Surveys of the Sea Snakes and Sea Turtles on Reefs of the Sahul Shelf

Monitoring Program for the Montara Well Release Timor Sea
MONITORING STUDY S6 SEA SNAKES / TURTLES

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Acknowledgements:

Two survey by teams of ten and eleven people respectively housed on one boat and operating out of three tenders for most of the daylight hours for 20 days and covering over 2500 km of ocean can only succeed with enthusiastic members, competent and obliging crew and good organisation. I am indebted to my team members whose names appear in the personnel list. I thank Drs Arne Rasmussen and Kate Sanders who gave their time and shared their knowledge and experiences. I thank the staff at Pearl Sea Coastal Cruises for their organisation and forethought. In particular I thank Alice Ralston who kept us on track and informed. The captains Ben and Jeff and Engineer Josh and the coxswains Riley, Cam, Blade and Brad; the Chef Stephen and hostesses Sunny and Ellen made the trips productive, safe and enjoyable.

I thank the Department of Environment and Conservation WA for scientific permits to enter the reserves of Sandy Islet, Scott Reef and Browse Island. I am grateful to the staff at DSEWPaC, for facilitating and providing the permits to survey sea snakes and marine turtles at Ashmore Reef and Cartier Island. Activities were conducted under Animal Ethics Approval A11028 from Charles Darwin University.

Olive Seasnake, *Aipysurus laevis*, on Seringapatam Reef.

Table of Contents:

List of Figures

List of Tables

1 Executive Summary

The surveys of the sea snakes and marine turtles inhabiting the six reefs of the Sahul Shelf were initiated in response to an uncontrolled release of hydrocarbons from the West Atlas Rig on the Montara Well in August 2009. The team from Charles Darwin University comprised three members of the IUCN Species Survival Commission's Sea Snake Specialist Group with one member also being a member of the Marine Turtle Specialist Group. Other team members were all graduates with years of experience in their respective fields of marine turtle and sea snake surveys and animal pathology. The initial survey in 2012 was shortened due to adverse weather conditions. A second survey in 2013 completed the assessment of those reefs missed the previous year and reassessed the surveyed reefs and included an additional site, Montgomery Reef on the Kimberley coast.

The surveys aimed to quantify the presence of sea snakes, marine turtles and seagrass in areas of the Sahul Shelf that were potentially impacted by the release from the West Atlas Rig. The pre-impact status of the fauna and flora of the reefs known from previous surveys by the author was compared with the post impact status to quantify any effect and subsequent recovery resulting from the presence of oil.

Reefs were assigned a likelihood of impact status based on observations at the time of the hydrocarbon release. Observers reported sheen on the sea surface during aerial surveys following the hydrocarbon release. Such potentially impacted reefs included Ashmore Reef, Cartier Island and Hibernia Reef. Reefs that were likely to be un-impacted were Scott Reef, Seringapatam Reef and Browse Island. This latter group with Montgomery Reef were considered to be control or reference reefs in this survey. Ashmore Reef and Cartier Island are Marine Protected Areas under Commonwealth protection. Sandy Islet and southern reef at Scott Reef and Browse Island are reserves under the control of the Western Australian Government.

1.1 Sea Snakes

The surveys assessed the sea snake populations by:

- paired manta board transects of the reef crests and lagoons,
- standard snorkel surveys for fixed periods of time in known locations,
- foot transects at low tide over the reef flat,
- boat transects over the reef and lagoon at high tide,
- night spotlighting of the reef flats, reef crest and deeper waters adjacent to the reef

Habitat assessment consisted of inspecting the intertidal areas, seagrass beds and sediment cores from nesting beaches for waxy or oily residues.

No sea snakes were seen on Ashmore Reef in either of the surveys. Sea snake numbers had dwindled on Ashmore Reef since 1998 to a level where sea snakes have not been seen on the reef for some years. Sea snakes were not recorded on Browse Island in this survey nor had they been reported in any of the previous fauna surveys.

The numbers of sea snakes on the other reefs varied between surveys although the effort was similar in each year. Extra time was spent on Hibernia Reef in 2013 because of the abundance of sea snakes and the potential for capturing rare species. Seringapatam Reef was the only site that had a decline in sea snake numbers between the two surveys. Seven species of sea snake were encountered out of 17 species recorded from the reefs of the region. The diversity of sea snakes comprised generalist feeders such as *Aipysurus* species as well as specialist feeding hydrophine species. Not all species were found on all reefs. The two endemic species of sea snakes belonging to the genus *Aipysurus* were not encountered in either survey.

1.2 Marine Turtles

Marine turtles were assessed by recording their presence during the manta board surveys. The numbers of foraging turtles were assessed by boat surveys over the reef flat at high tide. Possible hydrocarbon contamination of the diet of foraging Green Sea Turtles was assessed by analysing blood samples taken from sub-adult turtles that were resident on Ashmore Reef (a potentially impacted site) and Montgomery Reef (WA) as a control site. Beaches were monitored for adult turtles and their nesting success recorded along with the hatching success of recently emerged nests.

Marine turtle nesting was recorded at Sandy Islet Scott Reef, Browse and Cartier Islands and the islands of Ashmore Reef. Sandy Islet and Browse Island had tens of Green Sea Turtles nesting during the spring tides of the surveys. Eight individual Green Sea Turtles nested on West Island Ashmore Reef over the four nights of the first survey and 12 nested during the same time of the second survey. One of the females tagged while nesting in 2012 was harvested six months later by indigenous hunters at King Sound on the mainland coast.

Foraging sub-adult Green Sea Turtles were abundant at Ashmore Reef with over 477 individuals recorded during one afternoon. Blood samples were obtained from 16 individuals at Ashmore Reef in 2012. In 2013 twelve individuals were caught at Montgomery Reef, a control site, and blood samples collected and analysised. Several of the blood parameters were significantly different to, but within the reference values of those reported previously from foraging Green Sea Turtles at Ashmore Reef and the literature. The liver-function indicating product, Bilirubin, was the exception in having values in excess of those from previous studies at Ashmore Reef and from the literature for Green Sea Turtles. The blood samples from Green Sea Turtles at Montgomery Reef, the control site, had similar elevated Bilirubin values. An explanation for these elevated levels remains unexplained but cannot be attributed to any hydrocarbon residue on the reef or seagrass.

1.3 Study Limitations

This survey of sea snakes and marine turtles in the wake of the hydrocarbon release from the Montara Well is the most thorough ever conducted on the reefs of the Sahul Shelf. It augments but also highlights the paucity of information gained previously by many fragmented and opportunistic surveys over the past two decades. Missing from this analysis is a clear indication of how the populations of sea snakes fluctuate over time and the likely causes of declines as seen at Ashmore Reef and now possibly Seringapatam Reef. The population densities on Seringapatam Reef varied between surveys with no obvious explanation. Sea snake populations, in particular, are dynamic and require more regular monitoring to provide security in the population

status. There is no evidence of the impact of the hydrocarbon release having a long term impact on sea snakes and marine turtles of the six reefs of the Sahul Shelf. Two of the reefs that were potentially impacted, Hibernia Reef and Cartier Island had the highest species diversity and the greatest numbers of individuals. Ashmore Reef, the remaining potentially impacted Reef, had few if any sea snakes prior to the 2009 hydrocarbon release.

Marine turtles may have been potentially impacted beyond the area of the hydrocarbon release due to their migratory behaviour. Although the four control reefs may not have been impacted, the marine turtles living on the reefs and nesting on the beaches of two islands may have come into contact with hydrocarbons through their travels or diet. However the analysis of blood chemistry indicated individuals from potentially impacted reefs had similar results to those from control areas. The release from the Montara well occurred prior to the start of the major marine turtle breeding time at Ashmore Reef and Cartier Island and well prior to when hatchlings cross the beaches and disperse to the open ocean.

There was no visible evidence of hydrocarbon residue on any of the beaches. The seagrass beds and corals were also clear of any residue. No evidence of residue that could be attributable to hydrocarbon release was found in the intertidal reef flats or any areas visited by the survey team.

1.4 Recommendations

Recommendations include a repeat of this survey within a year to collect data from the reefs that were potentially impacted by the unscheduled release and nominated control reefs for comparison. The survey should be part of annual monitoring of the status of the sea snake and marine turtle populations of the Sahul Shelf. The sampling of foraging marine turtles should be extended to collecting blood samples for analysis from Green Sea Turtles from a control site such as Montgomery Reef. The concept of reference values for Green Sea Turtle blood using samples from just some tens of individuals needs to be addressed to identify the boundary conditions attributable to outliers in various blood parameter values.

2 Introduction

2.1 The Reefs of the Sahul Shelf

The Sahul Shelf is broadly defined as the shelf of shallow seas to the West of the Tiwi Islands (Figure 1) to the edge of the continental plate where water depths begin to increase into the abyssal plane (Russell and Hanley 1993; Teichert and Fairbridge 1948). The approximate area is 400,000 km^2 (Teichert and Fairbridge 1948). In the northern most section three reefs are exposed at spring low tides, Hibernia Reef, Ashmore Reef and Cartier Island. Two of these reefs, Ashmore Reef and Cartier Island support sand cays of which the four on Ashmore Reef are vegetated (Berry 1993; Commonwealth of Australia 2002; Guinea 1993a; Russell and Hanley 1993). Similarly in the southern part, three reefs are exposed at spring low tides, Seringapatam Reef, Scott Reef and Browse Island (Berry 1986; Guinea 2006d). The latter two supporting sandy beaches but only Browse Island is vegetated (Guinea

2006d). Montgomery Reef is located on the Kimberley coast. It is a mainland island consisting of rock similar to that found on the mainland. It is in a macro-tidal region with tide heights exceeding nine metres during spring tides. Although not on the Sahul Shelf it is adjacent to the Timor Sea and is expected to have sea turtles and sea snakes similar to those found on the Sahul Shelf. It was not impacted by the hydrocarbon release from the West Atlas Oil Rig in 2009 and considered as a control site.

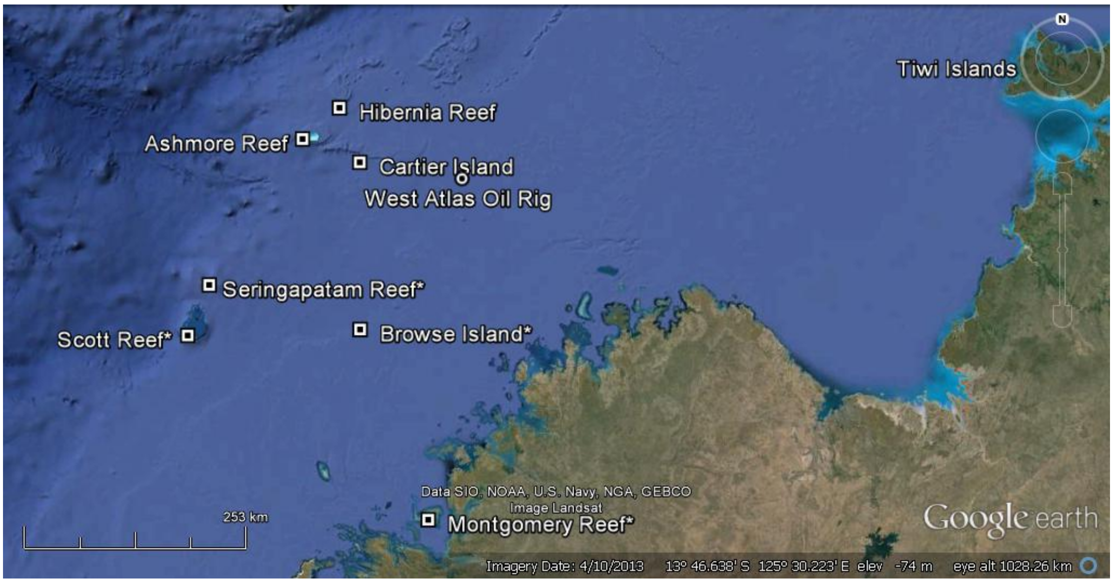


Figure 1.The locations of Ashmore Reef, Cartier Island, Hibernia Reef, Scott Reef*, Browse Island*, Seringapatam Reef*, Montgomery Reef* and the West Atlas Oil Rig on the Montara field (* indicates a control site).

2.2 Sea Snakes

Sea snakes are a diverse group of marine reptiles forming at least three evolutionary lineages (Hydrophine, Aipysurine and Ephalophine) in Australian waters with another two lineages in Asian waters (Guinea 2003; Heatwole and Cogger 1994). Being air breathers with a diet of either fish or fish eggs, sea snakes live in shallow, coastal, tropical waters of the Indian and Pacific Oceans. An exception to this is the Yellow Bellied Seasnake (*Pelamis platurus*) that lives a pelagic life feeding on small fish that shelter beneath the motionless snake that resembles drifting wood. The majority of sea snake species feed on the sea floor and rise to the surface to breathe. Even though up to 40 % of their oxygen requirement diffuses from the sea water through the skin as demonstrated in the Yellow Bellied Seasnake (Heatwole and Cogger 1994). The sea surface is also where they rest, bask and drink freshwater during showers of rain. The Hydrophine sea snakes tie knots with their bodies and squeeze through the coils to remove parasites and to slough their skin. All the sea snake species living in Australian waters give birth to live young at sea. Given the need for shallow waters with a plentiful supply of fish, the seas of northern Australia abounded with sea snakes fascinating the early navigators including William Dampier and Phillip Parker King (Hordern 2004).

One location with an historical reputation for sea snake abundance and species diversity is Ashmore Reef, situated to the west of the Sahul Shelf in the Eastern Indian Ocean. Hibernia Reef also on the Sahul Shelf shared the diversity of sea snake species with Ashmore Reef (Guinea 1993b). Unexplainably, other reefs in the region like Cartier Island, Seringapatam Reef, Browse Island and Scott Reef had fewer species recorded (Table 1) (Berry 1986; Berry 1993; Guinea 1993b). Using Jaccard's Similarity Coefficients (Sj) on presence and absence data and unweighted pair-group analyses using arithmetic averages (UPGMA) comparisons are possible between historical and modern distributions of sea snakes. Historically Ashmore Reef and Hibernia Reef hosted almost identical species diversity (Figure 2). Surveys in 2005 and 2006 revealed a decrease in species diversity at all locations including Scott Reef (Figure 3). The duration of the surveys at Hibernia Reef and Cartier Island have been very short and restricted to a brief period (2 to 3 hours) in the tide cycle compared to the longer surveys at Ashmore Reef and Scott Reef. The results for Ashmore Reef indicate that species that were once commonly encountered (Ginea1995) had become rare by 2006 (Francis 2006) and absent thereafter (Efles *et. al*. 2013).

The sea snakes that inhabit the coral reefs live out their lives within a few hectares with very little movement between reefs (Burns and Heatwole 1998; Burns 1984; Lukoschek 2007; Lukoschek, *et al.* 2007; Lukoschek and Keogh 2006; Lukoschek, *et al.* 2007). Essentially, once a species becomes resident on a reef active dispersal and migration between reefs ceases. The distance between reefs on the Sahul Shelf and the deep water between reefs inhibits migration and supports the concept of the sea snakes of each reef forming a discrete 'management unit' for each species and prevents species from occupying all reefs.

Table 1 Recorded distribution of the common reef-dwelling sea snake species on the shelf edge reefs of the Sahul Shelf prior to the 2009 hydrocarbon release.

Species	Ashmore Reef	Browse Island	Cartier Island	Hibernia Reef	Mont-gomery Reef	Scott Reef	Seringa-patam Reef
Leaf-scaled Seasnake	√	-	-	√	-	-	-
Dusky Seasnake	√	-	√	√	-	√	-
Short-nosed Seasnake	√	-	-	√	-	-	-
Olive Seasnake	√	-	√	√	-	√	√
Horned Seasnake	√	-	√	√	-	√	-
Stokes' Seasnake	√	-	√	√	√	-	-
Dubois' Seasnake	√	-	-	√	-	√	-
Turtle-headed Seasnake	√	-	√	√	-	√	√

Species living between reefs are believed to move to some extent with ocean currents yet still remaining within unspecified home ranges. The seasonal presence of species in more temperate regions is associated with the southern movement of tropical waters (Cogger 1975; Limpus 1975). There has been no study of sea snake migration done on the open water species to determine the extent of their movements.

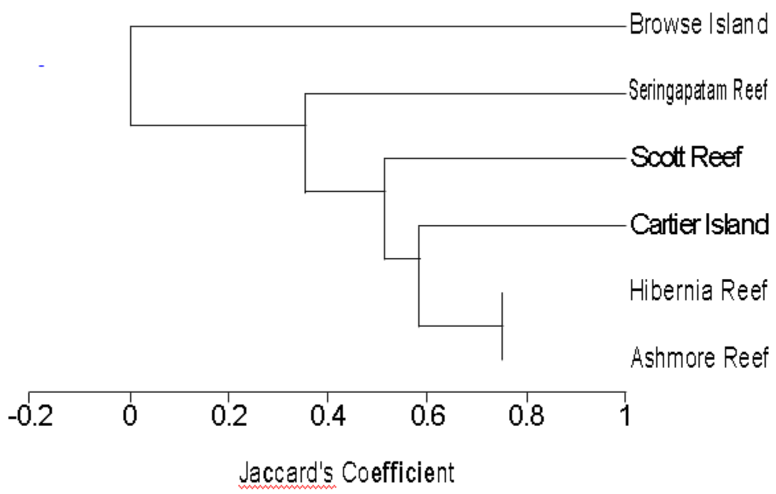


Figure 2 Jaccard similarity coefficient illustrates the historical species similarity of sea snake species on the reefs on the Sahul Shelf (Francis 2006).

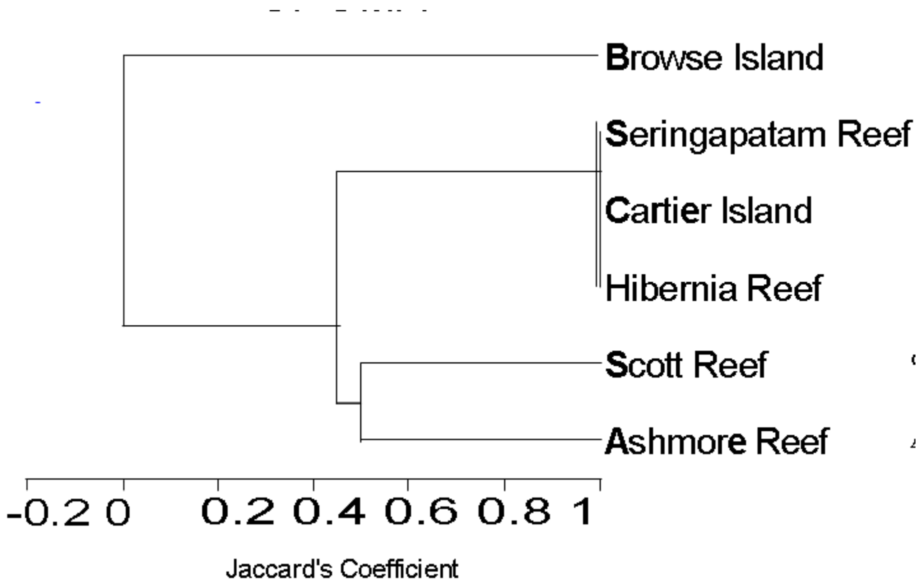


Figure 3 Jaccard similarity coefficient illustrates the species similarity of sea snakes on the reefs on the Sahul Shelf in 2006 (Francis 2006).

2.3 Marine Turtles

The reefs and waters of the Sahul Shelf support various life stages of marine turtles. They belong to several genetic sub-populations from Indian Ocean countries but are dominated by those with their nesting beaches in northern and Western Australia. In

contrast to sea snakes, marine turtle species have complex life cycles involving active dispersal and several stages and periods of migration. Two discrete genetic sub-populations nest on beaches of the Sahul shelf islands. Ashmore Reef and Cartier Island host a common gene pool. Scott Reef and Browse Island supports the other. Both have a similar life cycle (Figure 4).

The current understanding of the life cycle begins with hatchlings moving from the nest above the high water mark to the beach and beyond to oceanic and coastal habitats before returning 30 to 50 years later to the region of their birth to breed. In the case of Scott Reef and Ashmore Reef turtles, this life cycle may involve feeding and moving between reefs in the tropical Indian Ocean and northern Australia. During the breeding season the marine turtles from the Scott Reef and Ashmore Reef management units, congregate in October at their respective reefs (Whiting *et al*. 2005) where they mate. The females nest on several occasions above the high tide mark on the beaches and spend the inter-nesting periods in shallow water beyond the reef edge. Nesting activity reaches a peak in January and February with a peaking in hatching about 7 weeks later in March and April. Also on the reef during the breeding season and throughout the year are the non-breeding sub-adult and adult turtles that forage and reside in the area. Genetic studies (Dethmers, *et al.* 2005) have revealed these belong to other management units in Western Australia and the Indian Ocean.

Within the generalised life cycle, there are at least two cycles that involve breeding females using the reefs, lagoons and beaches at Scott Reef:

- the female nesting cycle – every 2 to 8 years when female green turtles migrate from their foraging grounds to Ashmore Reef and Scott Reef respectively to breed (remigration interval),
- the inter-nesting cycle – females spend 2 to 3 months within the vicinity of the nesting island moving only short distances of some tens of kilometres or less and nesting from 3 to 6 times during the nesting season every 8 to 16 days.

2.3.1 Female Nesting Cycle

The female nesting cycle involves an individual female attaining sufficient body fat and reserves in the foraging grounds to become reproductive (Hamann, *et al.* 2003). An unknown trigger initiates her migration, of up to several thousand kilometres, from the foraging grounds to a mating area close to her natal beach (Miller 1997). This migration coincides with similar movements by males (Hamann, *et al.* 2003). After mating, the female turtle becomes unreceptive to further courtship (Booth and Peters 1972) and moves closer to the nesting beach over the next few weeks. At this point, she enters the inter-nesting cycle (Hamann, *et al.* 2003). After laying several clutches of eggs, and having depleted the fat reserves and ripe ovarian follicles, the females undertake post-breeding migration back to the foraging grounds (Hamann, *et al.* 2003).

Being herbivorous, the time until the next breeding migration depends on the richness of the algal beds and seagrass pastures of the foraging grounds (Miller 1997). Typically, at least three years or more are required to replenish the fat reserves and to develop mature ovarian follicles (Arthur, *et al.* 2009; Miller 1997). The time between successive reproductive periods is called the remigration interval. Neophytes (first time nesters) are thought to undertake a breeding migration when they have sufficient fat reserves which have accumulated over many years (Hamann, *et al.* 2003; Miller

1997). However, they respond to the same triggers that initiate the reproductive migration of seasoned nesters and make the journey to their natal beaches (Miller and Limpus 2003; Plotkin 2003). In nesting seasons following a period of low productivity on the foraging grounds, the neophytes remain capable of making the nesting migration where as recently returned females may lack body condition (Miller and Limpus 2003). Smaller, and presumably younger, marine turtles may therefore have a disproportionately higher representation amongst the nesting population when fewer turtles make the breeding migration (Hamann, *et al.* 2003; Limpus, *et al.* 2003a). In years with little nesting the population may comprise individuals whose foraging grounds are closer and require fewer body reserves, individuals that have not nested for some time and individuals that are residents of very productive foraging grounds (Hamann, *et al.* 2003; Miller 1997; Miller and Limpus 2003).

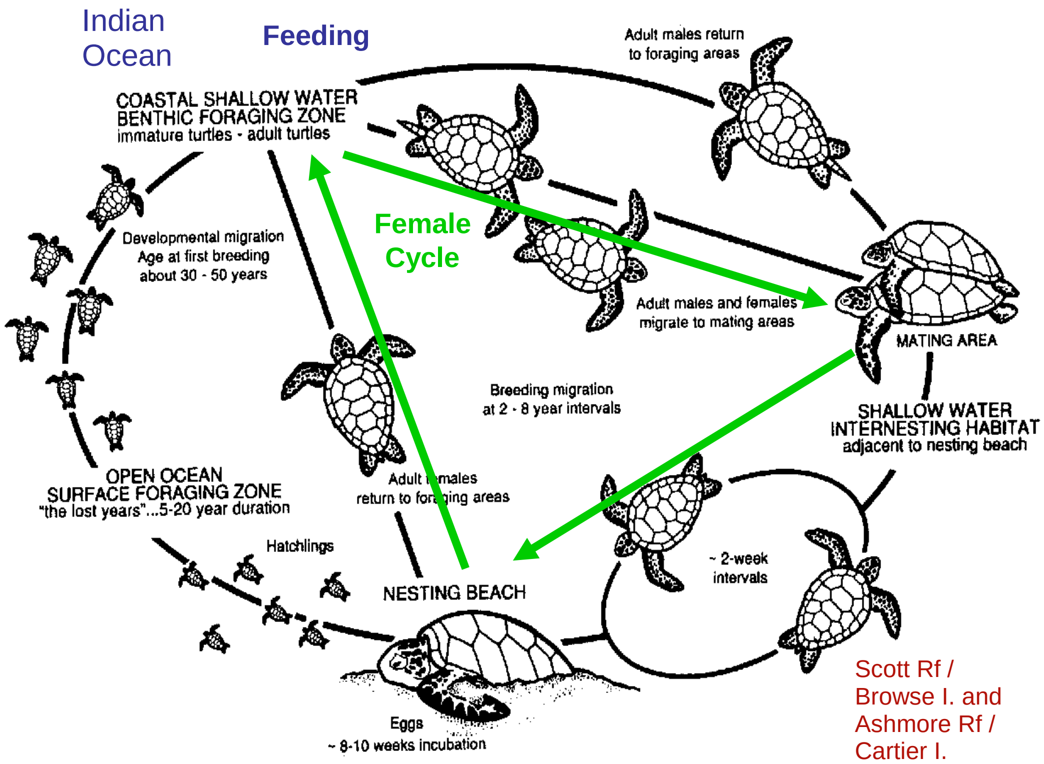
2.3.2 Inter-nesting Cycle

Once nesting starts, the inter-nesting cycle is approximately two weeks in duration and depends, in part, on water temperature (Hamann, *et al.* 2003; Hirth 1993; Miller 1997). The female occupies an inter-nesting habitat after each nesting event. For Green Sea Turtles these inter-nesting habitats are defined by their function rather than by location. Satellite tracking has demonstrated that during the inter-nesting period, female turtles visit different substrates, occupy different depths, and may move up to tens of kilometres from the nesting beach (Alvarado and Murphy 1999; Bell, *et al.* 2009; Hays, *et al.* 2002; Limpus, *et al.* 2003a). Turtles that remain close to the nesting beach also appear to move through several near shore habitats during the inter-nesting interval (Limpus 2008; Limpus and Reed 1985).

2.3.3 The Foraging Turtles

Other age classes present on the reefs of the Sahul Shelf comprise the hatchling of the present breeding season. These leave the nests above the tide line, cross the beach, the reef flat and into the open ocean. Any impediment to their movement across the beach and reef flat such as surface deposits of hydrocarbons jeopardise their survival by restraining their movement through viscous oils or through the toxic effect of lighter oils. While crossing the beach and reef flat, they are vulnerable to many predators including ants, crabs, octopus, fish, birds and even sea anemones.

Juvenile turtles in the 35 to 50 cm size are recently recruited to the reef from the open ocean. New recruits are characterised by having a brilliant white plastron (belly plate) and the trailing edges of the scales are very sharp having not been in contact with the sea floor, sand or coral (Whiting *et al.* 2005a; Whiting 2000). Turtles of this size that have darker plastrons have been resident on the reef for some time. Also resident on the reef are larger turtles that are not yet of breeding size (80 cm) and may not have the external sexual characteristics of adult males. These are considered sub-adult turtles. Additionally there are adult male turtles, easily recognised by their elongated tail and short tail adults comprising migrating breeding females in their pre-nesting and internesting habitat and non breeding resident females. Since the dark plastron juveniles and the sub-adults may have been resident on the reef for some years analysis of their body tissues may be useful in indicating whether some impact by hydrocarbon has occurred.



(Source Miller 1997)

Figure 4. Generalised life cycle of marine turtles showing the female cycle of 2 to 8 years (green), the inter-nesting cycle of 8 to 16 days, the nesting activities on Ashmore and Scott Reefs (red) and the pelagic and neritic foraging stages (blue).

2.4 Previous surveys of the reefs of the Sahul Shelf

2.4.1 Ashmore Reef

Ashmore Reef is an emergent continental shelf edge reef situated about 450 nautical miles west of Darwin, 330 nautical miles north of Broome and about 60 nautical miles south of the Indonesian island of Roti (Berry 1993; Commonwealth of Australia 2002; Pike and Leach 1997). The elongate reef straddles 12°15′ S latitude centred either side of 123° E longitude (Figure 5). Three substantially vegetated sand cays sit equidistant along the 25 km east-west axis with a sand bar supporting grasses and herbs formed to the east of East Island. The southern weather-side of the reef is unbroken, but two large lagoons penetrate the northern reef crest (Figure 5). It is a National Nature Reserve with a Marine Park extending seaward of the reef crest and is the focal area for assessing probable or possible impact from the 2009 hydrocarbon release from the Montara Well .

Figure 5. Ashmore Reef showing the location of the three major islands West Island, Middle Island and East Island (Image courtesy of AIMS).

2.4.1.1 Sea Snakes

The reef and these lagoons have been the focus of several sea snake studies. Malcolm Smith in his seminal monograph "Monograph of the Sea-snakes (Hydrophiidae)" described the abundance of sea snakes at Ashmore Reef with these words:

"A large collection of sea-snakes recently obtained for me by native (Malay) collectors on the Ashmore Reefs was remarkable in that it was composed entirely of *Aipysurus* (5 species) and *Emydocephalus* (1 species). Over 100 specimens were collected and many more could have been obtained." (Smith 1926 p.17).

In 1972 the RV Alpha Helix anchored in the most eastern lagoon. During the one-week visit divers collected over 400 sea snakes. This visit was the impetus for a compilation of what was known of the ecology, physiology and toxicology of sea snakes "The Biology of Sea Snakes" (Dunson 1975). This comprehensive work dealing with ecology, behaviour, physiology, toxicology and biology highlighted Ashmore Reef as the centre of sea snake diversity and abundance.

Reports of sea snake abundance at Ashmore Reef were sporadic, opportunistic and observational until staff from the Museum and Art Galleries of the Northern Territory and Western Australian Museum started expeditions to the reefs of the Sahul Shelf nearly two decades later (Berry 1986; Berry 1993; Russell and Hanley 1993; Russell and Vail 1988 ; Vail and Russell 1989). Ashmore Reef became the focus of sea snake studies (Guinea 1995b) that continued at yearly to two yearly intervals until 2000 when surveillance and apprehension of increasing numbers of suspected illegal immigrants made research trips difficult. Ashmore Reef has been publicised as the sea snake capital of the planet in "Serpents of the Sea" (Natural History New Zealand and Discovery Channel 1999) and "Mark O'Shea Big Adventure: Sea Serpents" (Animal Planet: Yorkshire Television/ Producers Pty Ltd 2001). It has been the study area for two PhD theses on sea snakes (Guinea 2003; Lukoschek 2007) and continuing studies by these researchers.

The reputation of Ashmore Reef being an area of high species abundance and diversity including being the home of three endemic species of *Aipysurus* has stood for almost a century. The nine reef dwelling species in Table 1 have been the focus of previous reports (Guinea 1995b) and publications (Guinea, *et al.* 2004; Guinea, *et al.* 2004; Guinea and Whiting 2005; Minton and Heatwole 1975). However at least 13

species of sea snakes are reported from the waters of Ashmore Reef (Commonwealth of Australia 2002) and a further four species are thought to exist in the area (Heatwole and Cogger 1994) but specimens have not been collected from within the marine reserve (Table 2).

In April 2003 when visits to Ashmore Reef recommenced after a break of three years, the most noticeable finding was the absence of sea snakes. Only the generalist feeding species such as the Olive Seasnake (*Aipysurus laevis*) and the Dusky Seasnake (*A. fuscus*) remained in small numbers. In November 2005 even their presence had dramatically reduced as no sea snakes were seen within the West Island channel and the inner mooring at Ashmore Reef. This trend continued in the survey of 2008 (Figure 6) when only six sea snakes were seen in almost three weeks of surveys (Guinea 2008). Reasons for these declines in species abundance and diversity remain speculative (Guinea 2012a). Global warming was assumed to be a cause of such decreases. However Ashmore Reef was less impacted than was Scott Reef in the coral bleaching events of 1998 where sea snakes still occur. Suggested causes of this decline rest with more direct human activities at a local or regional scale. Another important question is if whatever caused the decline has passed, what is preventing the recolonisation of sea snakes to Ashmore Reef?

Table 2 List of sea snake species reported from Ashmore Reef (Cogger 2000, Heatwole and Cogger 1994) with the common reef-dwelling species indicated by an asterisk (*).

Common Name	Systematic Name	Distribution
Horned Sea snake*	*Acalyptophis peronii*	Australia, Taiwan, China
Short-nosed Sea snake*	*Aipysurus apraefrontalis*	Sahul Shelf Australia (endemic)
Dubois's Seasnake*	*Aipysurus duboisii*	Australia, Melanesia
Spine-tailed Seasnake	*Aipysurus eydouxii*	Australia, South East Asia
Leaf-scaled Seasnake*	*Aipysurus foliosquama*	Sahul Shelf Australia (endemic)
Dusky Seasnake*	*Aipysurus fuscus*	Sahul Shelf, (endemic) Indonesia (?)
Olive Seasnake*	*Aipysurus laevis*	Australia, Melanesia
Stokes' Seasnake*	*Astrotia stokesii*	Australia, South East Asia
Spectacled Seasnake	*Disteira kingii*	Australia (endemic)
Turtle-headed Seasnake*	*Emydocephalus annulatus*	Australia, Indonesia, Melanesia
Black-headed Seasnake	*Hydrophis atriceps*	Australia, South East Asia
Belcher's Seasnake	*Hydrophis belcheri*	South East Asia, New Guinea
Slender-necked Seasnake*	*Hydrophis coggeri*	Australia, Melanesia
Elegant Seasnake	*Hydrophis elegans*	Australia (endemic)
Ornate Seasnake	*Hydrophis ornatus*	Persian Gulf to Australia
Spine-bellied Seasnake	*Lapemis hardwickii*	South East Asia, Australia
Yellow-bellied Seasnake	*Pelamis platurus*	Tropical Indian and Pacific Oceans

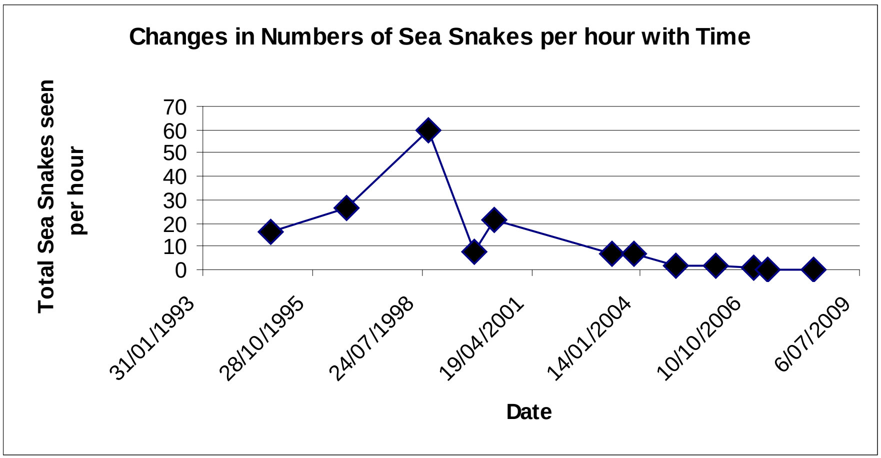


Figure 6 Standardised catch rates for sea snakes in the inner mooring at West Island Channel from 1994 to 2008.

2.4.1.2 Marine Turtles

The presence of nesting marine turtles on the islands of Ashmore Reef was first reported in the early 1950s (Serventy 1952a; Serventy 1952b) but was ignored largely until the signing of the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974 (Campbell and Wilson 1993; Wilson 1993). Australia declared a marine protected area around Ashmore Reef in 1983 and marine turtle management was a feature of the management plan (Commonwealth of Australia 2002). Assessing the numbers of nesting turtles was on an *ad hoc* and voluntary basis in the 1980s with patrol officers recording numbers and some tagging initiated by crew of Off-Shore Petroleum employees, the crew of the contract vessel "Aurelia IV" on station and the Department of Parks Australia North. In 1994 assessment of marine turtle numbers became more standardised yet remained fragmentary with surveys being conducted every two years or so (Guinea 1995b; Whiting and Guinea 2005a).

Three species of marine turtles have been recorded nesting on Ashmore Reef. The most common species is the Green Sea Turtle that nests mainly on West Island with a few Hawksbill Sea Turtles also nesting on West Island but also on Middle and East Islands. A single Loggerhead Sea Turtle was photographed nesting on West Island (Des Pike personal communication). Loggerhead Sea Turtles are found on the reef flat foraging on molluscs. Genetic studies indicate the nesting Green Sea Turtle of Ashmore Reef form a distinct management unit with those nesting on Cartier Island (Dethmers, *et al.* 2006a). Up to 50 Green Sea Turtles nest at night in the peak of nesting season that coincides with the Australian summer months (Whiting and Guinea 2005a). During the 8 days of the survey in November 2007, 63 Green Sea Turtles nested on West Island and 14 nests hatched. The successful nests were in stark contrast to the records for the previous two years when many turtles failed to nest successfully (Guinea 2007b).

The foraging Green Sea Turtles are a mixture of gene pools. Individuals feeding on Ashmore Reef are from a number of different metapopulations. Almost 70% of small (<60 cm) Green Sea Turtles belong to the North West Shelf gene pool (Lacepede Islands to Ningaloo Reef) another 20% are from Scott Reef (Dethmers et al. 2005).

These turtles remain on Ashmore Reef feeding on algae and seagrass for some years or even decades before moving to other locations on their developmental migration along the north Australian coast and into Indonesia (Whiting and Guinea 2005a). The genetic identities of turtles foraging on reefs other than Ashmore Reef have not been investigated but are expected to be from a similar mix of gene pools.

The reef flat supports a large number of Green Sea Turtles foraging on sea grass and algae. Initial estimates indicated 10,714 Green Sea Turtles foraged over the reef flat at high tide giving a density of 61.6 turtles per km^2 (Guinea 1995a) and later estimated as 10,665 Green Sea Turtles on the entire reef flat (182 km^2, excluding the deep lagoons) (Whiting and Guinea 2005a). The density of sub adult Green Sea Turtles over three years from 1996 to 1998 were 53.8, 45.8 and 76.2 turtles/km^2 respectively giving an average value of 58.6/km^2 (Whiting and Guinea 2005a). Hawksbill and Loggerhead Sea Turtles were too few to produce a density estimate.

Surveys by boat at high tide from the West Island channel to Middle Island varied in length from year to year but consistently recorded large numbers of Green Sea Turtles. On 2 December 2004, 126 marine turtles were seen within 20 m of the boat as it crossed from West Island to Middle Island. On 17 November 2003, nine transects of five minutes each, recorded 289 marine turtles. In November 2004 and 2005, 248 and 277 juvenile Green Sea Turtles were reported respectively (Whiting and Guinea 2005a). On 23 March 2007, 248 turtles were recorded on seven transects of the Ashmore Reef flat (Guinea 2007b). Ashmore Reef is the only reef recorded on the Sahul Shelf where such numbers of Green Sea Turtles gather to feed.

2.4.2 Scott Reef

Scott Reef is a continental shelf edge island located 234 nautical miles north of Broome, Western Australia. Sandy Islet is an elongated unvegetated sand cay 300 m in length by 70 m in width and is the only emergent land at high-water. The remains of a derelict weather station, a more recent concrete sledge inscribed “Cape Grafton 12 94”, and the concrete headstones and graves of Indonesian fishers are the remaining man-made structures of what was once a significant port of call for trepang and guano vessels. Sandy Islet and portions of the Southern Reef are a nature reserve of Western Australia. The reef extends 20 nautical miles from north to south and is 15 nautical miles from west to east (Figure 7). It comprises a horseshoe-shaped southern reef and a near circular northern lagoon within a ring reef. This is an area unlikely to have been impacted by the hydrocarbon release in 2009. Scott Reef had been visited ten times by the author since 1994 prior to the current surveys. Previous visits have focused on sea snakes and nesting turtles in 2006 and only nesting turtles in 2008 to 2010. It was considered to be a “control” in this survey and examined for sea snake, marine turtles and for the collection of habitat data.

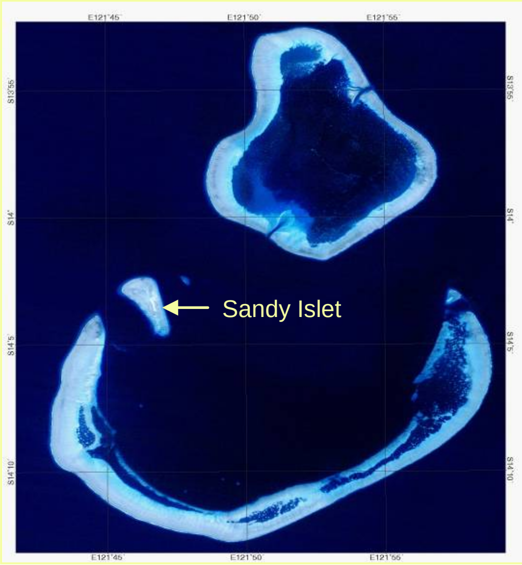


Figure 7 Scott Reef comprises of the southern horseshoe-shaped reef, a small isolated reef supporting the sand cay, Sandy Islet, and a northern ring reef with two distinct channels. (Image courtesy of AIMS).

2.4.2.1 Sea Snakes

Scott Reef was visited three times in 2006 to assess sea snake and marine turtle abundance. Multiple manta board surveys were conducted in February 2006 along the reef crest, in the channels and lagoons. Manta board surveys on Scott Reef at that time totalled 6 hours and 20 minutes with only one of the 16 transects lacking sea snakes. The maximum sighting rate was 35 sea snakes per hour or about one sea snake every two minutes. The average rate of sightings was 12.7 snakes per hour or about 3 snakes per kilometre of reef crest (Guinea 2006d), This was similar to that seen at Hibernia Reef and Cartier Island (Francis 2006) in the same year. Sea snakes were not evenly distributed over the reef crest as demonstrated by several manta board surveys in the southern parts of the reef. The outer reef crest had from 0.9 to 1.26 snakes per ha. In the inner lagoon had 0.9 to 1.1 snakes per ha. Other regions had densities of 0.26 and 0.57 snakes per ha (Guinea 2006c). Olive Seasnakes and Turtle-headed Seasnakes were about equal in their reporting and made up 75% of the sightings (n = 36). The Dusky Seasnakes were next most numerous being 15 % of the sightings. The remainder were unidentified.

The reef was visited again in for eight days in September 2006 when 52 sea snakes were seen. Four species were recorded Olive Seasnakes (52%), Turtle-Headed Seasnakes (32%), Dubois's Sea Snakes (10%) and Dusky Seasnakes (6%). Manta board surveys proved the most efficient means of assessing the numbers of snakes present. Sea Snake sightings were: one snake every 3.3 minutes for manta board and one every 9.75 minutes for drift diving. Mating and courtship behaviours were reported in September for Olive Seasnakes, Turtle-Headed Sea snakes and Dubois's Seasnakes (Guinea 2006b).

The November survey in 2006 revealed the presence of the Slender-Neck Seasnake (*Hydrophis coggeri*) that was identified from an underwater video recording of the deep sandy regions of the lagoon. A manta board survey over many regions of the reef recorded 37 sea snakes in 16 transects covering a total of 16.11 km. Olive Seasnakes and Turtle-Headed Seasnakes were about equal in occurrence and together accounted for 80% of the snakes recorded. Dusky Seasnakes and Dubois's Seasnakes made up the remainder. Sea snake densities ranged from 0 to 2 snakes per hectare (mean ± sd = 0.76 ± 0.71) (Guinea 2006c).

2.4.2.2 Marine Turtles

Sandy Islet was visited three times in 2008 and once in 2009 to asses nesting marine turtle abundance (Guinea 2009) and in 2010 to identify internesting habitats of nesting Green Sea Turtles (Guinea 2010). Green Sea Turtles were the most common nesting species on Sandy Islet as only one Hawksbill Sea Turtle nested over the three years of survey. This was the same individual nesting three years apart. Genetic studies indicate the Green Sea Turtles at Scott Reef form a discrete management unit with those turtles nesting on Browse Island (Dethmers 2010; Dethmers, *et al.* 2006b).

2.4.2.2.1 Nesting Marine Turtles

Nesting numbers vary on the time of the year and the size of the nesting season (Table 3). Sandy Islet is regarded as a moderate nesting site with up to 1000 individuals nesting per year. The size of the nesting population varied from 779 (± 383) estimated in 2009 to 79 (± 25) in 2010. The peak of the nesting season is in middle to late January (Guinea 2009; Guinea 2010; Guinea 2012b) with most of the nesting occurring in spring and summer months.

Table 3 Numbers of Green Sea Turtles tagged per visit to Sandy Islet, Scott Reef and the number of tracks on the beach in 2006, 2008 and 2010 (Guinea 2010).

Start Date	Number of ashore nights	Number of Green Turtles tagged	Mean Number of tracks /night ± sd
15 Feb-06	3	29	16.2 ± 4.87
2 Sep-06	1	0	0
23 Nov-06	5	92	23.6 ± 7.57
27 Aug-08	2	10	9.3 ± 1.15
28 Sep-08	6	4	7.8± 5.89
10 Dec-08	7	107	53.1 ± 16.87
25 Jan 2009	7	193	71.9 ± 6.98
29 Jan Feb 2010	13	54	13.2 ± 5.43
Total	44	489	

2.4.2.2.2 Foraging Marine Turtles

In February 2006 very few marine turtles of non-nesting size were seen during the 19 manta board surveys. Only three sub-adult Green Sea Turtles were seen in 19 km of reef flat. In the 8 km of manta board surveys in September 2006 only one sub-adult Green Sea Turtle was recorded. (Guinea 2006b). Similar low numbers were seen in November 2006 with only five sub-adult Green Sea Turtles recorded in the 16.11 km of manta board surveys (Guinea 2006c). In February 2006, two boat transects each 7.7 km in length were conducted in the Northern Lagoon of Scott Reef. No turtles of any size were seen within 25 m of the boat in spite of macro algae and seagrass being present, although sparse.

2.4.3 Cartier Island

Cartier Island is an emergent reef situated approximately 137 nautical miles north-east of Scott Reef and 38 nautical miles south-west of Ashmore Reef (Berry 1993;

Commonwealth of Australia 2002; Russell and Hanley 1993; Teichert and Fairbridge 1948). A small, round unvegetated sand cay approximately 600 m in circumference is positioned close to the middle of the reef flat (Guinea 2006a). The cay has a central depression that traps Green Sea Turtles, on occasion, after nesting and at times supports a Crested Tern rookery. The remains of a WW2 RAAF Beaufighter and a grave from which the body was exhumed in 2003 are the only man-made structures on the cay. The reef extends in the east-west direction with the long axis being approximately 5 km in length (Figure 8). The reef is about 2 km in width (Russell and Hanley 1993) Both Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve are within Commonwealth waters and management plans have been prepared under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Being so close to Ashmore Reef, Cartier Island is another area of probable or possible impact from the hydrocarbon release in 2009.

Figure 8 The sand cay on Cartier Island sits near the centre of the reef. The island lacks a lagoon (image courtesy (Russell and Hanley 1993).

2.4.3.1 Sea Snakes

Only the northern edge of Cartier Island reef is surveyed by manta boards because the swell on the southern side is considered too dangerous for the tender vessel crew and the researchers. Manta board surveys on the northern edge last usually from 45 to 75 minutes and comprise three, one-kilometre-long, individual tows. In 70 minutes of snorkelling on 8 May 1992, 14 Turtle-headed Seasnakes were reported along with a single Olive Seasnake (Guinea 1993b). On 22 November 2005, 5 Turtle-headed Seasnakes and an adult Olive Seasnake were seen in 35 minutes of snorkelling on the northern reef crest (Guinea 2006a). On 19 March 2007, 11 Olive Seasnakes, 7 Turtle-Headed Seasnakes were recorded along with 11 others that were unidentified due to their depth (Guinea 2007a). In the afternoon of 14 May 2008, 12 sea snakes were recorded on the northern reef crest of Cartier Island. This equates to at least four sea snakes per kilometre of reef crest (Guinea 2008).

2.4.3.2 Marine Turtles

Green Sea Turtles nest on the sand cay at Cartier Island (Guinea 1993b; Guinea 2006a; Guinea 2007a; Guinea, *et al.* 2006). Most visits to the sand cay have been very short; lasting only a couple of hours. The longest visit lasted 24 hrs on 6 May 1992 during that time one adult green turtle nested. Tracks of 15 other nesting attempts indicated that others were trying to nest at the time but were prevented from doing so by the soft dry sand. Hatched nests were more numerous with 53 being identified in

the previous couple of days indicating nesting was more intense and conditions for nesting more favourable in late February and early March some 60 days earlier (Guinea 1993b) and probably shared a late summer peak in nesting with the Green Sea Turtles on Ashmore Reef. Genetic studies indicate Green Sea Turtles on Ashmore Reef share a common gene pool with those nesting on Cartier Island (Dethmers, *et al.* 2006a).

Green Sea Turtle are regularly seen during manta board surveys on the northern side of Cartier Island. On 19 March 2007, 33 juvenile and 2 adult Green Sea Turtle were recorded in the 3 km transect of the northern Cartier Reef (Guinea 2007a; Guinea 2007b) Six sub-adult Green Sea Turtles were seen in a 35 min manta board survey of the northern reef crest in 2008 (Guinea 2008).

2.4.4 Hibernia Reef

Hibernia Reef is a platform reef approximately 30 nautical miles north-east of Ashmore reef. It rises steeply from a depth of 100 m and dries during spring low tides (Figure 9). The sand bar on Hibernia Reef is sub-tidal and is only exposed at low water on spring tides. The southern and western regions of the reef form a continuous crest but the northern and eastern sides are less well defined. A narrow channel allows small vessels entry to the lagoon, which reaches 40 m in depth. It may be an area of potential impact given its proximity to Ashmore Reef and reports of surface sheen following the 2009 release.

Figure 9 Hibernia Reef with the central lagoon and near complete ring reef.

2.4.4.1 Sea Snakes

Several days were spent in Hibernia Reef Lagoon in May 1992 during which time single-observer, manta board surveys, SCUBA dives and boat transects recorded nine species of sea snakes inhabiting the lagoon (Guinea 1993b). The reef was visited again in 2005 for only four hours during which time two divers surveyed the entire inner wall of the lagoon recording 35 sea snakes. Turtle-Head Seasnakes were the most common making 68% of the sightings. Olive Seasnakes and two Dusky Seasnakes comprised the rest of the sample. In 2007, twenty-one sea snakes were recorded by two observers using manta boards. Rough sea state and a rising tide reduced the visibility and the survey was terminated after 3 hours. Turtle-headed Seasnakes and Olive Seasnakes made up over 70% of the sightings. The remaining sea snakes were unidentified (Guinea 2007a).

2.4.4.2 Marine Turtles

Hibernia Reef lacks a suitable sea turtle nesting beach because the sand bar is covered at all tides except spring low tides (Russell and Hanley 1993). Sub-adult Green Sea Turtles are seen on the reef but their numbers are much lower than at Ashmore Reef. In the 1992 surveys only four sub-adult Green Sea Turtles were recorded in the lagoon. Similar numbers were seen in 2005 and 2007.

2.4.5 Seringapatam Reef

Seringapatam Reef is 30 nautical miles north of Scott Reef. Like Hibernia Reef it is a ring reef with a central lagoon (Figure 10). A small sand cay in the northern lagoon dries at spring low water. A single channel to the East allows access to the lagoon with several drainage channels running to the west (Teichert and Fairbridge 1948). This is unlikely to have been impacted by the hydrocarbon release. The survey on this reef is to provide a control site for changes in sea snake and marine turtle populations.

Figure 10 Seringapatam Reef with a central lagoon and near complete ring reef.

2.4.5.1 Sea Snakes

In February 2006, sea snakes were common on the reef crest. During a snorkel on the reef crest 16 sea snakes were seen within 30 metres of the vessel at anchor during 60 minutes. Only Olive and Turtle-Headed Seasnakes were seen during surveys on Seringapatam Reef. Of the 35 sea snakes recorded Turtle-headed Seasnakes (68.57%) were more commonly seen than Olive Seasnakes (31.43%). A crewmember reported seeing a Stokes's Seasnake (*Astrotia stokesii*) while at anchor but this was not verified.

Sea snakes were seen on all but one of the manta tows. Sighting rates varied from zero in 20 minutes to 16 sea snakes in 20 minutes with most sighting rates being in the order of one snake every 1.25 to 24 minutes. When converted to densities using the transect lengths of 1 km, sea snake densities varied from 0 to 5.3 snakes per hectare

(mean ± sd = 1.94 ± 2.19 snakes/hectare, n = 6) of reef crest, pavement and back reef edge. The standard deviation being greater than the mean further highlights the patchiness of the sea snake distributions.

2.4.5.2 Marine Turtles

The absence of a beach prevents marine turtles nesting at Seringapatam Reef. The small sand cay in the north of the lagoon is covered at high tide. Only sub-adult marine turtles were recorded during manta tows. These were sparse, less than 1 per kilometre, as were the potential sources of food. Seagrasses were present in small patches but appeared to be insufficient to support a large foraging population of marine turtles or dugongs (Francis 2006; Guinea 2006d).

2.4.6 Browse Island

Browse Island is an uplifted vegetated near-circular island 92 nautical miles east of Scott Reef. It sits near the centre of a near-circular reef exposed to strong winds and swell (Figure 11). The island is a Western Australian Nature Reserve. Remnants of buildings and wharf from the guano mining days in the late 1800s remain on the island as does a modern functional light house.

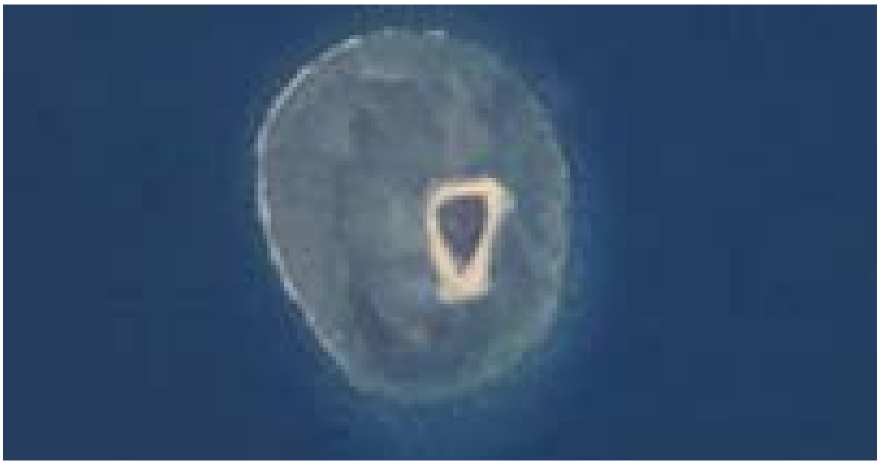


Figure 11 Browse Island with the central island and a circular platform reef.

2.4.6.1 Sea Snakes

No sea snakes were seen during the brief manta tows and drift snorkels over the reef flat in February 2006. Although there are limited marine biodiversity reports of Browse Island sea snakes are not mentioned in those that have been published such as "Prelude Floating LNG Project Draft Environmental Impact Statement" (Shell 2009). Baseline information on the sea snakes at Browse Island is lacking as there have been no dedicated sea snake surveys of the reef. A report by a crew member of a sea snake on the reef flat may have been a misidentification of a moray eel which are plentiful.

2.4.6.2 Marine Turtles

A single night was spent on Browse Island looking for nesting marine turtles in February 2006. Numerous Green Sea Turtle tracks indicated the area had considerable nesting activity. The night spent ashore resulted in only one Green Sea Turtle

emerging as the tides were at neaps. Four Green Sea Turtles came ashore to nest on 8 September 2006. This was more than had been reported for Sandy Islet in the previous10 days (Guinea 2006b). Over the past decades there have been numerous reports of marine turtles being slaughtered by presumably Indonesian fishers on the beach before laying and their eggs removed.

A number of Green Sea Turtles (11 in 10 minutes) were recorded in less than 10 m of water during a manta tow in February 2006. These marine turtles appeared to be feeding on filamentous green algae. This reef was unlikely to have been impacted by the hydrocarbon release in 2009 and will be considered as a control site. A survey of the intertidal area and the beach may provide information on this control site.

2.4.7 Montgomery Reef

Montgomery Reef is 8 nautical miles from the mainland on the Kimberley coast. The reef has an extensive reef flat with several mangrove islands towards its centre and two rocky island to the East; the reef is cut in several places by deep drainage channels, the largest of which runs to the north to the middle of the reef (Figure 12). This is an un-impacted reef and is used as a control site for obtaining blood samples from foraging Green Sea Turtles.

Figure 12 Montgomery Reef on the Kimberley coast with its extensive reef flat.

2.4.7.1 Sea Snakes

There have been no published accounts of sea snakes from Montgomery Reef. Stokes' Seasnakes have been seen in the channels at low tide (personal observations in 2001) and photographed on the reef flat (T. Willing no date). Little else is known of the sea snakes at Montgomery Reef and the Kimberley coast.

2.4.7.2 Marine Turtles

There are no published accounts of marine turtles at Montgomery Reef. Sub-adult Green Sea Turtles were seen foraging in the shallows at the edge of the channels in July 2001 (personal observations). The channels appeared to be a suitable location to capture by hand a number of sub-adult Green Sea Turtles as the tide rises.

2.5 Objectives:

The aims of this survey were to investigate the waters of Scott Reef, Seringapatam Reef, Browse Island, Ashmore Reef, Hibernia Reef and Cartier Island to assess their sea snake and marine turtle populations and the possible impact of the 2009 hydrocarbon release from the Montara Well and any detectable recovery should there have been an impact. Special attention was warranted for Ashmore Reef and Cartier Island being National Nature Reserves and Marine Protected Areas and Scott Reef and Browse Island being Western Australian Fauna Reserves. The data set used to detect a change in the species present at each reef and their respective numbers is drawn from 256 days of surveys over the reefs of the area spanning almost 20 years (Table 4). The specified objectives were:

1. To quantify the presence of EPBC listed fauna (sea snakes and marine turtles) and flora in the subject area pre-impact in order to determine the level of potential exposure to hydrocarbons.

2. To identify and quantify the pre-impact status of fauna (e.g. nesting and breeding activity) and health of reefs.

3. To identify and quantify the post-impact status of fauna (e.g. nesting activity) and health of reefs.

4. To quantify recovery from any harmful effect of oil impact on flora, fauna, habitat or communities in the subject area.

As the 2012 survey was interrupted by bad weather and a cyclone, a subsequent survey in 2013 aimed to survey the remaining impacted reef, Cartier Island, and the control reef, Browse Island. Montgomery Reef on the Kimberley coast was chosen for its abundance of sub-adult Green Sea Turtles as a control site from which blood samples could be collected. The samples would be analysised for blood chemistry and enzymatic parameters and compared with samples collected from Ashmore Reef in 2012.

Table 4 Dates of Surveys and their durations of the reefs and islands of the Sahul Shelf and the Kimberley Coast. The present survey is shown in bold.

Start Date and Duration (days)	Ashmore Reef	Browse Island	Cartier Island	Hibernia Reef	Mont-gomery Reef	Scott Reef	Seringa-patam Reef
6 May 1992 (14)			√	√			
17 Sept 1994 (26)	√					√	
31 Aug 1996 (11)	√						
18 Sept 1998 (26)	√						
21 June 2001(10)					√		
22 Apr 2003 (9)	√		√				
14 Nov 2003 (11)	√		√				
27 Nov 2004 (9)	√						
15 Nov 2005 (21)	√		√	√			
15 Feb 2006 (12)		√				√	√
2 Sept 2006 (6)		√				√	
21 Nov 2006 (9)						√	
16 Mar 2007 (13)	√		√	√		√	
9 May 2008 (21)	√		√				
24 Aug 2008 (10)						√	
28 Sept 2008 (7)						√	
10 Dec 2008 (9)		√				√	
25 Jan 2009 (9)		√				√	
18 May 2009 (10)					√		
29 Jan 2010 (13)		√				√	
1 Mar 2012 (13)	√			√		√	√
5 Mar 2013 (18)	√	√	√	√	√	√	√

3 Approaches and Methods

This survey was designed to provide a rapid, but thorough assessment and detection of possible effect of the hydrocarbon release on sea snakes and marine turtles in the region. Several survey techniques were employed to record the animals when they were most easily observed i.e. of maximum detectability. For sea snakes this was at the low tides during the day when the reef flat and crest drain and the sea snakes move to the channels and fore-reef. Marine turtles similarly wait out the low tide in channels and at the reef front. Surveying the reef front and channels at low tide was likely to produce the maximum population estimate for the survey area. Low tide allowed access to the seagrass beds for visual assessment of any hydrocarbon residue on the

reef. Sea snakes were identified using pictorial keys, instructional videos and authoritative books on sea snake species identification (Appendix A) as well as induction snorkel swims where several common species were present and easily observed.

High tides allowed boat access to the beaches to assess the numbers of nesting marine turtles and success of their nesting activity and their hatched nests. Beaches were assessed for evidence of hydrocarbon residue. High tide also provided the opportunity to assess the marine turtles in their foraging habitat at Ashmore Reef. The wide reef flats of Ashmore Reef retained water in channels and hollows where the turtles rested and fed during the low tides. Tides below 2.4 m prevented boat access to the reef flat channels on Ashmore Reef. It was with this combination of tides, reef access and animal availability that assisted in formulating this study proposal. The low tide survey techniques included:

- manta board surveys,
- standard snorkel survey and
- foot surveys of the reef flat for habitat assessment.

High tide surveys included:

- boat transects surveys,
- standard snorkel surveys and
- beach surveys for habitat assessment and for nesting marine turtles.

The Standard Operational Procedures (SOP) with Personal Protective Equipment (PPE) for each participant in each of the methods was provided in the Environmental Health and Safety Manual prepared for the survey.

3.1 Itinerary

Access to the reef at high tide and conducting manta board surveys at low tide were considered in constructing the itinerary and work schedule. At Ashmore Reef the tide needed to be in excess of 2.4 m access the reef flat to capture marine turtles. Access to Seringapatam was not influenced by the tide and surveys could be conducted in neap tides. The itineraries (Table 5 and Table 6) were influenced by the fluctuation of tide heights during the daylight hours (Figure 13). On 11 March 2012 the weather conditions deteriorated producing poor visibility underwater and excessive swell for manta board surveys. Marine turtle catching was confined to the nearby waters of West Island at low tide. On 13 March with a tropical low over the Kimberley and Tropical Cyclone Lua forming near Broome and the ACV and the Ashmore Guardian having left their mooring to ride out the weather elsewhere, the survey was abandoned and the “Kimberley Quest II” headed to Cartier Island. The sea state was too dangerous to launch the tenders at Cartier Island and the vessel headed south to the protection of Yampie Sound. As we passed Browse Island the swell reached 6 m and winds reached 57 knots making for an uncomfortable trip. The survey team disembarked in Derby and travelled by bus to Broome as the town went to blue cyclone alert and to amber alert the following day as Tropical Cyclone Lua crossed the coast south of Broome.

The 2013 survey aimed to survey the reefs missed the previous year. Heavy weather prior to the departure determined the first reef surveyed was Montgomery Reef in the protected macro-tidal waters of Yampi Sound. The weather improved and Browse Island was surveyed en route to Scott Reef. Scott Reef had three survey stations, being South Scott, Sandy Islet and North Scott reefs. Seringapatam Reef was surveyed in the morning and afternoon. Permission to enter Cartier Island was delayed so the "Kimberley Quest II" steamed to Hibernia Reef where the vessel entered the reef and anchored at the western end of the lagoon for two nights before relocating to the eastern lagoon. The arrival at Ashmore Reef coincided with neap tides that restricted vessel movements. Most activities were confined to the West Island Channel where previous surveys were conducted. Permission was granted to transit Cartier Island and to survey the northern reef edge. The passage to Broome was uneventful with fine weather.

Table 5 Itinerary of the survey of sea snakes and marine turtles on the reefs of the Sahul Shelf in 2012.

Date	Locality	Activity
29 February 2012	Broome	Research Team arrives
1 March 2012	Broome	1700 Depart for Scott Reef
2 March 2012	Arrive at Scott Reef late	Anchor at Sandy Islet
3 March 2012	Scott Reef Sandy Islet	Manta board and snorkel surveys Sandy Islet. Habitat assessment of nesting beach
4 March2012	Scott Reef Sandy Islet	Manta board snorkel survey
5 March 2012	North Scott Reef.	Manta board snorkel survey
6 March 2012	Seringapatam Reef	Manta board snorkel survey
7 March 2012	Hibernia Reef	Manta board snorkel survey. SEWPAC Permits arrive for Ashmore Reef
8 March 2012	Ashmore Reef	Afternoon arrival, West Island survey, Manta board snorkel survey, nesting turtle survey habitat assessment of nesting beach.
9 March 2012	Ashmore Reef	Marine turtle survey-blood chemistry, manta board snorkel survey, habitat survey of beach and reef flat nesting turtle survey.
10 March 2012	Ashmore Reef	Marine turtle survey-blood chemistry, manta board snorkel survey, habitat survey of beach and reef flat nesting turtle survey.
11 March 2012	Ashmore Reef	Marine turtle survey-blood chemistry, boat survey of reef flat, habitat survey of beaches on Middle, East and sandbank east of East Island, nesting turtle survey.
12 March 2012	Ashmore Reef	Marine turtle survey-blood chemistry, manta board snorkel survey cancelled,

Date	Locality	Activity
		weather conditions deteriorate.
13 March 2012	Ashmore Reef	Weather conditions deteriorated further and departed Ashmore Reef for Cartier Reef that was too rough to deploy the tenders and water too turbid and sea state too dangerous continue heading South
14 March 2012	At sea	Change course to Yampie Sound to avoid the seas created by TC Lua arriving late at night
15 March 2012	Yampie Sound	TC Lua heads to Broome, "Kimberley Quest II"goes to Derby arriving at 1700, road transport to Broome arriving at 2000. Broome is on Blue Cyclone Alert.
16 March 2012	Broome goes to Amber Cyclone Alert,	Shops and airport closed
17 March 2012	Broome on Amber Cyclone Alert	TC Lua crosses the coast south of Broome.

Table 6 Itinerary of the survey of sea snakes and marine turtles on the reefs of the Sahul Shelf in 2013.

Date	Locality	Activity
5/3/2013	Broome	Depart Broome at 1600 heading to Montgomery Reef
6/03/2013	Montgomery Reef	Anchor at 1350 and lower tenders to investigate channels for green sea turtles. Spotlight at night for sea snakes.
7/03/2013	Montgomery Reef	Caught Green turtles on the rising tide and collected blood samples, Spotlight at night for sea snakes.
8/03/2013	Montgomery Reef	Caught Green turtles on rising tide and collected blood samples. Departed for Browse Island at 1700.
9/03/2013	Browse Island	Shore party investigated sea turtle nesting and beach of any signs of oil contamination. Surveyed the reef edge and reef flat for sea snakes. Headed to Scott Reef at 1430
10/03/2013	Scott Reef south	Anchored at South Scott Reef at 0145. Sea snake survey started at 0800. Spotlight at night for sea snakes.
11/03/2013	Scott Reef Sandy Islet	Arrived at 1100 and anchored to the East of the islet. Shore party investigated sea turtle nesting and beach of any signs of oil contamination. Surveyed by manta board the western reef edge and reef flat for sea snakes. Spotlight at night for sea snakes.

12/03/2013	Scott Reef Sandy Islet	Surveyed by manta board the eastern reef edge and reef flat for sea snakes. Snorkel survey of reef flat.
13/03/2013	Scott Reef North	Relocated to North Scott Reef at 0600. Surveyed by manta board the outer reef edge and reef flat for sea snakes. Snorkel survey of reef flat. Surveyed by manta board the inner reef edge and reef flat for sea snakes. Spotlight at night for sea snakes.
14/03/2013	Seringapatam Reef	Relocate to Seringapatam Reef at 0600. Surveyed by manta board the outer reef edge and reef flat for sea snakes. Snorkel survey of reef flat. Surveyed by manta board the inner reef edge and reef flat for sea snakes. Spotlight at night for sea snakes. Departed for Hibernia reef
15/03/2013	Hibernia Reef (west lagoon)	Anchored inside the lagoon at 0830. Surveyed by manta board the northern inner reef edge and reef flat for sea snakes. Snorkel survey of reef flat. Surveyed by manta board the southern inner reef edge and reef flat for sea snakes. Spotlight at night for sea snakes.
16/03/2013	Hibernia Reef (west lagoon)	Surveyed by manta board the northern outer reef edge and reef flat for sea snakes. Snorkel survey of reef flat. Surveyed by manta board the southern outer reef edge and reef flat for sea snakes. Spotlight at night for sea snakes.
17/03/2013	Hibernia Reef (east lagoon)	Reef walk for sea snakes on the low tide at sunrise. Snorkel survey of reef flat with rising tide. Relocate "Kimberley Quest II" to Eastern end of the lagoon. Surveyed by manta board the eastern reef edge and reef flat for sea snakes. Snorkel survey of eastern reef. Spotlight at night for sea snakes.
18/03/2013	Hibernia Reef (east lagoon)	Snorkel the entrance and inner reef of the lagoon. Relocate to Ashmore Reef.
18/03/2013	Ashmore Reef	Moored in the West Island Channel at 1300. Shore party investigated sea turtle nesting and beach of any signs of oil contamination. Snorkel survey of inner channel reefs.
19/03/2013	Ashmore Reef	At 0830 scientists from James Cook University visited from ACV Ashmore Guardian. Snorkel survey of the inner reef in West Island Channel. Shore party investigated sea turtle nesting beach.
20/03/2013	Ashmore Reef	Shore party investigated sea turtle nesting beach. Snorkel survey of the eastern inner reefs in West Island Channel. Deck watch for sea snakes on the falling tide. Surveyed by

Date	Locality	Activity
		manta board the eastern inner reef edge and reef flat for sea snakes.
21/03/2013	Ashmore Reef	Shore party investigated sea turtle nesting beach. Snorkel survey of the eastern inner reefs in West Island Channel. Deck watch for sea snakes on the falling tide. Relocate to outer mooring. Sea turtle survey of reef flat.
22/03/2013	Cartier Island	Arrived at Cartier at 0900. No Anchoring. Surveyed by manta board the northern outer reef edge and reef flat for sea snakes. Snorkel survey of reef flat. Surveyed by manta board the outer reef edge and reef flat for sea snakes. Departed Cartier at 1400 for Broome.
23/03/2013	In transit	
24/03/2013	Broome	Arrived in Broome at midday and disembarked.

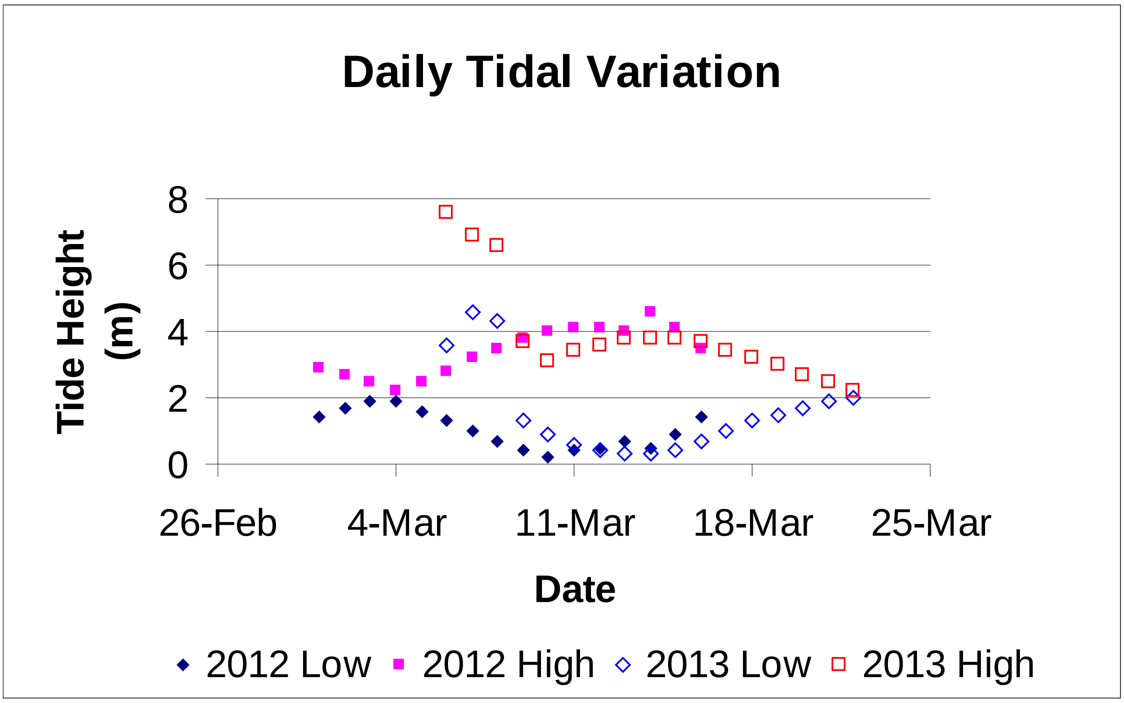


Figure 13. Fluctuation in tide height during daylight hours controlled access to the reef flat at high tide for capturing foraging marine turtles at Ashmore Reef and determined the itinerary and the schedule of events. The first three days of the 2013 survey were at Montgomery Reef with daily tidal variation of almost 8 m.

3.2 Survey Techniques and General Methods

3.2.1 Manta Board Surveys

Manta board surveys have been used in sea snake abundance assessments on Scott Reef, Ashmore Reef, Cartier Island and Hibernia Reef in previous research trips (Guinea 1995b; Guinea 2006a; Guinea 2006b; Guinea 2006c; Guinea 2006d; Guinea

2007a; Guinea 2008). Manta boards are a standard survey tool of the Australian Institute of Marine Science for surveys of benthic marine fauna (Done, *et al.* 1982; English, *et al.* 1994; Fernandes 1990; Fernandes, *et al.* 1990; Moran and De'ath 1992).

The manta board consisted of a piece of wooden marine grade ply attached to 25 m of 4 mm polypropylene rope and connected to the transom of a dinghy. The researcher held onto the board and recorded observations of the target fauna on an underwater slate. Tow speeds varied with rate of data entry and duration of the monitoring period. Tow speeds were approximately 4 km/hr (2 knots) measured between waypoints by GPS (Garmin 72H or 60CSx). The length of the tow was obtained by measuring the track length using tracking software (Garmin Mapsource®). Water clarity was judged by coloured twine markings at 5 m intervals along the tow rope. Two manta boards were used in each survey with one researcher recording on the port side and the other the starboard. Times of observations and species were checked to avoid duplicate recordings at the end of the towing period. The perpendicular distance of the animal from the transect line was judged by the observer and recorded. These distances and transect lengths and areas were used to estimate sea snake densities per hectare and marine turtle densities per square kilometre using Distance 6 (Thomas, *et al.* 2009). Sea snake and marine turtle abundance per kilometre of reef crest were also calculated. Simpson's index of species diversity (Simpson 1949) was calculated for sea snakes on each reef (MVSP 3.1, Kovach Computing Services) $D = 1 - \Sigma(p_i)^2$ where D = Simpson's index of diversity and p_i = proportion of individuals of each species (i) at each reef (Krebs 1985).

Researchers breathed by snorkel and wore a half face mask. Their helmets supported a HD video camera (Tachyon micro HD or GoPro HD). Each researcher as well as the observer in the boat, stand-by snorkelers and the coxswain wore PPE appropriate to their task. A Perspex slate and waterproof graphite pencil attached to the manta board enabled researchers to record the start time, their respective side of the transect path, their name, the time of observation and the perpendicular distance from the transect line to the sea snake or marine turtle and the species and the respective life stage (adult or immature). Marine turtles were sexed by observing the length of the tail: adult males have long tails; immature males and females have short tails. When a sea snake was difficult to identify, the researcher signalled the observer and released the manta board to capture and examine the animal for further inspection, skin biopsy collection and photographic recording at the surface. All sea snakes were released at their point of capture.

Boat crew consisted of a coxswain and a dedicated observer facing the stern and in visual contact with the researchers on the manta boards. Start and finish locations were recorded with GPS by the boat crew, along with the time and the names of the researchers on the manta boards and their respective sides of the transect path. Hand signals and communications were in accordance with Australian Institute of Marine Science protocols (English, *et al.* 1994).

Manta board surveys of sea snakes and marine turtles were conducted in shallow waters to 10 m in depth. The surveys were in daylight hours at a time when underwater visibility was at its best (0900 to 1600) and the tide was low. Each survey period lasted 15 minutes. Researchers often opted for a consecutive survey but each 15 minute interval was recorded separately. Fatigue was avoided by restricting the manta tows to two consecutive 15 minute surveys.

3.2.2 Standard Snorkel Surveys

Surveys on snorkel were conducted during daylight hours in the vicinity of the contract vessel's tender. An observer in the tender recorded the GPS locations and time. Sea snakes that were not identified from a distance were captured for closer examination and photographic recording. Snorkelers swam or drifted between the two points recorded by GPS so that the area surveyed was recorded. All sea snakes seen along the transect line were identified. All specimens were handled with appropriate PPE and released at the point of capture.

3.2.3 Sea Snakes

Sea snakes were not captured during manta board surveys and standard snorkel surveys unless their identification was uncertain. Capturing involved placing a gloved hand into a mesh bag and grasping the sea snake in the mid body region and carefully drawing the snake into the bag. The neck of the bag was secured and the sea snake taken to the surface for identification and photographing. A photographic index of sea snakes species was compiled for identification purposes. Records were made of any mating or feeding behaviours of sea snakes observed by the snorkelers during the in-water surveys. Sea snake densities were recorded as sightings per unit per area of reef or per length of reef examined in both the potentially impacted and the control sites.

3.2.4 Marine Turtles

3.2.4.1 Non Nesting Turtles

Turtles were recorded during manta board surveys of the reefs along with their numbers, species and estimated distance from the transect line. These distances and transect lengths and areas were used to estimate marine turtle densities per square kilometre using Distance 6 (Thomas, *et al.* 2009). Marine turtle abundance per kilometre of reef crest was also calculated.

Boat transect surveys across the lagoon and reef flat at North Scott Reef and Ashmore reef recorded marine turtles either side of the transect line. As the turtles swam away from the moving boat, their perpendicular distance from the line was difficult to estimate as was their angle to the transect line when first seen. A boundary to the field of view and recording was set by the observers at between 20 and 25 metres depending on visibility, sea conditions and glare. The boundaries were estimated for each section of the transect line.

3.2.4.2 Foraging Marine Turtles

Feeding turtles were captured using a modified "turtle rodeo" method. A turtle foraging in shallow water on the reef flat was intercepted by a tender carrying a driver, a researcher and a coxswain. The clear waters of Ashmore Reef and expanse of sand flats enable the boat to turn the turtle from its path until it is stationary within a curtain of bubbles produced from the propeller. The researcher jumps into the water and secures the turtle bringing it on board the tender. The turtle is then measured tagged and weighed. In Western Australian waters the tags are supplied by DEC Perth an carry the "WA" prefix. In Commonwealth waters "K" series tags from EPA Queensland are applied. All capture localities are recorded with a GPS and samples identified to the tag number of the turtle.

In areas with poor water clarity and unsuitable for the modified “turtle rodeo”, foraging turtles are captured on foot. The researcher or several researchers walk the shallows as the tide rises. Green sea turtles feeding in the shallows are approached from behind and either grabbed or secured in a hand-held landing net. The turtles are then carried back to the waiting dinghy. Capture efficiency is improved when several researchers, spaced at five metre intervals, form a line that angles forward from the shore. Foraging turtles that are disturbed by the approaching line of bodies are captured by hand or landing net as they swim for deeper water along the front of the line of researchers.

The sea conditions at the capture sites were judged too unstable for taking blood samples from the turtles in the tender. Captured turtles were taken to “Kimberley Quest II” which provided relative stability for collecting blood samples. The blood samples were taken from the medial or lateral cervical sinus of the foraging Green Sea Turtles using 10 ml hypodermic syringe with a #21 gauge needle (Owens and Ruiz 1980; Whiting, *et al.* 2007). Three millilitres of blood was sufficient for analysis. If a sample could not be obtained from a turtle in two attempts, the turtle was released near the site of capture. When a sample was obtained the hypodermic was removed from the syringe and the blood sample was gently delivered into a heparinised tube for biochemical analysis and a small volume placed in EDTA tube for Packed Cell Volume (PCV) determination.

The blood in the heparinised tube was mixed gently and placed into centrifuge tubes and spun at 2,000 rpm for 5 minutes (Whiting, *et al.* 2007). The plasma was removed by pipette and placed in labelled sample tubes and frozen until analysis. The EDTA tubes were refrigerated and stored. Both the plasma and the EDTA tubes were transported frozen and chilled respectively to Berrimah Veterinary Laboratories in Darwin for biochemical analysis and PCV determination by the standard procedures of the laboratory.

3.2.4.3 Nesting Marine Turtles

The islands were examined for evidence of recent marine turtle nesting activity and the presence of hatchling tracks. All recent nests were identified to species by the tracks of the female and recorded with GPS receiver. A sample of hatched nests was excavated and the contents identified and allocated to the following categories: number of shells, live hatchlings, dead hatchlings, undeveloped eggs, unhatched eggs and emerged hatchlings. These data provide an indication of hatching and emergence successes for each species (Miller 1999).

While at Ashmore Reef in 2012, West Island was patrolled at night during the high tide. Ambient moonlight and starlight was used to patrol the beach of nesting turtles. A dim red light emitting diode (LED) headlamp (Energizer HDL33A) was used while tagging and recording data when close to the turtle. Nesting turtles were tagged with two, individually numbered, 4.1 gram titanium tag (K series from Wildlife Queensland) attached through the axillary scale (closest to the body) of the left and right front flipper. Carapace dimensions and any individual distinguishing marks or injuries were recorded for each adult turtle. Curved carapace lengths (CCL) and curved carapace widths (CCW) were measured with a flexible fibreglass tape (± 0.05 cm). The CCL is measured from the junction of the skin and the nuchal (most anterior carapace) scale to the notch between the post vertebral scutes at the posterior of the carapace (Guinea, *et al.* 2005; Limpus, *et al.* 2001; Limpus, *et al.* 2003b). The CCW

was measured across the carapace at its widest point with the same tape. A delay in permits in 2013 restricted access to West Island during daylight hours.

3.2.5 Habitat Assessment

The intertidal reef habitat was examined for evidence of hydrocarbon contamination. The sampling sites were on reef flats with small stands of the seagrass, *Thalassia hemprichii*. The sampling regime consisted of examining the reefs with four sites per reef each about 1 km apart in sediments supporting growths of *Thalassia hemprichii*. Within each site three sites were selected indiscriminately. At each site a cylinder of stainless steel, 600 mm in length and having a diameter of 53 mm, was forced into the sand to the maximum depth of penetration. The core of sediment was removed and examined and tested physically for homogeneity including the presence of discoloured layers or cohesion between particles similar to physical examination by other surveys (Maughan, *et al.* 2009). Each core was photographed and GPS recorded along with notes and observations. Marine turtle nesting beaches were assessed in a similar manner in the intertidal zone at about 200 m intervals along the beach.

3.3 Site Specific Methods

3.3.1 Sandy Islet Scott Reef: A control site

The eastern and western reefs at Sandy Islet, Scott Reef (Figure 14), were surveyed during the morning and afternoon respectively to avoid duplicate recording of the same sea snake and marine turtle.

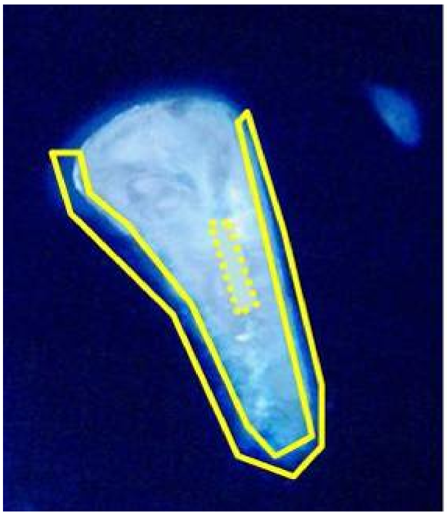


Figure 14 Eastern and Western reefs of Sandy Islet were surveyed by manta board (solid line) on separate days to avoid duplication. Habitat assessment and nesting turtle track counts were conducted on the island (dotted line).

3.3.2 North Scott Reef: A control site

North Scott Reef was surveyed in the afternoon to prevent duplicate counts of individuals Manta board surveys were conducted to the north and south of the lagoon entrance both inside and outside on the reef crest (Figure 15). Boat transects were conducted to the south western channel with standard snorkel survey conducted out side the channel and inside the channel in

5 to 8 m of water over sandy sea floor. The boat transect continued as the group returned to the “Kimberley Quest II”. Boat transect with spotlights were conducted after dark from 2000 to 2100 hrs outside the channel to water depths of 60 m.

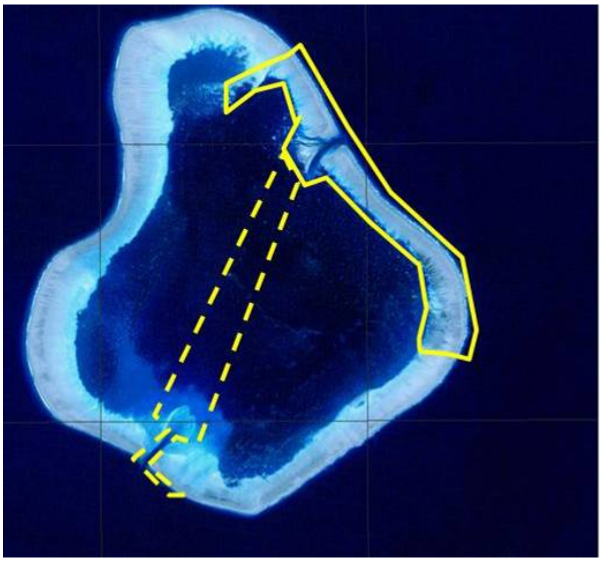


Figure 15 The ring reef of North Reef, Scott Reef. Manta board surveys were conducted in the leeward side (solid line) and boat transects and standard snorkel surveys conducted to the South Western Channel (dashed line).

3.3.3 Seringapatam Reef: A control site

The leeward side of Seringapatam Reef was surveyed at low tide. Surveys were conducted north and south of the inside of the channel entrance in the morning and outside of the channel in the afternoon (Figure 16). Boat transect surveys were conducted whilst returning to “Kimberley Quest II” from the north and south extremities of the surveys. Boat transect surveys were conducted after dark with spotlights 2000 to 2100 hrs in water depths from 6 m to 80 m.

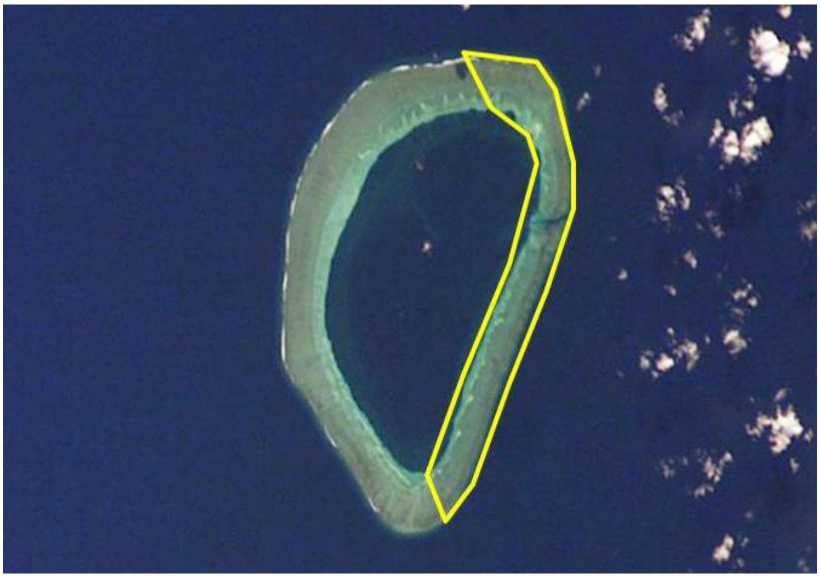


Figure 16 Seringapatam Reef showing the region of the manta board surveys inside and outside the lagoon that incorporated boat surveys, standard snorkel surveys and spotlight surveys at night.

3.3.4 Hibernia Reef: A potentially impacted site

In 2012 the "Kimberley Quest II" steamed overnight to Hibernia Reef and entered through the North Channel. The teams conducted manta board surveys to the north and south of the channel meeting at the western end of the lagoon (Figure 17). One team concentrated on snorkel surveys following the manta board teams to capture and identify specimens. Boat Surveys were conducted along the length of the lagoon. Two 500 Watt deck lights and 4 in-water spotlights illuminated the surface water until 2300 hrs. The following morning additional manta board surveys were needed to finish the southern rim of the lagoon and standard snorkel surveys were conducted on the southern reef.

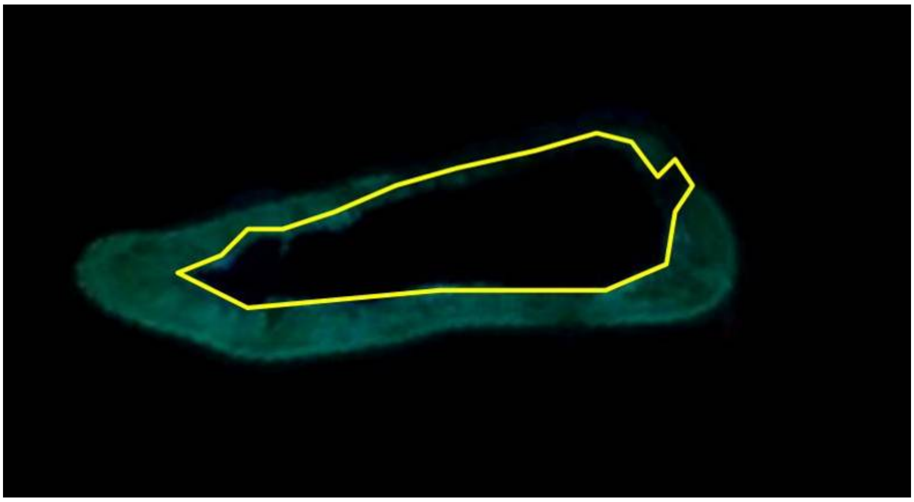


Figure 17 The inner rim of the lagoon Hibernia Reef enclosed the area covered by manta board surveys, boat survey and snorkel surveys.

In 2013 the "Kimberley Quest II" entered through the north passage and steamed to the western end of the lagoon to gain shelter form the prevailing wind. Spotlights were used at night as in the previous year and manta board surveys were conducted around the inner lagoon and over the reef crest with foot surveys of the southern reef crest at low tide.

3.3.5 Ashmore Reef: A potentially impacted site

The "Kimberley Quest II" arrived at Ashmore at 1530, 8 March 2012 and 18 March 2013, and completed formalities with the customs officers and proceeded to the inner mooring. The team went ashore to assess the level of turtle nesting and hatching and to assess the beach habitat for visible residue. The shore party went to West Island from 2230 to 0030 for nesting turtle surveys in 2012 (Figure 18). In 2013, delays in permits limited the nesting beach surveys to observations along the Eastern Beach and snorkel surveys to the West Island Channel only.

Figure 18 The 2012 survey areas at Ashmore Reef are indicated: manta board surveys (solid line), foot surveys habitat assessment (dotted line), boat transects and foraging turtle catching (dashed line). In 2013 snorkel surveys were conducted in the West Island Channel only.

3.3.6 Cartier Island: A potentially impacted site

A special permit was issued to transit Cartier Island for 22 March only. Permission was not given to survey the sand cay. The northern edge of the sand cay was examined with binoculars. The surveys consisted to two manta board survey teams covering the three survey lines at increasing distances from the reef edge to avoid duplicate counts of individuals and a snorkel survey that lasted in total three hours (Figure 19).

Figure 19 The location of three manta tows from West to East along the northern edge of Cartier Island (Landsat overlay from CPS Visualiser and Google Earth).

4 Results

The surveys in March 2012 involved 500 person hours of boat, foot and underwater surveys of four reefs of the Sahul Shelf. During this time the survey team conducted 98.2 km of manta board surveys with a survey area of just over 877 hectares of reef crest and lagoonal habitats. Boat survey transects over the reef flat and lagoons recorded over 286 km with a survey area of 10,100 hectares. Surveys were restricted to the calmer leeward side of the reefs and in the lagoons as in previous sea snake surveys.

In March 2013 the survey covered seven reef of the Sahul Shelf and Kimberley coast. More than 780 person hours by 11 individuals covered almost 100 km of in and on water surveys and more than 10,000 hectares of reef flat, lagoon and reef crest (Figure 20).

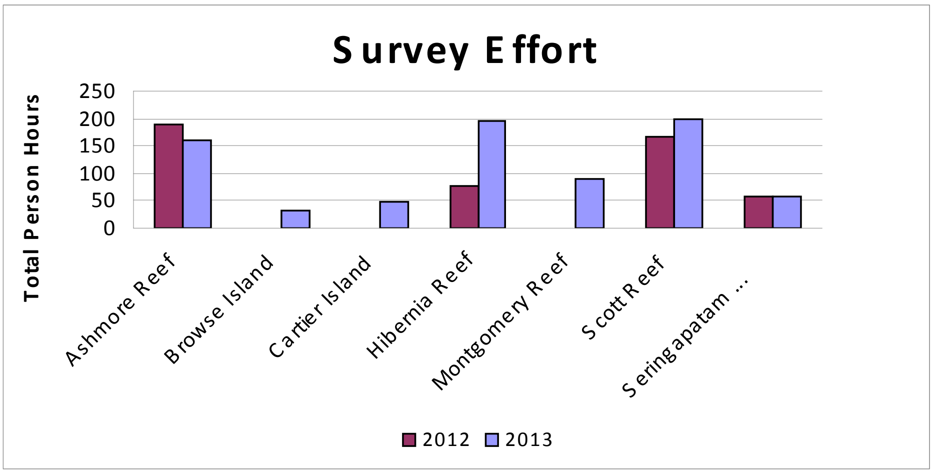


Figure 20 Comparison between the effort involved in the 2012 and 2013 surveys of the Sahul Shelf.

4.1.1 Sea Snake Diversity

Sea snakes were identified visually; however any that were not readily identifiable were captured for closer examination and a skin biopsy taken. The sea snakes recorded on each of the reefs and their numbers highlight the differences in each of the reefs in both surveys (Table 7). In 2012 North Scott and Seringapatam Reefs had the largest number of sea snakes and accounted for 68 % of the snakes recorded in spite of having the shortest survey durations. Olive Seasnakes were the most commonly seen species making up 71% to 90% of the sightings. In 2013 the numbers of snakes on Seringapatam had decreased and contributed only 17% of the sea snake sightings. Cartier Island had the most snakes in 2013 with 27.3% of the survey total recorded in just two hours (Figure 21). Seringapatam was the only reef to have fewer snakes recorded in 2013 than in 2012. All other reefs had increased number of sea snakes. No sea snakes were recorded from Ashmore Reef and Browse Island. Again Olive Seasnakes were the most common species on those reefs supporting sea snake populations and comprised 73%of the total sightings. Turtle-headed sea snakes were the next most common in both years comprising 16 % and 12 % respectively. The remaining

species were seldom encountered and usually amounted to a few individuals, if any, on each reef.

Only one sea snake, Olive Seasnake was seen on the surface during the nigh spot light surveys. It surfaced for a breath at Seringapatam Reef and dived again while the spotlight was shining on it. No sea snakes were attracted to the lights of the "Kimberley Quest II" while it was at anchor at any of the reefs. No sea snakes were seen in any of the surveys at Ashmore Reef. The standardised snorkel surveys produced no extra species. Because of the low numbers encountered in the snorkel surveys, the team eventually followed the manta board surveys and identified where possible the obscure specimens. Aspects of the field activities are shown in Figure 23. At Montgomery Reef, Scott Reef, and Hibernia Reef sea snakes were attracted to the stern lights at night. Stokes'; Seasnake was the most common night species at Montgomery Reef and Hibernia Reef. Other species were the Slender-necked Seasnakes at Scott Reef and the Horned Seasnake at Hibernia Reef. No *Aipysurus* species were attracted to the lights at night in spite of their being present on the reef during the day.

Ashmore Reef remained devoid of sea snakes. No sea snakes were seen in the West Island channel in the two year of the survey. In addition, the crew of the "ACV Ashmore Guardian" indicated they had not seen a sea snake while on station in the last two years. Also a marine survey team on the "AVC Ashmore Guardian" has not seen a sea snake in six days of surveys of the reef crest. Because of zero sightings of sea snakes at Ashmore Reef and Browse island Simpsons index of diversity cannot be calculated (Table 8) and have a Jaccard's coefficient of zero (Figure 22).

Of the potentially impacted sites Cartier Island and Hibernia have very similar indices of diversity almost equal to Scott Reef and Seringapatam Reef (Table 8).

Table 7 Numbers of the common reef-dwelling sea snake species on the shelf edge reefs of the Sahul Shelf seen during manta board surveys in 2012[a] and 2013[b].

Species Common Name	Ashmore Reef	Cartier Island	Hibernia Reef	Browse Island*	Seringa-patam Reef *	Sandy Islet, Scott Reef *	North Reef, Scott Reef *
Olive Seasnake	0[a] 0[b]	0[a] 45[b]	13[a] 30[b]	0[a] 0[b]	32[a] 24[b]	16[a] 18[b]	36[a] 38[b]
Turtle-headed Seasnake	0[a] 0[b]	0[a] 5[b]	4[a] 2[b]	0[a] 0(b	10[a] 8[b]	4[a] 8[b]	3[a] 2[b]
Dubois' Seasnake	0[a] 0[b]	0[a] 3[b]	0[a] 0[b]	0[a] 0[b]	2[a] 2[b]	1[a] 4[b]	0[a] 2[b]
Dusky Seasnake	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]	1[a] 1[b]	1[a] 4[b]	1[a] 2[b]
Stokes' Seasnake	0[a] 0[b]	0[a] 6[b]	0[a] 3[b]	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]
Slender-necked Seasnake	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]	0[a] 0[b]	0[a] 1[b]	0[a] 3[b]	0[a] 0[b]

* indicates a control site.

Table 8 Simpson's index of Diversity for sea snakes of the seven reef surveyed in 2013 (* indicates a control site).

Locality	Simpson's Index	Evenness	Number of .Species.
Ashmore Reef	****	****	0.000
Browse Island*	****	****	0.000
Cartier Island	0.558	0.725	4.000
Hibernia Reef	0.588	0.776	4.000
Montgomery Reef*	0.000	0.000	1.000
Scott Reef*	0.591	0.733	5.000
Seringapatam Reef*	0.636	0.777	5.000

Cartier Island and Hibernia Reef, both potentially impacted sites, had the greatest similarity in species present (Figure 21). The numbers of sea snakes at Seringapatam Reef had decreased from the 2012 survey but the diversity remained almost equal to that of Scott Reef.

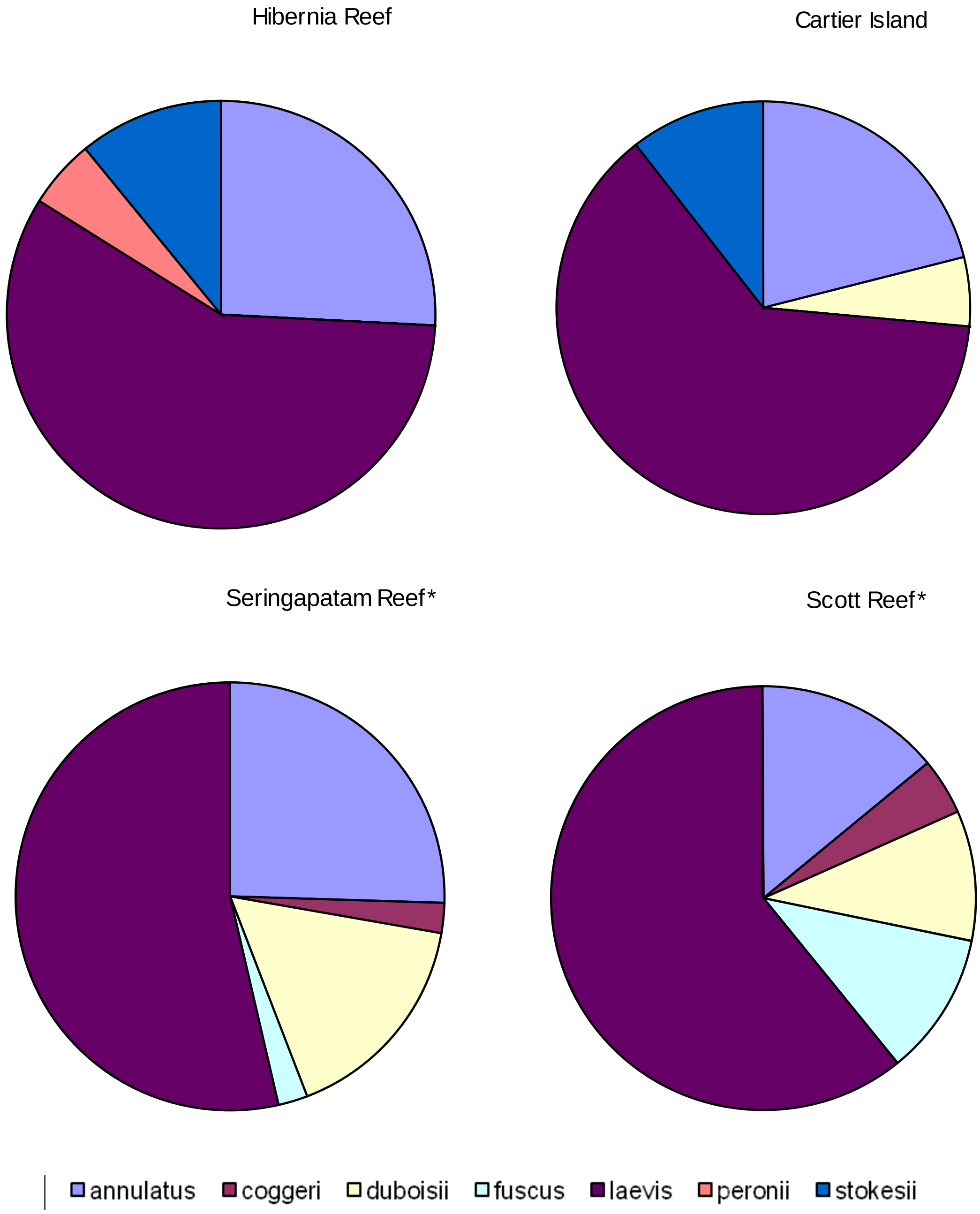


Figure 21 Comparison between the relative numbers of sea snakes recorded from the four reefs: Cartier Island, Hibernia, Seringapatam and Scott Reefs, in the 2013 survey (* indicates a control site).

Note: The abbreviations are: annulatus = *Emydocephalus annulatus*, coggeri = *Hydrophis coggeri*, duboisii = *Aipysurus duboisii*, fuscus = *Aipysurus fuscus*, laevis = *Aipysurus laevis*, peronii = *Acalyptophis peronii*, stokesii = *Astrotia stokesii*.

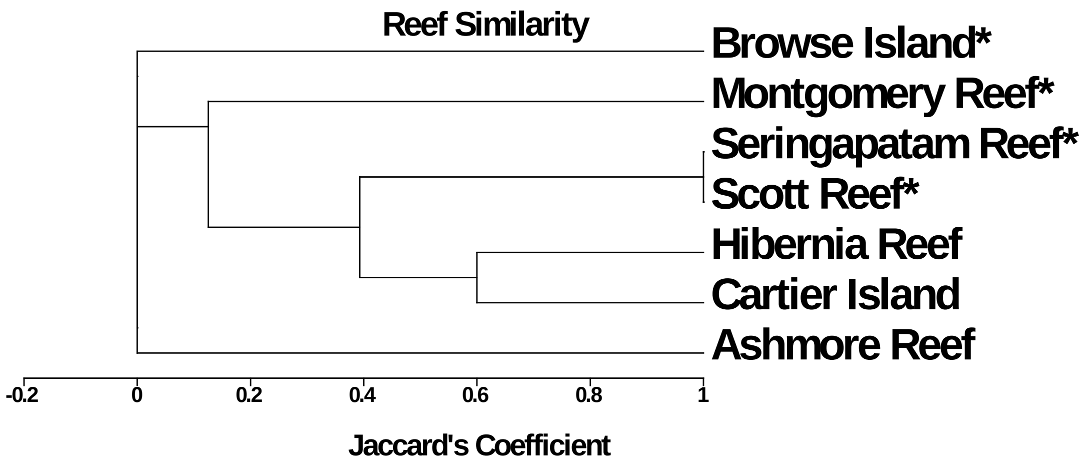


Figure 22 Species diversity (Jaccard's coefficient) of sea snakes on the seven reefs survey in 2013 (* indicates control site).

4.1.2 Sea Snake Density

Of the reefs surveyed, Seringapatam Reef had the highest density of sea snakes with an average of 4.4 sea snakes per hectare (95% confidence limits were 2.8 to 6.6 sea snakes per hectare (Table 9). No sea snakes were seen on Ashmore Reef.

The density of sea snakes (Table 9) and their abundance in manta board surveys (Table 10) support the observations that Seringapatam Reef had the highest density of sea snakes with the greatest abundance per kilometre of reef crest.

Table 9 The density of sea snakes on the five reefs where sea snakes were recorded are given for the 2012[(a)] and 2013[(b)] surveys with the 95% confidence limits of the estimate and coefficient of variation along with the area surveyed and the number of transects on each of the reefs.

Locality	Density (snakes/ hectare)	95% confidence levels	Coefficient of Variation	Survey Area (ha)	Number of transects
Sandy Islet Scott Reef*	1.79[(a)]	1.13 - 2.83[(a)]	0.22[(a)]	26.6[(a)]	12[(a)]
	6.21[(b)]	3.5 – 10.9[(b)]	0.27[(b)]	23.3[(b)]	17[(b)]
North Reef Scott Reef*	1.44[(a)]	0.84 - 2.46[(a)]	0.27[(a)]	89.8[(a)]	15[(a)]
	3.6[(b)]	2.21 – 5.89[(b)]	0.25[(b)]	53.7[(b)]	21[(b)]
Seringapatam Reef*	4.44[(a)]	2.89 - 6.80[(a)]	0.22[(a)]	44.0[(a)]	23[(a)]
	1.89[(b)]	1.34 – 2.68[(b)]	0.22[(b)]	52.4[(b)]	21[(b)]
Hibernia Reef	2.35[(a)]	1.36 - 4.06[(a)]	0.27[(a)]	59.5[(a)]	18[(a)]
	2.69[(b)]	1.76 – 4.13[(b)]	0.21[(b)]	42.2[(b)]	16[(b)]
Cartier Island	6.16[(b)]	4.00 – 9.46[(b)]	0.21[(b)]	37.3[(b)]	13[(b)]

* indicates a control site

Table 10 The abundance of sea snakes estimated per kilometre of reef flat at each of the reefs where sea snakes were observed in the 2012[(a)] and 2013[(b)] surveys along with the range of the estimate and the standard deviation along with the survey length and the number of transects of each reef.

Locality	Mean Abundance (snakes/ km)	Range	Standard Deviation	Survey Length (km)	Number of transects
Sandy Islet Scott Reef*	2.53[(a)]	0.71 – 5.45[(a)]	1.67[(a)]	12.7[(a)]	12[(a)]
	4.41[(b)]	0.91 – 27.44[(b)]	6.59[(b)]	13.4[(b)]	17[(b)]
North Reef Scott Reef*	1.83[(a)]	0.56 – 4.61[(a)]	1.21[(a)]	23.9[(a)]	15[(a)]
	2.0[(b)]	0 – 6.64[(b)]	1.94[(b)]	16.2[(b)]	21[(b)]
Seringapatam Reef*	3.21[(a)]	0.63 – 8.80[(a)]	2.41[(a)]	21.6[(a)]	23[(a)]
	1.94[(b)]	0 – 8.1[(b)]	1.97[(b)]	22.4[(b)]	21[(b)]
Hibernia Reef	1.48[(a)]	0 – 6.09[(a)]	1.78[(a)]	14.1[(a)]	18[(a)]
	2.47[(b)]	0 – 12.07[(b)]	3.14[(b)]	17.2[(b)]	16[(b)]
Cartier Island	5.27[(b)]	0.83 – 10.87[(b)]	3.03[(b)]	12.9[(b)]	13[(b)]

* indicates a control site

4.2 Skin biopsies for species identification and validation

Juvenile specimens of Olive Seasnakes and Dusky Seasnakes are very similar in their colouration, banding pattern and size. This became evident on Scott Reef and was even more noticeable on Seringapatam Reef with the Turtle-headed Seasnake being darker with prominent bands. Skin biopsies were taken from the distal edge of caudal scales of some specimens (Table 11). White connective skin was exposed by the procedure but none of the biopsies produced any blood at the site of collection.

Table 11 Numbers of the specimens and their putative identification from which a small skin biopsy was taken for reference and identification.

Genus	Putative Identification	Locality	Number of individuals 2012	Number of individuals 2013
Aipysurus	*laevis/fuscus?*	Scott Reef*	16	19
Aipysurus	*laevis/fuscus?*	Seringapatam Reef*	13	2
Aipysurus	*laevis/fuscus?*	Hibernia Reef	11	6
Emydocephalus	*annulatus?*	Scott Reef*	2	8
Emydocephalus	*annulatus?*	Seringapatam* Reef*	10	3
Emydocephalus	*annulatus?*	Hibernia Reef	4	17
Aipysurus	*duboisii*	Scott Reef*	0	6
Aipysurus	*duboisii?*	Seringapatam Reef*	2	5

* indicates a control site

Photographing an Olive Seasnake

Surfacing with the snake catch bag

Drs Rasmussen and Guinea discussing the identification of a sea snake

Drs Sanders and Guinea removing a skin biopsy from a Dubois' Seasnake.

Dr Rasmussen photographing a dusky sea snake as it rested on the beach at Sandy Islet Scott Reef

Drs Rasmussen, Sanders and Guinea examining a sea snake restrained in the catch net aboard a tender

Figure 23 Sea snake research activities involving photographing, catching, scale counts, skin biopsy, photographic recording and identification.

4.3 Marine Turtles

4.3.1 Non Nesting Marine turtles

4.3.1.1 Manta board surveys

Observations of marine turtles from the manta boards were less frequent than for sea snakes. Hibernia Reef recorded the highest density with 26.32 turtles per square kilometre in 2012 (Table 12). Similarly their abundance along the reef in 2012 was low with Hibernia Reef displaying the greatest abundance (Table 13). The most common turtles seen in the reef crest habitat were sub-adult Green Sea Turtles with only two Hawksbill Sea Turtles recorded.

In 2013 the numbers of foraging marine turtles had increased in all reefs with the exception of Seringapatam and North Scott reefs. Cartier Island had the greatest density with an estimated 371 turtles per square kilometre (Table 12).

Table 12 The density of marine turtles from manta board surveys of the reefs surveyed in 2012[(a)] and 2013[(b)] with the 95% confidence limits of the estimate and coefficient of variation along with the area surveyed and the number of transects on each of the reefs.

Locality	Density (turtles/ km^2)	95% confidence levels	Coefficient of Variation	Survey Area (ha)	Number of transects
Sandy Islet Scott Reef*	23.69[(a)]	1.9 - 281.7[(a)]	1.22[(a)]	26.6[(a)]	12[(a)]
	57.3[(b)]	27 - 121[(b)]	0.38[(b)]	23.3[(b)]	17[(b)]
North Reef Scott Reef*	14.67[(a)]	2.8 - 77.3[(a)]	0.89[(a)]	89.8[(a)]	15[(a)]
	12.5[(b)]	4.5 – 34.9[(b)]	0.52[(b)]	53.7[(b)]	21[(b)]
Seringapatam Reef*	21.24[(a)]	5.6 - 80.9[(a)]	0.67[(a)]	44.0[(a)]	23[(a)]
	10.7[(b)]	3.8 – 30.17[(b)]	0.53[(b)]	52.4[(b)]	21[(b)]
Hibernia Reef	26.32[(a)]	6.3 - 110.5[(a)]	0.74[(a)]	59.5[(a)]	18[(a)]
	42.6[(b)]	16.1 – 112.5[(b)]	0.49[(b)]	42.2[(b)]	16[(b)]
Cartier Island	371.0[(b)]	223.0 – 616.1[(b)]	0.25[(b)]	37.3[(b)]	13[(b)]
Browse Island*	182.1[(b)]	25.0 – 1325.7[(b)]	0.80[(b)]	5.3[(b)]	4[(b)]

* indicates a control site

Table 13 The abundance of marine turtles estimated per kilometre of reef flat from manta board surveys at each of the reefs in 2012[(a)] and 2013[(b)] along with the range of the estimate and the standard deviation along with the survey length and the number of transects of each reef.

Locality	Mean Abundance	Range	Standard Deviation	Survey Length (km)	Number of transects
Sandy Islet Scott Reef*	0.33[(a)]	0 – 2.47[(a)]	0.80[(a)]	12.7[(a)]	12[(a)]
	1.87[(b)]	0 – 12.0[(b)]	2.96[(b)]	13.4[(b)]	17[(b)]
North Reef Scott Reef*	0.38[(a)]	0 – 2.73[(a)]	0.74[(a)]	23.9[(a)]	15[(a)]
	0.18[(b)]	0 – 1.29[(b)]	0.42[(b)]	16.2[(b)]	17[(b)]
Seringapatam Reef*	0.51[(a)]	0 – 1.56[(a)]	0.61[(a)]	21.6[(a)]	23[(a)]
	0.44[(b)]	0 – 3.0[(b)]	0.83[(b)]	22.5[(b)]	21[(b)]
Hibernia Reef	0.62[(a)]	0 – 6.97[(a)]	1.54[(a)]	14.1[(a)]	18[(a)]
	0.78[(b)]	0 – 7.24[(b)]	1.82[(b)]	17.2[(b)]	16[(b)]
Cartier Island	2.09[(b)]	0 – 7.13[(b)]	1.71[(b)]	12.9[(b)]	13[(b)]
Browse Island*	1.75[(b)]	0 – 5.0[(b)]	2.21[(b)]	2.6[(b)]	4[(b)]

* indicates a control site

4.3.1.2 Boat Surveys

Boat surveys were conducted in the lagoons in North Reef Scott Reef, Seringapatam Reef, Hibernia Reef and Ashmore Reef with varying results in 2012 and 2013. A transect survey involving 10 observers in three boats travelled from the north eastern passage of North Reef Scott Reef to the south western passage and return. This was a total distance of 14 km during which time three sub-adult Green Sea Turtles were recorded. A similar survey of 4 km in length travelled from the northern sand banks of Seringapatam Reef to the Eastern entrance and recorded 2 marine turtles. On Hibernia Reef a survey involving 3 boats and 10 observers travelled the eight kilometre length of lagoon and failed to see a marine turtle.

The above low numbers of turtles on the reef are vastly different to observations on Ashmore Reef. On 11 March three boats each with two observers and a recorder travelled roughly parallel to each other and at least 500 metres apart over the reef flat at high tide. The total distance travelled was 28.3 km. A total of 477 Green Sea Turtles were recorded on the 16 unequal sectors of the boat survey. The average numbers of marine turtles on the reef flat was 17.75 turtles / km (sd = 15.64) or 4.44 turtles / ha (sd = 3.91). A single boat survey from West Island channel to Middle island on a neap tide on 21 March 2013 recorded 87 sub-adult green turtles in the 10 km trip indicating there had been little change in the sub-adult green turtle population in the intervening 12 months.

During the boat survey in 2012 two dugongs, a mother and a calf, were reported swimming over the reef flat.

4.3.2 Nesting Marine turtles

On 3 March 2012, Sandy Islet at Scott Reef had 13 tracks belonging to Green Sea Turtles crossing the beach from below the high tide of the previous evening. The success of the nests was not verified because of time constraints imposed by approaching evening, the difficulty of tracing individual tracks over the pitted surface of the island, the falling tide and the requirement of habitat assessment of the beach for evidence of hydrocarbon residue. On 11 March 2013 eight Green Sea Turtles came ashore after sunset to nest. None appeared to carry flipper tags and because of time constraints and failing light remained untagged as the tender vessels continued with spotlighting for sea snakes.

Browse Island was visited in the 2013 survey. A single walk around the island revealed 28 recent nests from the night of 8 March by Green Sea Turtles and 143 sets of Green Sea Turtle tracks since the previous spring tides, six nights earlier. Six dead Green Sea Turtles were on the western Beach. All appeared to have died over a period of several days to weeks from natural causes. All were in upright positions with one still in the body pit in the process of nesting. None were tagged. There was no evidence of any species other than Green Sea Turtles nesting on the island.

Eight individual Green Sea Turtles nested on West Island Ashmore Reef over the four nights of the 2012 survey (Figure 24 and Figure 25). They ranged in curved carapace length from 89.4 to 112.3 cm (mean = 101.6 cm, sd = 7.4). Curve carapace widths ranged from 78.0 to 99.6 cm (mean = 92.5 cm, sd = 7.0) (Figure 26). These values are within the range of carapace dimensions previously recorded (Whiting and Guinea 2005a). Recent and continuing rain had moistened the sand thereby facilitating successful nesting. In 2013 twelve Green Sea Turtles nested on West Island Ashmore Reef during the four days of the survey. Three nests hatched including that of a Hawksbills Sea Turtle.

In 2012 several marine turtle nests hatched prior to our arrival with three (two Green and one Hawksbill) being examined for nesting success. Green Sea Turtle hatching successes were 76 and 87% while that of the hawksbill was 96%. Ginger ants were responsible for the death of some tens of Hawksbill Sea Turtle hatchlings in the nest and on the beach. A file note has been sent to DSEWPaC requesting an expansion of the ginger ant control program (Appendix B).

Only one hatched nest was examined in 2013. The Green Sea Turtle nest had 65.7% hatching success in spite of possible having been washed over by high seas.

Figure 24 Green turtle filling the nest after laying on West Island Ashmore Reef.

Figure 25 Researcher measuring the curved carapace length of a Green Sea Turtle after laying on West Island Ashmore Reef.

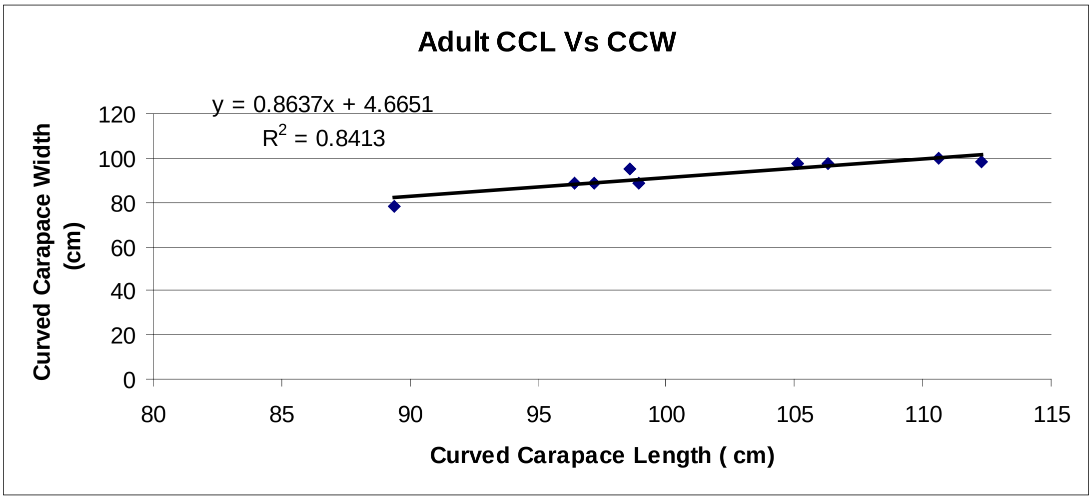


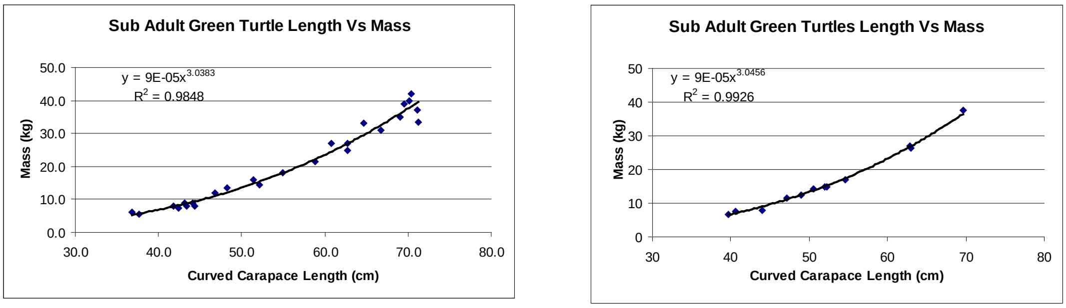
Figure 26 Relationship between the curved carapace length and curved carapace width of nesting Green Sea Turtles encountered on West Island, Ashmore Reef.

4.3.3 Foraging Marine turtles

Green Sea Turtles were caught while they were feeding on the reef flat at Middle and West Island Ashmore Reef. Smaller turtles were caught on the reef around Middle Island and although some small turtles were present on the reef at West Island, they were outnumbered by larger, yet still not adult, Green Sea Turtles. Twenty-five Green Sea Turtles were caught, measured, tagged and had a blood sample (max 3 ml) collected before release. Nineteen blood samples were collected with the others not yielding a satisfactory sample before release (Figure 27). This sample was further reduced to 16 samples when three samples contained cerebrospinal fluid. All of the foraging turtles were judged to be healthy as none had depressed plastrons and all displayed ample fat around the flippers.

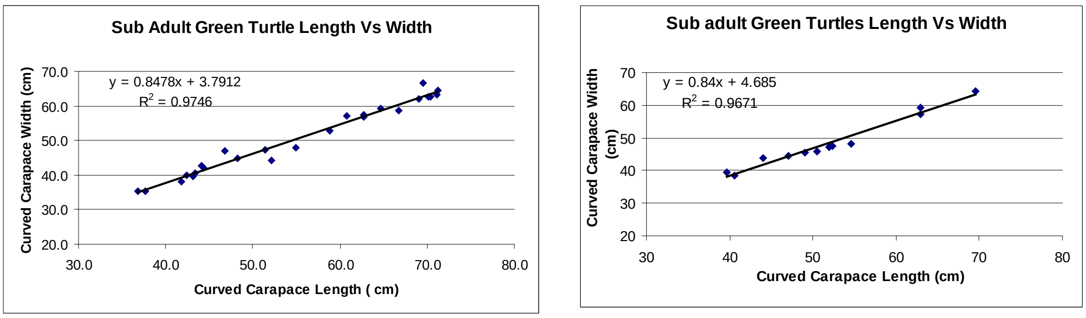
Twelve sub-adult Green Sea Turtles were caught on Montgomery reef on 7 and 8 March 2013. One was caught in the evening and the remainder caught in the morning with 9 caught between 0500 and 0700. The Body Mass Index (Figure 28) revealed an absence of outliers in both collections and growth appeared to be linear (Figure 29) as expected for Green Sea Turtles of this size. There was no evidence of illness, fibropapillomas, or turtle barnacle (*Chelonibia testudinaria*). All of the Green Sea Turtles were tanned ventrally indicating they had resided on the reef for some time and were not recent recruits from the open ocean (Figure 30).

Figure 27 Obtaining a blood sample from the medial cervical sinus of a sub-adult Green Sea Turtle.



Ashmore Reef March 2012 | Montgomery Reef March 2013

Figure 28 Body Mass Index of sub-adult Green Sea Turtles caught on Ashmore Reef in 2012 and Montgomery Reef 2013.



Ashmore Reef March 2012 | Montgomery Reef March 2013

Figure 29 The relationships between curved carapace length and curved carapace width of sub-adult Green Sea Turtles caught on Ashmore Reef in March 2012 and Montgomery Reef in March 2013.

4.3.4 Blood Chemistry

The results of the blood chemistry (Table 14) were mostly within the reference values from similar studies conducted previously at Ashmore Reef (Whiting, *et al.* 2007) and within the reference values of Green Sea Turtles in the Southern Great Barrier Reef (Flint, *et al.* 2009). At a finer scale the mean values of blood sample from the foraging turtles in this survey differed in some parameters from previous studies at Ashmore Reef (Whiting, *et al.* 2007). Significant differences ($p<0.05$) were found in most electrolytes (Na, K, Ca, P, and Mg) with the exception of Cl. The values of Total Serum Iron and blood enzymes were also significantly different. However the Total Protein, Albumin, Globulin and their ratio along with Urea and Uric Acid were not significantly different to those reported previously. The urinary enzyme, Creatine Phosphokinase, and liver function indicator, total Bilirubin, were significantly different to previous studies. Differences in Bilirubin concentration were the most prominent with values ranging from 6 to 102 µmol/l, with no sample falling within the reference range of 0 to 4 µmol/l (Whiting, *et al.* 2007)or 0.5 to 3.3 µmol/l (Flint, *et al.* 2009). Values for ALT, Alanine Aminotransferase, ranged from 11 to 35 U/l with only 5 values below the maximum reference value 17 U/l (Whiting, *et al.* 2007).

The collection from Montgomery Reef in 2013 displayed significant differences to the 2012 collection for Ashmore Reef. Potassium, Phosphorus, Urea, total Bilirubin, Creatinine, Uric Acid and Glucose were all significantly different fromr the Ashmore collection yet most were within the suggested reference values (Whiting, *et al.* 2007). Total Bilirubin was still significantly high as were the Ashmore Reef specimens from the previous year. Again all turtles appeared healthy and lacked any indication of compromised liver function such as jaundice. It is worthy to note the individual caught in the evening had the highest concentrations of Potassium, Glucose, Urea and Uric Acid which indicates a possible temporal change in blood parameters throughout the day.

Figure 30 The tender of the “Kimberley Quest II” transporting foraging turtles for blood sampling with researcher recording body condition. Note the tanned plastrons indicating residence on the reef for some lengthy period of time.

4.4 Habitat Assessment

A visual inspection of the beaches of Sandy Islet Scott Reef, West, Middle, and East Islands, the unnamed sand cay east of East Island on Ashmore Reef and Browse Island revealed no evidence of possible hydrocarbon residue (Figure 31). At each site the beach was assessed by a sample of three test holes at approximately 200 m intervals around each island to the depth of maximum penetration (15 to 25 cm) of the sampling tube (diameter 53 mm). The sand in each core was friable and crumbled on release from the tube. There was no sign of discolouration or cohesion of particles or inclusions of waxy droplets within the sample (Appendix C).

The members of the survey team made two transects across the reef flat at Ashmore Reef starting from West Island and surveying to the north to the reef crest and the other from the south from West Island and surveying to the East towards Middle Island. Team members were up to ten metres apart forming a transect width of over 100 metres. There was no evidence of hydrocarbon residue on the reef flat.

The foot transects were repeated on West Island Ashmore reef in 2013 from the northern beach on West Island to the West Island channel. There was no evidence on any residue that could have been attributed to being of hydrocarbon origin. The seagrass, *Thalassia hemprichii*, appeared much reduced and too sparse to assess. The calcareous algae, *Halimeda sp*., was the most obvious intertidal macrophyte but was not assessed.

Table 14 Blood Chemistry for the variables and parameters measured from Green Sea Turtles from Ashmore Reef in 2012 and Montgomery Reef in 2013 and the mean values and reference values obtained previously from Ashmore Reef (Whiting *et al.* 2007).

Variable	Ashmore Reef 2012 Mean ± sd (n)	Montgomery Reef* 2013 Mean ± sd (n)	Whiting *et al.* 2007 Reference Values
CCL (cm)	57.33 ± 11.59 (19)	52.1 ± 9.23 (12)	36.6 – 87.9
PCV (%)	25.13 ± 8.87 (8)	Not Available	14.5 – 46.5
Na (mmol/l)	141.31 ± 4.67 (16)	144.33 ± 7.46 (12)	105 – 172
K (mmol/l)	4.02 ± 0.52 (16)	4.51 ± 0.58 (12)	3.1 – 6.7
Cl (mmol/l)	109.69 ± 5.17 (16)	97.47 ± 31.26 (51)	80 – 131
Ca (mmol/l)	2.59 ± 0.69 (16)	2.43 ± 0.27 (12)	0.70 – 2.61
P (mmol/l)	2.76 ± 0.57 (16)	1.97 ± 0.30 (12)	0.92 – 3.00
Mg (mmol/l)	3.89 ± 0.52 (16)	3.53 ± 0.49 (12)	1.79 – 3.78
Total Serum Iron (µmol/l)	17.25 ± 14.10 (16)	Not Available	2 – 104
ALT (U/l)	21.13 ± 6.63 (16)	24.5 ± 8.45 (12)	1 – 17
AST (U/lP	208.75 ± 58.29 (16)	152.83 ± 87.30 (12)	88 - 296
ALP (U/l)	31.63 ± 6.99 (16)	30.83 ± 6.24 (12)	5 – 71
CK (U/l)	1608.00 ± 1280.80 (16)	1512.5 ± 1157.4 (12)	194 - 3110
Total Protein (g/l)	40.94 ± 12.58 (16)	37.5 ± 6.36 (12)	20 - 61
Alb (g/l)	13.75 ± 2.86 (16)	12.43 ± 1.78 (12)	8 - 18
Glob (g/l)	27.25 ± 11.91 (16)	25.08 ± 5.21 (12)	13 - 45
Alb/glob ratio	0.47 ± 0.13 (16)	0.52 ± 0.11 (12)	0.3 - 0.7
Urea (mmol/l)	3.53 ± 1.46 (16)	1.79 ± 1.73 (12)	0.6 – 10.8
Bili (µmol/l)	27.06 ± 27.93 (16)	10.75 ± 7.16 (12)	0 – 4.0
Creat (mmol/l)	26.44 ± 7.47 (16)	20.67 ± 3.96 (12)	18 - 42
Uric (µmol/l)	183.35 ± 76.18 (16)	69.70 ± 27.29 (12)	92 - 257
Gluc (mmol/l)	6.58 ± 1.54 (16)	5.34 ± 1.53 (12)	4.4 – 9.5

CCl Curved Carapace Length, *PCV* packed cell volume, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *ALP* alkaline phosphatase, *CK* creatine kinase, *Alb* albumin, *Glob* globulin, Al*b/glob* albumin/globulin ratio, *Bili* bilirubin, *Creat* creatinine, *Uric* uric acid, *Gluc* glucose

* indicates a control site

Unstained friable sand from a beach test core at Sandy Islet, Scott Reef.

Coral and sponge growth Ashmore Reef.

Intertidal biota Ashmore Reef

Corals at North Scott Reef

Corals at Hibernia Reef

Snorkel survey at North Scott Reef

Dr Rasmussen with olive sea snake Hibernia Reef

Corals and fish in the Lagoon Hibernia Reef

Olive sea snake on the reef crest Hibernia Reef

Green Sea Turtle tracks on West Island Ashmore Reef.

Subadult Green Sea Turtle Ashmore Reef.

Olive Seasnake Cartier island (C. Malam).

Cartier Island reef crest (C. Malam)

Catching subadult Green Sea Turtles on Montgomery Reef (J. Crowe-Riddell).

Figure 31 Views of the intertidal and sub-tidal activities and areas.

5 Discussion

These surveys were the first to assess the relative population density and species diversity of sea snakes and marine turtles on the six major reefs of the Sahul Shelf. Previous surveys (Table 4) established the presence of sea snakes and foraging marine turtles throughout most of the year. June, July and October are the only months not surveyed. Green and Hawksbill Sea Turtles nest mostly in the summer months with isolated nesting throughout the year. The numbers of Green Sea Turtles nesting at Ashmore Reef varies from year to year (Whiting and Guinea 2005) and within the lunar tidal cycle. Long term studies are required to detect trends in the nesting marine turtle population. Comparisons between years in this study are further complicated by the 2012 survey at Ashmore Reef coincided with spring tides whereas the 2013 survey was during neap tides. Similarly previous surveys differed in their timing, duration, objectives, vessels and personnel. These two surveys of this study were the first to assess the marine turtles and sea snakes of the six reefs of the Sahul Shelf at the same time of the year using the same methods, personnel and equipment.

5.1 Sea Snakes

The reef dwelling sea snakes appear to have very small home ranges (Burns and Heatwole 1998; Shine, *et al.* 2005) and are present year round at most of the reefs on the Sahul Shelf (Guinea and Whiting 2005). Standard procedures have now been established by combining the techniques of previous studies, to assess changes in sea snake and marine turtle abundance and species diversity over large spatial and temporal scales. Standardised procedures for assessing the abundance of these species away from the reef environment are yet to be developed and tested.

The sea snake population at Ashmore Reef, a potentially impacted site, has been in decline since a recorded peak in 1998. Surveys up to that time indicated a relatively stable population of 6 to 17 snakes per hectare of reef flat at low tide and between 1 and 3 snakes per hectare on the sand flats at high tide, but between

30 to 70 snakes per hectare in the lagoons and seagrass beds at low tide (Guinea 2012a). Mark and recapture studies over three years indicated between 94 and 192 Turtle-headed Seasnakes (*Emydocephalus annulatus*) frequented a single coral head 30 metres in diameter (Guinea and Whiting 2005). Spawning events by Damselfish (*Chromis*) attracted feeding aggregations of Turtle-headed Seasnakes to the algal-covered coral heads. The reef at that time was prolifically abundant with new individual sea snakes swimming into view each minute during snorkel surveys.

By 2008 Ashmore Reef supported less than 1 sea snake for every 10 hectares, regardless of habitat, with only three snakes seen in three weeks of intensive survey. Sea snake populations on neighbouring reefs, at 30 to 250 nautical miles distant, appeared unaffected. The present surveys found none of the reefs to have a population density as high as that seen on Ashmore Reef in the 1990s.

The maximum density in the 2012 survey was Seringapatam with 4.4 snakes / ha and in 2013 Scott Reef and Cartier Island shared densities greater than of 6 snakes / ha. The decline in species diversity and population numbers appeared to be gradual at Ashmore Reef with the more specialised feeding sea snakes becoming scarcer until only the generalist feeders remain. The specialist feeders included the snake eel feeding Slender-necked Seasnake (*Hydrophis coggeri*) and the Horned Seasnake (*Acalyptophis peronii*) which were once super abundant on Ashmore Reef but have not been encountered on Ashmore Reef since 2005. Missing from the 2012 survey but present in 2013 were these hydrophine sea snakes. Stokes' Seasnake (*Astrotia stokesii*), Slender-necked Seasnake (*Hydrophis coggeri*) and the Horned Seasnake (*Acalyptophis peronii*) were seen during the day and at night at Hibernia Reef.

From our limited understanding, the hydrophine and aipysurine sea snake species differ in their behaviours. The hydrophines often sleep on the surface or at least spend much more time on the surface at night. They are more attracted to spotlights at night. They spend time on the surface "knot coiling" to slough their old skin. Aipysurine species tend to sleep on the sea floor. They snag their old skin on coral to slough it. They are not attracted to lights at night. Both groups drink from fresh water on the surface during rain and feed on benthic fish or their eggs. As such the night anchorage of the "Kimberley Quest II" played a significant role in recording the hydrophine species. All three of these hydrophine species were recorded from the western anchorage of Hibernia Reef yet none were seen on the eastern anchorage on the following night.

The effects of oil spills and dispersants on wildlife have been poorly documented. Sea birds are more commonly reported than other species (Shigenaka *et al*. 2003). From surveys of the effects of the oil spills in the Arabian Gulf during the conflicts in the early 1990s, Tawfiq (1993) suggested sea snakes were the second most vulnerable species ahead of marine turtles (Tawfiq and Olsen 1993). Marine oil spills in tropical Australian waters have been linked to the deaths of sea snakes (AMSA 2010). The cause of the death of sea snakes collected for post-mortem examination from the region of the Montara Well release was inconclusive (Gagnon 2009, Gragon and Rawson 2010). Lethargic, possibly ill, sea snakes were reported in the slick emanating from the West Atlas Rig (Watson, *et al*. 2009). Unexplainably fewer sea snakes were seen away from the slick in the same study.

The Sahul Shelf contains the world's greatest diversity of Aipysurine sea snakes (Guinea 2003). Yet only hydrophine sea snakes, *Hydrophis* and *Acalyptophis*, were collected from the oil slick or the region of the spill (Gagnon 2009). The oil release from the Montara Well may have affected individual sea snakes but the data and observations are lacking. Hydrophine sea snakes because of their behaviour may be more susceptible to the adverse effects of oil on the sea surface. The potential effect on the populations of sea snakes require continued monitoring of the control reefs to detect population trends. Continued monitoring is also required of sea snake populations inhabiting those reefs that because of their location, have a potential to be impacted by future uncontrolled releases of oil.

Given the populations of sea snakes were declining at Ashmore Reef prior to the 2009 release and numbers and species diversity have decreased at Seringapatam Reef in the past 12 months coinciding with increased exploration and drilling in the vicinity, constant vigilance is needed to identify potential impacts that may adversely affect the sea snake species. From this study there is no evidence of detriment to sea snake populations of Cartier Island, Hibernia Reef and Ashmore Reef from the 2009 hydrocarbon release from the Montara well.

Sea snake populations at Ashmore Reef were in decline prior to the 2009 hydrocarbon release. Observations on the distinctive colourations of the sea snake species of the Sahul Shelf reefs indicate a possible restricted gene flow between reefs. Although there are good populations of sea snakes at neighbouring reefs, the re-colonisation of populations on Ashmore Reef may take some time. An objective of continuing monitoring is to assess the ability of sea snake species to re-establish populations at Ashmore Reef.

5.2 Marine Turtles

Marine turtles appear to be less affected by surface oil than are sea snakes (Tawfiq and Olsen 1993). The physical nature and chemical consistency of the oil will influence the severity of the impact on the various life stages of marine turtles (Shigenaka *et al.* 2003). However when their intertidal habitats are affected by surface hydrocarbons the impact can be significant not only to the individual marine turtle but also to their food source. Nesting beaches fouled with oil are dangerous to hatchlings and limit their ability to behave normally (AMSA 2010). Oil coating or hydrocarbon contamination of their food species may have harmful effects to their health. Benthic flora and fauna coated with oil eventually die leaving the soft substrate exposed to erosion and habitat degradation (Shigenaka *et al.* 2003).

There are no published reports of blood chemistry values for marine turtles that have been affected by oil (Dr. Mark Flint personal communication). According to Dr Flint the marine turtles in this survey should have displayed external symptoms of liver abnormalities such as jaundice and lethargy had they been affected by the oil. Such was not the case with the 25 Green Sea Turtles captured at Ashmore Reef. A review of the results from the laboratory indicated no irregularities that could be attributed to dilution factors or changes of units. As the smallest possible samples of blood were collected there was insufficient volume of plasma to repeat the analysis of the samples. The samples collected from the twelve individuals from Montgomery Reef provided an interesting insight to the reference values. Not only were the Bilirubin values large as in the Ashmore

samples from 2012, but also there appeared a temporal change in the values of Potassium, Glucose, Urea and Uric Acid collected by an individual late in the afternoon compared with those that were captured at dawn as they moved onto the reef to feed. These values would have been treated as outliers and excluded from the previous studies (Whiting, et al. 2007, Flint, et al. 2009). These studies present putative reference values based on some tens of individuals rather than a far larger dataset.

Foraging marine turtles are present at all times of the year on Ashmore Reef but numbers of marine turtles on the reef flat increase with the arrival of the breeding females and males into the reef environment with the approaching summer nesting season (Guinea, *et al.* 2005; Whiting and Guinea 2005c). The post-mortem examination of a deceased juvenile Green Sea Turtle collected at the time of the spill was inconclusive as to the cause of death (Gangon and Rawson 2010b). There is no evidence of negative impact on the numbers of juvenile Green Sea Turtles on Ashmore Reef from the Montara Well release in 2009. For as yet unexplained reasons Ashmore Reef still retains large numbers of sub-adult Green Sea Turtles. Scott Reef and Seringapatam Reef with almost identical intertidal habitats support relatively few foraging marine turtles as indicated in the current surveys.

The nesting Green Sea Turtles that visit Ashmore Reef, Cartier Island, Browse Island and Scott Reef are from feeding grounds scattered over northern Australia from the Gulf of Carpentaria to the Pilbara coast (Guinea 2009; Guinea, *et al.* 2005). As they utilised stored fat reserves during the nesting season their diet is unlikely to be influenced by hydrocarbon in the vicinity of the nesting beach. Breeding marine turtles that migrate to and from the nesting beaches on the Sahul Shelf from Australian coastal waters may come into contact with surface oil slicks with possible harmful effects, but this was not indicated in this survey.

This Sahul Shelf to mainland migration was demonstrated recently. Since the survey in March 2012 one of the Green Sea Turtles (K27605, K27606) that was tagged on 8 March while nesting on West Island Ashmore Reef was captured by Aboriginal hunters in King Sound in the Kimberley of Western Australia. With the number of oil and gas exploration and extraction facilities in the North-west Marine Region likely to increase, the threats to marine turtles and sea snakes using the Sahul Shelf require regular assessment and the populations of these species should be monitored for their status and to detect negative impacts and population declines.

Only by monitoring the natural large fluctuations in the numbers of nesting marine turtles, is it possible to identify localised anthropogenic impacts. The likely impact and recovery time of marine turtle populations experiencing localised detrimental events can be estimated using secure data sets and robust modelling. Using transient sensitivity analysis Leung *et al.* (2012) estimated from the simulations the decline in Loggerhead Sea Turtle populations is not greatly accelerated by a single localised oil spill. Our understanding of the population dynamics of the two Green Sea Turtle management units nesting on the islands at Ashmore Reef and Scott Reef remains too rudimentary to perform such simulations for the Sahul Shelf.

5.3 Conclusion

The current surveys demonstrate the lack of detectable impact on the sea snakes and marine turtles living on the reefs of the Sahul Shelf from the 2009 hydrocarbon

release from the Montara Well. Individual sea snakes were collected for the oil slick at the time. As the cause of their deaths was inconclusive there is lack of attributability to the Montara Well release. The impact, if any, on the populations of sea snakes inhabiting the potentially impacted sites of Ashmore Reef, Hibernia Reef and Cartier Island is undetectable.

Surveys of sea snakes of the Sahul Shelf need to include control sites such as Scott Reef, Browse Island and Seringapatam Reef although these areas are in highly prospective natural gas fields. Our knowledge of veterinary pathology of marine turtles and sea snakes is incomplete. The reference values for the blood chemistry of Green Sea Turtles are restricted to two studies that provide no indication of the effects of exposure to hydrocarbons. There are no such values for other species of marine turtles and sea snakes.

The six reefs need to be monitored annually at the same time by the same methods to gain an understanding of their contribution to the biodiversity of the Sahul Shelf and to understand better the potential impact of unexpected releases in the region. There needs to be a better understanding of the pressure that has caused a steady decline in sea snake species diversity and population size on Ashmore Reef for over a decade. The added impact of a hydrocarbon release on already compromised populations of endangered and critically endangered sea snake populations requires closer investigation.

An additional pressure such as a hydrocarbon release may drive the geographically restricted, endemic and critically endangered species of sea snakes such as Leaf-scaled Seasnake and Short-nosed Seasnake to extinction. To address this gap in our knowledge and to assess and monitor the re-establishment of sea snake populations in the region, a yearly sea snake survey should be conducted using standardised techniques by trained observers and qualified researchers. The surveys should cover the six reefs of the Sahul Shelf and include studies of foraging and nesting marine turtles. Particular attention should be paid to sentinel indicators of harm such as abnormal blood chemistry profiles in foraging species. The sampling area for Green Sea Turtle blood chemistry parameters should expand to include a control site such as Montgomery Reef as well as potentially impacted sites such as Cartier Island, Hibernia Reef and Ashmore Reef.

In addition, the need to better understand how sea snakes and marine turtles interact with their environment and the toxicity of new chemicals (hydrocarbon and dispersants) they are likely to encounter as the number of oil and gas exploration and extraction facilities expand along the northern Australian continental shelf. With this expansion are increased vessel traffic, noise, seismic surveys, pile driving, drilling and removal of structures. There has been no study of how these activities affect the sea snakes and marine turtles all of which are EPBC listed threatened marine species.

6 Summary of Results and Recommendations

This was the most thorough sea snake survey of the reefs of the Sahul Shelf that has been conducted to date.

No visual evidence of hydrocarbon contamination was evident on the beaches or on the reef flats.

Sea snake numbers were in decline at Ashmore Reef prior to the 2009 release from the Montara Well. No sea snake was seen on Ashmore Reef or on the neighbouring reefs within the Ashmore Reef Marine Park.

With the exception of Seringapatam Reef, sea snake numbers were reduced from earlier studies. In 2013 Seringapatam Reef had fewer sea snakes than in the previous year.

Marine turtle numbers were relatively stable compared with earlier surveys. Numbers of nesting Green Sea Turtles were consistent given the annual fluctuation in nesting numbers with this survey period being after the peak of nesting in mid-summer.

Foraging Green Sea Turtles were in expected numbers at Middle Island and West Island. Aspects of the blood chemistry differed significantly for previous studies when the average values were compared. All of the blood samples from foraging turtles had Bilirubin concentrations in excess of the accepted reference values for this species at Ashmore Reef and southern Queensland. Blood samples from the same species on Montgomery Reef, a control site, also had elevated Bilirubin concentrations. The cause of this elevation and the implications for the health of the marine turtles remains unclear.

The analysis of sea snake population density and species diversity of the reefs of the Sahul Shelf and the potential impact of the hydrocarbon release indicated the potentially impacted sites of Cartier Island and Hibernia Reef had the highest sea snake densities of the six reefs.

It is recommended the survey be repeated annually to monitor the marine turtle and sea snake population status to gain a better understanding of the dynamics of these EPBC listed species living on the reefs in the region.

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8 Appendix A Instructional Material

List of instructive media and materials used to familiarise the team members with identification of sea snakes based on morphology, colour, behaviour and scale characters**.**

Videos include:

Mark O'Shea's Big Adventure featuring, beaked, olive, turtle-headed, dusky, dubois' and leaf-scale sea snakes,

Animal Planet's Sea Serpents featuring horned, olive, turtle headed, dusky, leaf-scale and short nose and stokes sea snakes,

Ben Crop's Rugged Coast featuring olive and turtle headed sea snakes and sea kraits

Ben crops Sea snakes of Marion Reef featuring olive and turtle headed sea snakes.

Books included:

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Key to the Sea Snakes of Ashmore Reef (Guinea 2008).

8.1 Key to the Species of Sea Snakes on Ashmore Reef

This key is designed to identify sea snakes with a minimum of handling. The characters that were selected are characteristic of adult specimens. Considerable variation in colour occurs in *Emydocephalus annulatus* in which males are generally smaller in size and darker or more banded than the mottled pattern of the females. *Aipysurus laevis* may be banded as a juvenile and change its colouration to either a uniform brown, white or blue-black with saddles of dark colouration extending to the ventral surface. Like *Aipysurus fuscus*, it retains a tan coloured head. *Aipysurus foliosquama* and *A. apraefrontalis* may be either black or blue in colouration and both have a white iris to the eye. *A. duboisii* also has a white iris but the colouration may be banded, or light to dark mottled or dark on the back with white triangles on the side. *Astrotia stokesii* is highly variable in colour from entirely cream to dark brown. Juveniles of this species are banded. *Acalyptophis peronii*, *Hydrophis coggeri*, *Hydrophis kingii* and *Hydrophis elegans* are all banded as juveniles with the intensity of the banding decreasing as they mature. Three species have foliform (leaf-like) scales on the body; *Aipysurus foliosquama*, *Aipysurus apraefrontalis* and *Astrotia stokesii*. Two species, *Pelamis platurus* and *Lapemis hardwickii*, have juxtaposed scales on the body.

1	a	Ventral scales broad - two to three times broader than neighbouring body scales	go to 2
	b	Ventral scales narrow - about the same width as neighbouring body scales	go to 7

2	a	Three scales on the upper lip	*Emydocephalus annulatus*	
	b	More than three scales on the upper lip	go to 3	
3	a	Head scales fragmented with tubercles and rugose interspaces	*Aipysurus duboisii*	
	b	Head scales entire	go to 4	
4	a	Prefrontal scale missing (frontal scale in contact with the nasal scales)	*Aipysurus apraefrontalis*	
	b	Prefrontal scale present	go to 5	
5	a	Body scales foliform (leaf like)	*Aipysurus foliosquama*	
	b	Body scales diamond shaped (almost as wide as long)	go to 6	
6	a	Body uniformly brown in colour with 19 - 21 scale rows at the mid-body	*Aipysurus fuscus*	

	b	Body variable in colour from uniform brown to light cream with or without dark saddles or bands	*Aipysurus laevis*	
7	a	Head shields irregularly fragmented forming spines at the free margin	*Acalyptophis peronii*	
	b	Head shields generally symmetrically arranged	go to 8	
8	a	Body approximately of uniform thickness	go to 9	
	b	Anterior third of the body slender	go to 10	
9	a	Ventral scales foliform and paired with body scales foliform	*Astrotia stokesii*	
	b	Ventrals scales small, body scaled juxtaposed and spinous on the belly of males	*Lapemis curtus*	
10	a	Body and head black above and yellow below	*Pelamis platurus*	
	b	Body banded with dark saddles on a pale background	go to 11	
11	a	Bands extending to the ventral surface without secondary bands between the saddles	Hydrophis coggeri	
	b	Bands with secondary bands, bars or spots between the saddles	go to 12	
12	a	Head black in colour with white ring	*Hydrophis kingii*	

	around the eye	
b	Body striped with bars between saddles and mid-lateral darker patches	*Hydrophis elegans*

9 Appendix B Ginger Ants on West Island

Extracts from field notes on trips to Ashmore Reef by M Guinea

File Note 21 May 2008 West Island Ashmore Reef.

I went ashore at 2:30 with the Ashmore Guardian crew (Rage and Khoj) to dig hatched marine turtle nests. The nest on the Northern Beach was particularly interesting because of the number of dead hatchlings still in the neck of the nest. The nest was located under an Argusia shrub at the top of the dune (12º 14.524 S, 122º 58.151E).
Thirteen Green Sea Turtle hatchlings were clumped together in the neck of the nest each facing towards the surface and all had their eyes eaten exposing the white bones of the eye sockets and opening to the brain as well as the skin from the neck region. The hatchlings were covered with ginger ants. The position of the nest, being under a shady bush, indicated the group were unlikely to have been killed by hyperthermia from the sun. It appears the hatchlings were waiting to emerge when they were attacked in the nest by ginger ants. The group at the top of the nest were killed and partly eaten blocking the exit of the rest of the clutch deeper within the nest.
This was the first evidence I have seen of ginger ants killing Green Sea Turtle hatchlings on West Island (Photo 1 and Photo 2).

File Note 10 March 2012 West Island Ashmore Reef.
The research group (Dean Wright, Tina Schroeder and Chris Malam) went ashore at 1500 to check for oil residue on the beach. In the western bay the group came across numerous dead Hawksbill Sea Turtles in the intertidal zone. This was unusual because hatchlings had emerged and made it to the intertidal zone after the high tide at 1115 that morning. About 20 hatchlings were dead on the beach below the day's high tide mark and more, approximately 20, were dead on the beach above the tide mark. The nest was located on the dune beneath an Argusia bush (12.24177S, 122.96274E). The group were prevented from investigating further by the presence of ginger ants.
At 2300 the group returned to the beach with protective gloves and excavated the hatched nest. The nest contained 21 dead hawksbill hatchlings and one live hatchling. Seven eggs failed to hatch with one of these containing a dead early developing embryo. The nest contained 167 empty egg shells. The dead hatchlings on the beach were photographed. All of the dead hatchlings on the beach were being eaten by ginger ants.
It appears the hatchlings were attacked in the neck of the nest and emerged onto the beach. Some possibly succumbed to the bites and stings and died on the beach with some making it as far as the intertidal zone. The other hatchlings may have escaped unharmed and made it to the water. The dead hatchlings were disoriented as they did not make a distinct fan from the nest. They were scattered over the surface of the sand in depressions and in open areas on the beach. The ginger ants were very persistent in removal of flesh from the hatchlings (Photo, 3, 4 and 5). I visited the site the

following day and recorded some of the dead hatchlings had been dismembered (Photo 6).
This is the second observation of ginger ants attacking marine turtle hatchlings in the nest.
I strongly recommend the baiting program for ginger ants be intensified this dry season and extended to West Island.

Michael Guinea

Photo 1 Green Sea Turtle hatchlings killed by ginger ants West Island 2008.

Photo 2 Green Sea Turtle hatchling killed by ginger ants West Island 2008.

Photo 3 Hawksbill Sea Turtle hatchling killed by ginger ants West Island 2012.

Photo 4 Hawksbill Sea Turtle hatchlings killed by ginger ants West Island 2012.

Photo 5 Ginger ants attacking Hawksbill Sea Turtle hatchlings West Island 2012.

Photo 6 The Remains of a Hawksbill Sea Turtle hatchlings attacked by ginger ants West Island 2012.

10 Appendix C Tagged Marine Turtle

10.1 Metadata of marine turtles tagged at Ashmore Reef, Sahul Shelf AD Montgomery Reef, Kimberley coast.

Date	Tag # Left	Tag # Right	CCL (cm)	CCW (cm)	Mass (kg)	CPS Location (WGS84)
9032012	K27609	K27610	43.4	40.7	8	S12.26387 E123.03020
10032012	K27617	K27618	36.8	35.2	6	S12.26589 E123.02913
10032012	K27619	K27620	42.4	40	7.5	S12.26677 E123.03531
10032012	K27621	K27622	48.2	44.8	13.5	S12.26754 E123.03793
12032012	K27623	K27624	37.7	35.3	5.5	S12.24501 E122.98040
12032012	K27629	K27630	43.1	39.6	9	S12.24541 E122.98137
12032012	K27631	K27632	62.7	56.7	25	S12.24650 E122.97983
12032012	K27633	K27634	51.4	47.2	16	S12.24727 E122.97878
12032012	K27635	K27636	52.1	44.1	14.5	GPS Mal Function
12032012	K27637	K27638	60.8	57.2	27	na
12032012	K27639	K27640	66.7	58.6	31	na
12032012	K27641	K27642	58.8	52.9	21.5	na
12032012	K27643	K27644	70.4	62.7	42	na
12032012	K27645	K27646	62.7	57.3	27	na
12032012	K27647	K27648	64.7	59.3	33	na
12032012	K27649	K27650	54.9	48	18	na
12032012	K27651	K27652	71.2	64.5	33.5	na
12032012	K27653	K27654	44.3	42	8	S12.24501 E122.98040
12032012	K27655	K27656	44.1	42.7	9	S12.24541 E122.98137
12032012	K27657	K27658	46.8	47.1	12	S12.24650 E122.97983
12032012	K27659	K27660	70.1	62.5	40	S12.24727 E122.97878
12032012	K27661	K27662	69	62	35	S12.24623 E122.97436
12032012	K27663	K27664	71.1	63.4	37	S12.24314 E122.96308
12032012	K27665	K27666	69.5	66.7	39	S12.23943 E122.97369
8032012	K27601	K27602	96.4	88.8	n/a	S12.24079 E122.96292
8032012	K27603	K27604	98.6	95	n/a	S12.24239 E122.96326
8032012	K27605	K27606	97.2	88.6	n/a	S12.24259 E122.96358
8032012	K27607	k27608	110.6	99.6	n/a	S12.24259 E122.96358
9032012	K27611	K27612	89.4	78	n/a	S12.24301 E122.96995
9032012	K27613	K27614	106.3	97.3	n/a	S12.24095 E122.96837
9032012	K27615	K27616	112.3	98.2	n/a	S12.24116 E122.96263
10032012	K27625	K27626	98.9	88.9	n/a	S12.24454 E122.96863
12032012	K27627	K27628	105.1	97.7	n/a	S12.24296 E122.96418
07032013	WA54021	WA54111	63	59.3	26.5	S16.01239 E124.28242
07032013	WA54226	WA54258	54.6	48.1	17	S16.01239 E124.28242
07032013	WA54161	WA54169	40.6	38.5	7.5	S16.01239 E124.28242
08032013	WA53066	WA53120	39.7	39.5	6.75	S16.01239 E124.28242
08032013	WA53503	WA53775	52.3	47.4	15	S16.01239 E124.28242
08032013	WA53965	WA53924	52	47.1	15	S16.01239 E124.28242
08032013	WA53776	WA54176	44	43.9	8	S16.01239 E124.28242
08032013	WA52930	WA54293	50.5	45.9	14.25	S16.01239 E124.28242
08032013	WA54149	WA54152	49	45.6	12.5	S16.01239 E124.28242
08032013	WA54300	WA54802	47.1	44.5	11.5	S16.01239 E124.28242
08032013	K51243	K51244	62.9	57.3	27	S16.01239 E124.28242
08032013	K51241	K51242	69.6	64.4	37.5	S16.01239 E124.28242

10.2 Habitat Assessment Beach Core Samples

(Datum =WGS84)

Date	Latitude	Longitude	Beach Core result
Sandy Islet Scott Reef			
3 March 2012	S14.05668	E121.77742	Negative for hydrocarbon
3 March 2012	S14.05641	E121.77721	Negative for hydrocarbon
3 March 2012	S14.05608	E121.77703	Negative for hydrocarbon
3 March 2012	S14.05559	E121.77687	Negative for hydrocarbon
3 March 2012	S14.05506	E121.77690	Negative for hydrocarbon
3 March 2012	S14.05469	E121.77725	Negative for hydrocarbon
3 March 2012	S14.05522	E121.77753	Negative for hydrocarbon
3 March 2012	S14.05573	E121.77760	Negative for hydrocarbon
3 March 2012	S14.05625	E121.77780	Negative for hydrocarbon
3 March 2012			Negative for hydrocarbon
West Island Ashmore Reef			
	S12.24415	E122.97132	Negative for hydrocarbon
	S12.24293	E122.96998	Negative for hydrocarbon
	S12.24151	E122.96883	Negative for hydrocarbon
	S12.24036	E122.96704	Negative for hydrocarbon
	S12.24140	E122.95838	Negative for hydrocarbon
	S12.24544	E122.96203	Negative for

			hydrocarbon
Middle Island Ashmore Reef			
	S12.26569	E123.03026	Negative for hydrocarbon
	S12.26643	E123.03609	Negative for hydrocarbon
	S12.26632	E123.03601	Negative for hydrocarbon
	S12.26492	E123.03445	Negative for hydrocarbon
	S12.26677	E123.03531	Negative for hydrocarbon
	S12.26754	E123.03793	Negative for hydrocarbon
East Island Ashmore Reef			
	S12.25954	E123.09430	Negative for hydrocarbon
	S12.25981	E123.09456	Negative for hydrocarbon
	S12.25987	E123.09436	Negative for hydrocarbon
	S12.25988	E123.09430	Negative for hydrocarbon
	S12.25973	E123.09469	Negative for hydrocarbon
	12.25942	E123.09536	Negative for hydrocarbon
East Sand Bar			
	S12.25944	E123.11083	Negative for hydrocarbon
	S12.25975	E123.11084	Negative for hydrocarbon
	S12.25986	E123.11133	Negative for hydrocarbon
Browse Island			
9 March 2013	S14.11075	E123.55019	Negative for hydrocarbon

9 March 2013	S14.11069	E123.54867	Negative for hydrocarbon
9 March 2013	S14.10980	E123.54751	Negative for hydrocarbon
9 March 2013	S14.10847	E123.54669	Negative for hydrocarbon
9 March 2013	S14.10794	E123.54995	Negative for hydrocarbon
9 March 2013	S14.10660	E123.54819	Negative for hydrocarbon

10.3 Observed Marine Turtle Nests on the islands of Sahul Shelf

Date	Locality	Latitude	Longitude	Notes
11March12	Middle Island	S12.26657	E123.03616	Green laid
11March12	Middle Island	S12.26657	E123.03616	Hawksbill laid
11March12	Middle Island	S12.26607	E123.03582	Green laid
11March12	Middle Island	S12.26667	E123.03568	Hawksbill laid
11March12	East Island	S12.26266	E123.09818	Hawksbill hatched nest
11March12	East Island	S12.26262	E123.09819	Green hatched nest
9 March 2013	Browse Island	S14.11073	E123.55087	Recent Green turtle nest
9 March2013	Browse Island	S14.11079	E123.55057	Recent Green turtle nest
9 March2013	Browse Island	S14.11085	E123.55029	Recent Green turtle nest
9 March2013	Browse Island	S14.11087	E123.55025	Recent Green turtle nest
9 March2013	Browse Island	S14.11075	E123.55019	Recent Green Turtle nest
9 March2013	Browse Island	S14.11083	E123.54970	Recent Green Turtle nest
9 March2013	Browse Island	S14.11080	E123.54908	Recent Green Turtle nest
9 March2013	Browse Island	S14.11071	E123.54865	Recent Green Turtle nest
9 March2013	Browse Island	S14.11069	E123.54867	Recent Green

				Turtle nest
9 March2013	Browse Island	S14.11068	E123.54827	Recent Green Turtle nest
9 March2013	Browse Island	S14.11028	E123.54781	Recent Green Turtle nest
9 March2013	Browse Island	S14.10998	E123.54751	Recent Green Turtle nest
9 March2013	Browse Island	S14.10998	E123.54741	Recent Green Turtle nest
9 March2013	Browse Island	S14.10959	E123.54708	Recent Green Turtle nest
9 March2013	Browse Island	S14.10847	E123.54669	Recent Green Turtle nest
9 March2013	Browse Island	S14.10729	E123.54733	Recent Green Turtle nest
9 March2013	Browse Island	S14.10701	E123.54757	Recent Green Turtle nest
9 March2013	Browse Island	S14.10660	E123.54820	Recent Green Turtle nest
9 March2013	Browse Island	S14.10663	E123.54857	Recent Green Turtle nest
9 March2013	Browse Island	S14.10794	E123.54995	Recent Green Turtle nest
9 March2013	Browse Island	S14.11123	E123.55127	Recent Green Turtle nest
9 March2013	Browse Island	S14.11123	E123.55127	Recent Green Turtle nest
9 March2013	Browse Island	S14.11091	E123.54900	Recent Green Turtle nest
9 March2013	Browse Island	S14.10849	E123.54663	Recent

				Green Turtle nest
9 March2013	Browse Island	S14.10666	E123.54923	Recent Green Turtle nest
9 March2013	Browse Island	S14.10967	E123.55077	Recent Green Turtle nest
9 March2013	Browse Island	S14.11131	E123.55140	Recent Green Turtle nest
9 March2013	Browse Island	S14.11131	E123.55140	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05731	E121.77812	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05734	E121.77806	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05686	E121.77794	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05679	E121.77797	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05658	E121.77790	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05653	E121.77786	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05605	E121.77766	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05569	E121.77751	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05551	E121.77744	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05550	E121.77755	Recent Green Turtle nest

11 March 2013	Sandy Islet Scott Reef	S14.05541	E121.77743	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05518	E121.77731	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05491	E121.77725	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05453	E121.77723	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05453	E121.77725	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05467	E121.77702	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05480	E121.77700	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05515	E121.77698	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05539	E121.77701	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05540	E121.77697	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05555	E121.77705	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05591	E121.77716	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05646	E121.77748	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05659	E121.77754	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05659	E121.77751	Recent Green

				Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05674	E121.77761	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05699	E121.77775	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05748	E121.77799	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05759	E121.77804	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05792	E121.77819	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05793	E121.77817	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05850	E121.77832	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05802	E121.77826	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05772	E121.77816	Recent Green Turtle nest
11 March 2013	Sandy Islet Scott Reef	S14.05743	E121.77810	Recent Green Turtle nest

11 Appendix D Personnel and Competencies

Name: Dr Michael Guinea

Qualifications and Experience: Michael is a Lecturer in Zoology at Charles Darwin University. He has more the 40 year of experience in handling sea turtles and sea snakes. Both his MSc and PhD addressed aspects of sea snake ecology, systematic and biogeography. He is skilled in underwater observations and use of manta board in surveys. He has visited the reefs of the Sahul Shelf since 1992 and published numerous reports for industry and the Commonwealth Government. He is a member of the IUCN SSC Marine Turtle Specialist Group and Sea Snake Specialist Group. He holds current TBOSIET, Senior First Aid and SCUBA certifications.

Name: Dr Kate Sanders

Qualifications and Experience: Kate holds a PhD in genetics and holds an Australian Postdoctoral fellowship at the University of Adelaide. She has published numerous papers on the evolution and phylogeography of sea snakes. She is experienced in capture and identification of sea snakes, has SCUBA and TBOSIET certifications. Kate is co-chair of the IUCN, SSC Sea Snake Specialist Group.

Name: Dr Arne Redsted Rasmussen

Qualifications and Experience: Arne is Associate Professor in the School of Conservation at The Royal Danish Academy of Fine Arts, Copenhagen, Denmark. Arne has published numerous works on sea snakes and their taxonomy based on morphology, anatomy and genetics. He is skilled in the identification and handling of sea snakes. He holds certification from Survival Training and Maritime Safety in Denmark as well as SCUBA. He is an active member of the IUCN, SSC Sea Snake Specialist Group.

Name: Dean Wright

Qualifications and Experience: Dean has a BSc with Honours at Griffith University. He has been involved with capturing, measuring, tagging sea turtles in the Northern Territory and Western Australia for the past six years. He is skilled in use of manta boards for underwater observations. He holds current Senior First Aid, TBOSIET and SCUBA certifications.

Name: Nirmala Nath

Qualifications and Experience: Nirmala has more than 20 year experience in laboratory safety and pathology. She is skilled in collection and preservation of blood for pathological and chemical analysis. She holds Certifications for laboratory studies from City and Guilds, London, TBOSIET, Senior First Aid and SCUBA.

Name: Daniel Guinea

Qualifications and Experience: Daniel holds a BSc in Chemistry and environmental Science from Australian National University. He is contracted to PowerWater, Darwin for sample collection and preservation, data analysis and report preparation. He is experienced in tagging and handling sea turtles, underwater observation, and holds current TBOSIET, Senior First Aid and SCUBA certifications.

Name: Chris Malam

Qualifications and Experience: Chris is a graduate of Australian National University who has been a participant in the Undergraduate Training and Research Opportunity Program (UTROP) at Charles Darwin University. He has experience in tagging and handling sea turtles, underwater observation, TBOSIET, Senior First Aid and SCUBA certifications. He is currently enrolled in BSc Honours at University of Adelaide.

Name: Jenna Crowe-Riddell

Qualifications and Experience: Jenna is a graduate of Australian National University who has been a participant in the Undergraduate Training and Research Opportunity Program (UTROP) at Charles Darwin University. She has experience in tagging and handling sea turtles, underwater observation, TBOSIET, Senior First Aid and SCUBA certifications.

Name: Sally Oughton

Qualifications and Experience: is a graduate of Australian National University who has been a participant in the Undergraduate Training and Research Opportunity Program (UTROP) at Charles Darwin University. She has experience in tagging and handling sea turtles, underwater observation, TBOSIET, Senior First Aid and SCUBA certifications.

Name: Tina Schroeder

Qualifications and Experience: is a student at the University of Melbourne. She has participated in sea turtle surveys in Northern Territory and Western Australia. She has experience in sea turtle identification, observation, tagging and measuring. She holds current TBOSIET, Senior First Aid and SCUBA certifications.

Name: Andrew Raith

Qualifications and Experience: He is a graduate of Charles Darwin University who has been a participant in the Undergraduate Training and Research Opportunity Program (UTROP).He has participated in sea snake surveys of Ashmore and Hibernia Reefs and Cartier Island. He has ten years experience in tagging and handling sea turtles, underwater observation of marine turtles and sea snakes using manta board, TBOSIET, Senior First Aid and Life Saving certifications.

Name: Christine Giuliano

Qualifications and Experience: graduated from La Trobe University with BSc Honours. She has participated in sea turtle surveys in Northern Territory. She has experience in sea turtle identification, observation, tagging and measuring. She holds current TBOSIET, Senior First Aid and SCUBA certifications

The 2012 Survey Team in Derby (L to R) Dean Wright, Sally Oughton, Tina Schroeder, Jenna Crowe-Riddell, Kate Sanders, Nirmala Nath, Mick Guinea, Chris Malam, Daniel Guinea, Arne Rasmussen.

The 2013 Survey Team (L to R) Blade (Coxswain), Jeff Ralston (Captain), Arne Rasmussen, Mick Guinea, Kate Sanders, Dean Wright, Jenna Crowe-Riddell, Christine Giuliano, Chris Malam, Steve Post (Chef), Andrew Raith, Tina Schroeder, Daniel Guinea, Nirmala Nath, Helen (Hostess).