial research in the area, has provided some preliminary data with which to compare the work now in progress on Field and Greenhill Islands and when combined with the current work will provide a more meaningful picture of turtle ecology in the area.

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