Assessment of the loggerhead turtle in the IOSEA region

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Loggerhead turtle overview

Summary - nesting

Loggerhead turtles nest in 10 nations within the Indian and Pacific Ocean basin. Seven of these nations are Signatory States of the IOSEA, one, Japan, is within the range of the IOSEA but is not a signatory, and two, New Caledonia and Vanuatu are outside of the IOSEA. Telemetry of post nesting turtles has been undertaken from South Africa, Oman, eastern and western Australia and Japan.

Summary – foraging

Data from tag recoveries, satellite telemetry (endpoints), and fisheries bycatch indicate that loggerhead turtles forage within the Exclusive Economic Zones of 22 Signatory States (and their Territories) of the IOSEA. In addition, loggerhead turtles have been recorded from six non signatory range states and four non-range states. Population and biological studies on foraging turtles have only been conducted in two nations (Japan and Australia – for the north and south Pacific Ocean populations respectively. Of the 22 Signatory States in which loggerhead turtles have been recorded threats to loggerhead turtles have been identified in 10.

Summary – population identification

There are five genetically distinct populations/management units of loggerhead turtles within the IOSEA region – South-west Indian Ocean, North-west Indian Ocean, North-east Indian Ocean, South-east Indian ocean, North Pacific and South Pacific. These have been classified as distinct based on a combination of genetic data, migration data, home range data, tag recoveries and expert opinion. While the nesting sites are distinct, individuals from more than one population may inhabit particular foraging areas.

The status of each of the populations has recently been assessed by both the United States National Marine Fisheries Service (US NMFS) and as part of the Burning Issues initiative of the Marine Turtle Specialist Group (Figure A; Wallace et al. 2011). In general the two assessments, which were conducted independently but with some experts were involved in both processes, derived similar conclusions (Table A). Two main differences - (1) US NMFS included the Sri Lankan loggerheads with the NW-Indian Ocean population (Oman and Yemen) whereas Wallace et al. (2010; 2011) considered it to be separate, and classed it as a high risk-high-threats population (and one of the 11 most endangered in the world) and (2) US NMFS classed the North-west Indian Ocean population as “Endangered” whereas Wallace et al. (2011) classed it as low risk-low threat because there is a lack of empirical data on population decline and threats. Clearly, there is a need to focus research and monitoring on this population to improve assessment accuracy.

Table A – Comparison of outputs from the US FWS determination and Wallace et al. (2011) for loggerhead turtle populations in the IOSEA region. 1 = denoted by Wallace et al. 2011 as a critical knowledge gap and 2 = listed as one of 11 of the worlds most endangered RMUs (Wallace et al. 2011).

Breeding location	**Population**	**NMFS Determination**	**Wallace et al. 2011**
Japan	North Pacific	Endangered	High Risk-High Threats[2]
Eastern Australia and New Caledonia	South Pacific	Endangered	High Risk-High Threats
Western Australia	South-east Indian	Threatened	High risk-Low Threats[1]
South-east Africa	South-west Indian	Threatened	High risk-Low Threats
Oman and Yemen	North-west Indian	Endangered	Low risk-Low Threats[1]
Sri Lanka	North-east Indian	Not assessed (inc. in NW Indian Ocean)	High Risk-High Threats[1,2]

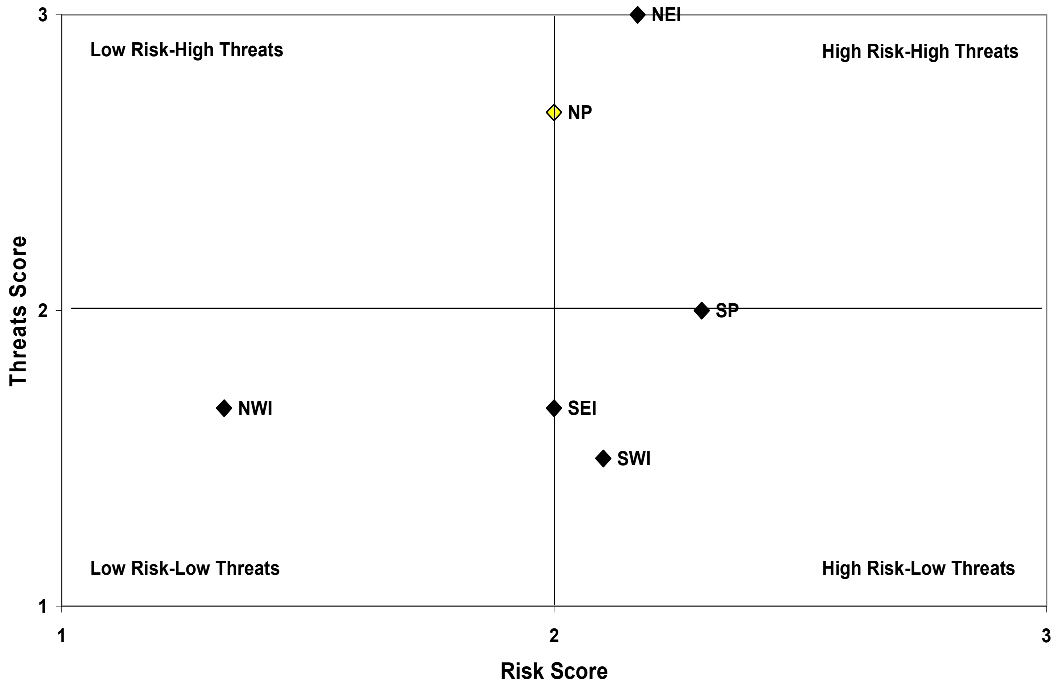

Figure A; Conservation priority portfolio approach to displaying and interpreting paired risk and threat scores for loggerhead RMUs (adapted from Wallace et al. 2011)

Gaps in the basic biological information

Population structure

There are some gaps in our understanding of loggerhead turtle population genetic profiling within the IOSEA region. To address the gap, and determine the genetic structure of loggerhead turtle populations the following rookeries need to be sampled and compared to each other, as well as to published genotypes; Sri Lanka, Yemen (Socotra), Somalia. There is also a need to sample turtles from foraging areas, or those that have stranded or been caught in fisheries to better understand population specific mortality.

Life history attributes

A. Nesting populations

There are substantial gaps in our knowledge of life history attributes for several of the loggerhead turtle nesting sites in the IOSEA region. The specific gaps vary between locations, and details can be found by referring to each population. Data on life history attributes are necessary for the development of accurate population models. It is preferential that life history parameters be collected from at least one rookery per management unit. The gaps in life history attributes evident in most management units include:

- The number of clutches per female per year/nesting season
- Temperature profile of nesting beaches
- The number of years between breeding seasons
- The rate of recruitment into the breeding population
- Nest success and hatchling recruitment
- Inter-nesting areas

B. Non-nesting beach aspects

Within the IOSEA region there are substantial gaps in our knowledge of loggerhead turtle foraging areas, habitat use (oceanic and coastal), inter-nesting area habitats, diet, growth, age and survivorship for all except the two Pacific Ocean populations. Additionally, while there have been substantial tracking and foraging area studies in the North and South Pacific, and the South and North-west Indian Ocean populations, few data on migration and home range exist for the North-east and South-east Indian Ocean populations.

Gaps in management

Reporting gaps

It was evident during the writing of this assessment that much of the threat, mortality and management information contained within the IOSEA website, and the Signatory States reports is not species specific. It could be that "species" level information is not collected, or that it is not reported on. In terms of threats such as bycatch it is most likely the former. Improving species-specific data collection about threats and mortality will improve management.

Bycatch and fisheries mortality
Incidental catch of marine turtles was reported to occur at varying levels of intensity in all nations in the IOSEA region, however, species specific data is often not available. Bycatch has not been quantified in most countries, and fewer bycatch data exist for the high seas fisheries, especially species specific data. There are also gaps in the ecological, social and economical aspects of marine turtle bycatch. Bycatch and fisheries based mortality needs to be addressed by Fisheries and/or Government organizations. This will take a coordinated international effort similar to those undertaken in the Atlantic and Pacific Ocean fisheries.

Hatchling production
Aside from the South-west Indian Ocean and the two Pacific Ocean populations there have been no detailed assessments of the hatchling production at other rookeries in the IOSEA region. Without these data it is impossible to conduct meaningful population assessments and design management strategies.

Rising beach temperatures associated with climate change can be expected to negatively impact on population sex ratio and incubation success of loggerhead turtle eggs. Sand temperature loggers have been deployed on index beaches for the South-east Indian Ocean and South Pacific Ocean, no adequate monitoring appears to be in place in any of the other IOSEA countries to guide rookery management in response to climate change.

Standard monitoring
Monitoring of several of the rookeries in the IOSEA region has been initiated relatively recently. There is a need for managers in each location to develop standard monitoring protocols that remain consistent year to year, and complements existing projects. Mostly importantly, if whole season monitoring is not possible at all rookeries, index beaches and standard monitoring periods need to be determined and used annually. The introduction of standard practices will substantially improve the ability to use the data effectively in the future.

Additional issues for loggerhead turtles in the IOSEA region

Climate change

Climate change is becoming a ubiquitous issue throughout the world. While marine turtles have coped with changing climates over past millennia, the rate of current and predicted change, coupled with a developed world are unprecedented. While it may be a ubiquitous issue, the degree to which various species or population of marine turtle are exposed, and how they are able to adapt will vary considerably. For loggerhead turtles Chaloupka et al. (2008) demonstrate that increased sea surface temperatures are likely to negatively influence the numbers of females breeding each year and studies from the US indicate that shifts in the nesting season, or impact of threats could change with a warming climate (Pike and Stiner 2007). Key research gaps include the conversion of global/ocean scale climate models down so they are relevant to local scale (e.g. for nesting beaches or foraging areas), understanding sensitivity and thresholds of concern (e.g. pivotal temperatures, and sand temperature ranges) and understanding adaptive capacity (see Hamann et al. 2007; 2010).

Recommendations for loggerhead turtle conservation

- Genetics and population identification in Sri Lanka – including national assessment
- Analysis of existing data from the NW Indian Ocean management unit (acknowledging that significant amounts of data exist)
- Collection of species specific bycatch and mortality data, including the collection of skin samples for genetics
- Understanding hatchling and post – hatchling dispersal in the Indian Ocean
- Initiation of studies to permit an assessment of the vulnerability of loggerhead turtle management units to climate change.
- Foraging area surveys to quantify abundance, and demography of loggerhead turtles in coastal waters.

Introduction

The loggerhead turtle (*Caretta caretta*) occurs in all of the world's tropical and temperate oceans. As widely distributed and long-lived marine mega-fauna, a challenge for managers has been the assessment of loggerhead conservation status at scales which are appropriate (Wallace et al. 2010). The global stock of loggerhead turtles is made up from numerous populations, which possess separate nesting locations and often display distinct life-cycle characteristics (Dodd, 1988, Fed Reg 2011). Yet different nesting populations may also share nursery and foraging areas (Bowen and Karl, 2007). As a result, the separation of populations into distinct entities for management purposes has proved difficult. However, for conservation strategies to be effective, it is crucial that the relationships between the geographic areas utilised by each population are identified, to permit impacts from anthropogenic threats to be determined at the population level (Wallace and Saba, 2009; Hamann et al. 2010).

There have been several attempts to categorize marine turtles into independent population units below the species level, but above the nesting population level. The first initiatives used population genetics to determine genetically distinct populations, and then classed these populations as stocks or management units (Moritz et al. 2002; Dethmers et al. 2006). More recently, the NMFS assembled a Loggerhead Biological Review Team (BRT) in 2008 to describe turtle management units and complete a status review of the loggerhead turtle. The NMFS and FWS based their review around what they consider to be 'distinct population segments' (DPS) which are defined as populations distinct from other populations of the same taxon due to physical, physiological, ecological, or behavioural factors; or due to differences in control or management as a result of international government boundaries. Simultaneously, in an attempt to address the challenges of data poor areas, migratory behaviour and foraging areas with mixed stocks, Wallace et al. (2010) described regional management units (RMU) for not only loggerhead turtles but all seven species of marine turtle. Thus providing precise demographic information about sea turtle population distributions in a spatial format to enable analysis in combination with other geo-referenced data-sets. Together these approaches identify the most appropriate management units for loggerhead turtles.

For the loggerhead turtle, genetic based studies from nesting turtles identified distinct population structure across the globe – Mediterranean, North-east Atlantic, South-east USA, Brazil, Japan, Eastern Australia, Western Australia, South-east Africa, Oman and possibly Sri Lanka. The NMFS appointed BRT agreed with these classifications in their assessment of loggerhead turtles across the globe – however renaming them, althought they combined Sri Lankan loggerheads into the same management unit as those in Oman (Table 1). Similarly, Wallace et al. (2010) also described ten RMU's globally (Figure 1, but in the absence of necessary biological information (e.g. genetic analysis) they considered the putative RMU suggested for the Northeast Indian Ocean (Sri Lanka) to be separate from those in the North-west Indian ocean. Thus regardless of the process, each review has identified similar structure.

Table 1 – Geographic locations of global loggerhead turtle populations and the descriptors used by the US FWS and Wallace et al. (2011) in their assessments.

Breeding location	**NMFS descriptor**	**RMU descriptor**
Japan	North Pacific	North Pacific
Eastern Australia and New Caledonia	South Pacific	South Pacific
Western Australia	South-east Indo Pacific Ocean	South-east Indian
South-east Africa	South-west Indian	South-west Indian
Oman and Yemen	North-west Indian	North-west Indian
Sri Lanka	Inc. in North-west Indian	North-east Indian
Mediterranean	Mediterranean Sea	Mediterranean
South-east USA	North-west Atlantic	North-west Atlantic
Brazil	South-west Atlantic	South-west Atlantic
Cape Verde Islands	North-east Atlantic Ocean	North-east Atlantic Ocean

With regard to identifying status of marine turtle species there has been considerable debate about the most effective scale to undertake the review, such as species level as in the IUCN, regional level as in ocean basin or at a national level (i.e. Hamann et al. 2006 – leatherback assessment). One aim of the NMFS BRT was to review all existing information and data focussed on loggerhead populations around the globe, to assess the threats posed to each population and to determine the appropriate conservation status of each loggerhead turtle DPS (Fed Reg, 2011). Using a different approach Wallace et al. (2011) assessed each of the RMU's in terms of population risk level (population size, recent trend, long-term trend, rookery vulnerability, and genetic diversity) and existing threats (fisheries bycatch, take, coastal development, pollution and pathogens, and climate change), identified those RMU's which could be considered most endangered at a global scale, and also highlighted existing gaps in necessary conservation information (Wallace et al. 2011). Combining these two approaches, and considering that some of the same people were involved in both processes, we get an overall perspective of the status of each of the loggerhead turtle management units globally and within the IOSEA MoU.

In compiling our assessment on loggerhead turtles in the IOSEA region we followed the same population boundaries as previous assessments. We then (1) collated data from the Signatory State reports which were downloaded from the IOSEA website (ioseaturtles.org), (2) reviewed the assessments of Wallace et al. (2010, 2011) and NMFS (Conant et al. 2009; Fed Reg, 2011), to summarise the status of five loggerhead populations of the Indian and Pacific Oceans – we also considered the Sri Lanka loggerhead turtles as separate from those elsewhere in the Indian ocean.

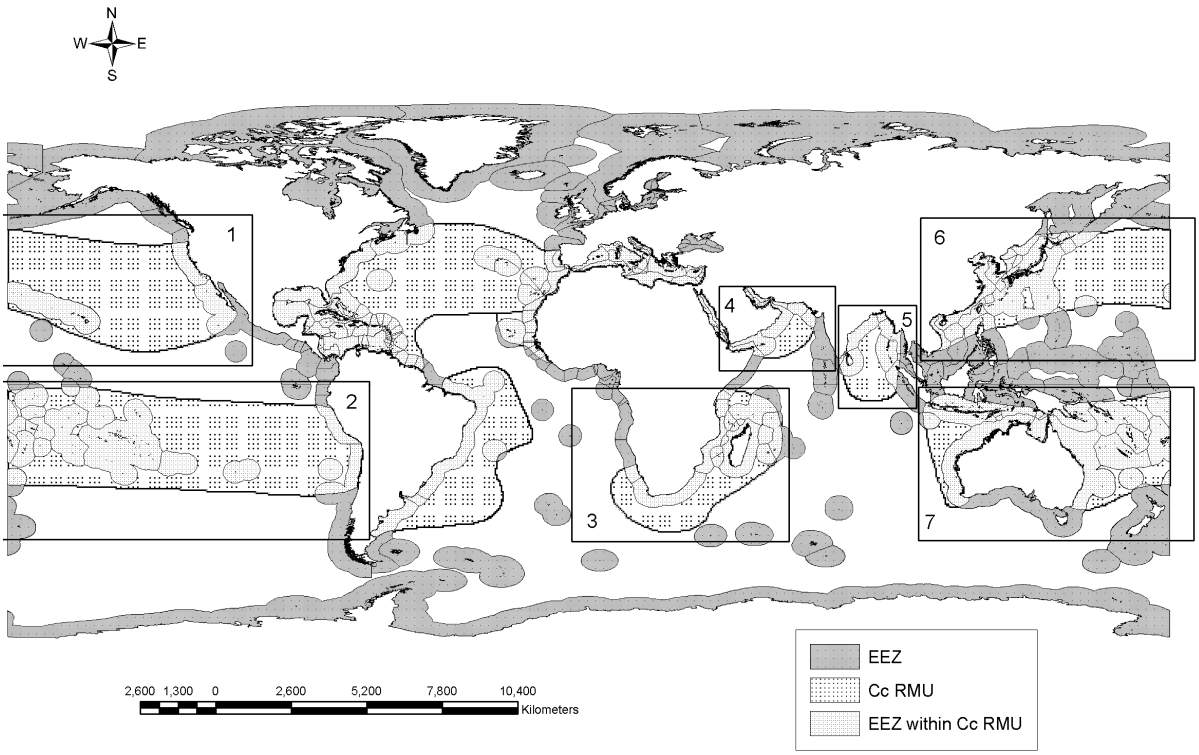

Figure 1. Distribution of Indian and Pacific Ocean RMUs/populations of loggerhead turtles, plus a putative population in central Indian Ocean (Sri Lanka). Numbers refer to RMUs that lie within the IOSEA region and the maps within each section.

South-west Indian Ocean management unit

Ecological range

The management unit which approximates ecological range, for the South-west Indian ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of 17 nations (Figure 2).

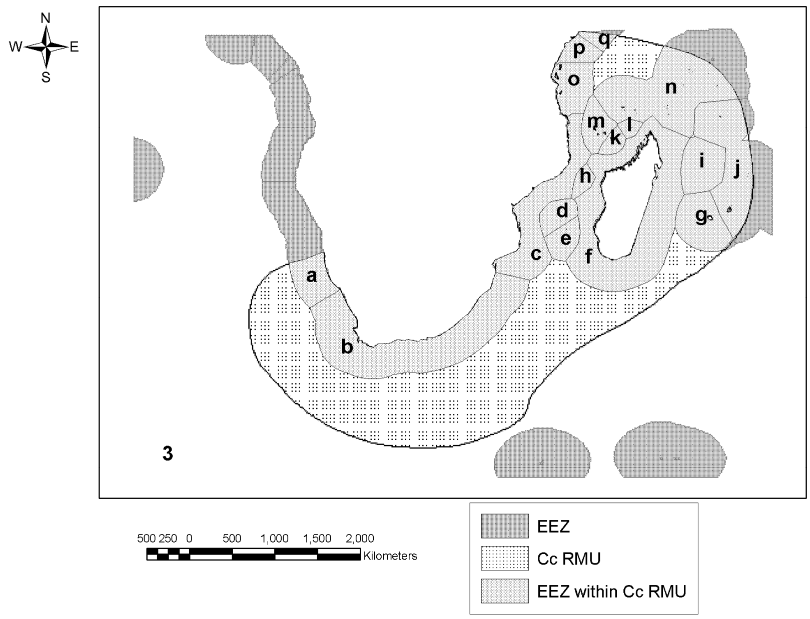

Figure 2. Overlay of the South-west Indian Ocean loggerhead turtle RMU (mesh), with the exclusive economic zones (grey) of inclusive nations.

Geographic spread of foraging sites

Loggerhead turtles from the south-west Indian Ocean management unit have been recorded along the east coast of Africa, as far north as southern Somalia. A combination of fisheries bycatch data, sightings and expert opinion indicate that loggerhead turtles from this management unit also move west into the south-eastern Atlantic (Namibian waters) and north-east into the waters of French Territories, Comoros, Seychelles and possibly Chagos (BIOT). Overall it is possible that loggerhead turtles from this management unit forage in the EEZ of eight nations plus their territories – (Figure 2).

Geographic spread of nesting

Loggerhead turtle nesting in the south-west Indian Ocean has been reported in the nations South Africa, Mozambique and Madagascar, Kenya, and Reunion Island, the Seychelles. Most nesting occurs on the south-eastern coast of Africa, from the Paradise Islands in

Mozambique to St. Lucia Estuary in South Africa and along the south and west coasts of Madagascar (Figure 3, Baldwin et al. 2003).

South Africa: iSimangaliso National Park (previously Greater St Lucia Wetland Park), KwaZulu-Natal (27º0'45"S; 32º51'59"E) World Heritage Site. Both terrestrial and marine protected areas exist within this park; the marine component extending 3 nautical miles into the ocean and the terrestrial component spanning ~56km of coastline. Loggerhead turtle nesting monitoring has been in place since 1963 in this park, and the magnitude of nesting has been estimated to range from 1,000 to 5,000 nests laid per year.

Madagascar: ABOHAZO (part of the Barren Islands), West -Madagascar Melaky Region (18º33'0"S; 43º48'0"E) is located approximately 52 kilometres south-west of Maintirano. Beaches between Fort-Dauphin and Manantenina, and at Besambay and Maromena (SWOT database). This habitat consists of coral and rocky reefs. This area is of high importance of loggerheads for nesting, feeding, and developmental habitats.

Mozambique: Loggerhead females nests predominantly in the south of Mozambique, from the Bazaruto Archipelago National Park to Ponto do Ouro. High density nesting occurs at the Maputo Special Reserve and in the vicinity of Ponta Malongane (Hughes 1971; Lombard 2005; Louro et al. 2006). Other index sites include Inhaca Island Special Control Zone, Ponta Chemucane, Milimangalala Beach, Paradise Islands (SWOT database). There has been monitoring on various beaches since 1996.

Figure 3. Map of major and minor nesting sites within the South-west Indian Ocean population

Trends in nesting data

Nesting trends for this population are described for some populations, mostly those occurring on national park beaches (Baldwin et al. 2003). This population saw a significant decline around the 1980s, but has recovered markedly since the implementation of mitigation measures on trawling and use (see Figure 4).

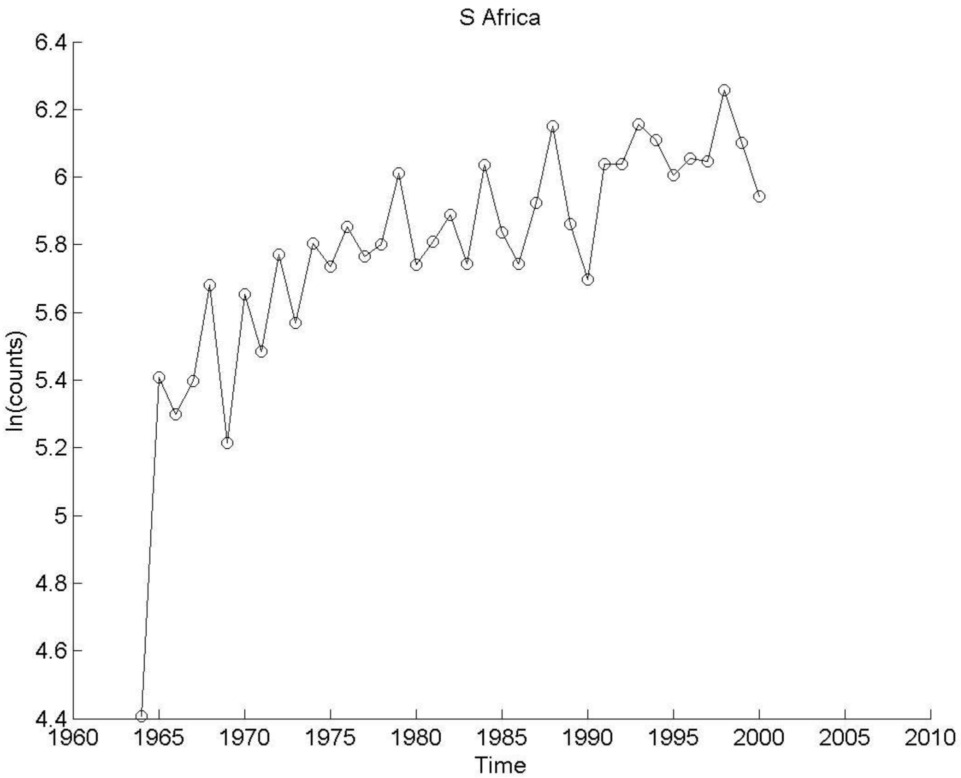

Figure 4. Change in the number of nesting females for the Southwest Indian Ocean DPS (re-created from the US Endangered Species Status Report 2009)

Migration and distribution of foraging areas

Evidence from strandings, tag returns, and observations indicate loggerhead turtle foraging grounds are located in the waters surrounding Réunion Island, Mauritius, Madagascar, Tanzania, Kenya, Seychelles, South Africa, and Mozambique.

Tagging data shows that post-nesting female loggerheads from Tongaland, South Africa, migrate eastward to Madagascar, northward to Mozambique, Tanzania (especially southern Tanzania), and Kenya, and southward to Cape Agulhas at the southernmost point of Africa and some enter the Atlantic Ocean (Baldwin et al. 2003, Luschi et al. 2006).

Threats to the population

Type of threat	**Location** 1=nesting beach 2=migration zone 3=foraging area (local) 4=foraging area (widespread)	**Managed** 1=managed completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	**Quantified** 1=comprehensive documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data

Egg predation/collection	1	2,3	2
Beach erosion	1	2,3	2
Increasing beach T	1	4	2
Coastal development (urban)	1	4	4
Coastal development (industrial)	1,3	4	4
Bycatch in inter-nesting zone	2,3	2	3
Bycatch in migration zone	2	4	3
Bycatch in foraging habitat	3,4	2	3
Entanglement in discarded fishing gear	2,3,4	2	3
Impact to benthic ecology from fisheries	2,3,4	2	3
Solid pollution (e.g. plastics)	1,2,3,4	2	2
Water quality	2,3,4	2	2
Disease issues	1,2,3,4	2	2
Ecosystem level impacts	1,2,3,4	4	2
Other (list)			

Threats to the population

No monitoring programme exists for in-water species counts for this region, however fisheries bycatch data are compiled by Government Agencies.

South Africa: Fisheries (long-line and bather protection nets) pose the greatest quantified threat to this population. Trawling and ghost fishing may also pose significant threats, but these require more monitoring. Egg harvest and urban, agricultural and tourism driven habitat degradation are considered to pose a low threat level to this population. Other threats including marine debris, boat strike and natural threats (such as egg predation and disease) remain unassessed.

Madagascar: A high level of egg harvest occurs on the western coast, and nests and females are at high risk from natural threats such as predation and disease. The exploitation of nesting loggerhead females and the rate of incidental bycatch in artisanal fisheries are considered to be a moderate risk. Loggerheads are found in high density in the waters of Madagascar for both feeding and developmental stages.

Mozambique: A low level of egg harvest and exploitation of females occurs on the main nesting beaches within the Ponto do Ouro coast. However in central Mozambique, high exploitation occurs on several of the beaches with low nesting density. Overall, the exploitation of nesting loggerhead females and the rate of incidental bycatch in coastal and artisanal fisheries are considered to be a moderate risk.

Tanzania: Loggerhead turtles are reported to be rare in Tanzanian waters. Low level bycatch has been reported, and turtles tagged while nesting in South Africa have been caught in Tanzania. In particular since 2001five tagged turtles were caught in coastal fisheries. It has been estimated that 54 turtles per year are caught in trawl based fisheries with 12% of these being loggerhead turtles.

Kenya: Loggerhead turtles are rarely caught or sighted in Kenya

French territories: The indirect capture of animals in fisheries is considered a considerable threat. It has been recorded in La Reunion and Mayotte.

Seychelles: A low density feeding habitat exists in the Cosmoledo, Astove, Assomption, Aldabra Group and de facto nature reserves Anonyme, Bird, Cousine, Denis, Fregate, North, and Inner Islands. Developmental life stages are also present in this area. There is a high degree of direct harvest occurring in coastal waters of this region.

Management and protection

Site name	Type	Index site Y/N	Relative importance (to the population)	Protection
iSimangaliso National Park, KwaZulu-Natal, South Africa	Nesting and foraging	Y	High	-Monitoring, protection, education, awareness programmes -Designation / management of protected areas, sanctuaries, exclusion zones etc. -Regulations on building location, design, artificial lighting -Removal of debris, beach clean-up -Vehicle and access restrictions
Abohazo, Barren Islands, Madagascar	Nesting, foraging and developmental stages	Y	High	- Monitoring, protection, education, awareness programmes -Requirements for modification of fishing gear or fishing practices (e.g seasonal or temporal closures) -Designation and management of protected areas, sanctuaries,

				exclusion zones etc. -Predator control
Mozambique	Ponto do Ouro	Y	Med	- Monitoring, protection, education, awareness programmes -Designation and management of protected areas, sanctuaries, exclusion zones etc.

Biological data - breeding

Parameter	Value (if known)	Reference(s)
Pivotal temperature	unknown	
Remigration interval	2.6yrs	Hughes, 1982
Clutches per season	3.6 - 4.4	Hughes, 1974b; Rees et al. 2008
Mean size of nesting adult (first breeding)	unknown	
Age at maturity	30 +/-5 SD	Snover 2002

Biological data - foraging

Parameter	Value (if known)	Reference(s)
Mean size at recruitment (to inshore foraging)	unknown	
Growth rates	unknown	
Survivorship estimates	unknown	

Summary from Wallace et al. 2010/2011

Loggerheads in the Southwest Indian RMU were given a risk matrix score of 2.10, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 101-1,000 females, an increasing recent population trend, an increasing long-term population trend, a high likelihood of complete loss of nesting rookeries, and comprise only one genetic stock. A threats matrix score of 1.50 was determined from expert opinion that loggerheads in the Southwest Indian Ocean RMU faced a medium threat from fisheries bycatch, a low-medium threat from take, and a low threat from coastal development, pollution and climate change. Overall Wallace et al (2011) categorised this RMU as High Risk-Low Threat.

Summary from US NMFS (2011)

Similar to Wallace et al (2011), the US NMFS found that loggerheads in the SWI Ocean have shown an increasing population trend since the 1960s, and also that the magnitude of the threat of climate change for loggerheads in this region was impossible to establish. However the US NMFS also determined that population declines could occur in the foreseeable future as a result of fisheries bycatch affecting mainly juvenile loggerheads. The BRT consider it unlikely that mortality due to bycatch can be adequately reduced or eliminated due to limitations in enforcement capabilities, geopolitical complexities, and not enough information regarding fishing efforts and distribution. The authors also recognise that significant conservation efforts are likely to have benefited this loggerhead population. Given the increasing population trend observed, but also the small nesting population and likely continuing impacts from fisheries, the US NMFS have determined that the Southwest Indo-Pacific Ocean DPS of the loggerhead sea turtle is not currently in danger of extinction, but is likely to become so in the foreseeable future throughout its range. It is currently listed by the NMFS as 'Threatened'.

North-west Indian Ocean management unit

Ecological range

The management unit which approximates ecological range, for the North-west Indian ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of 17 nations (Figure 5).

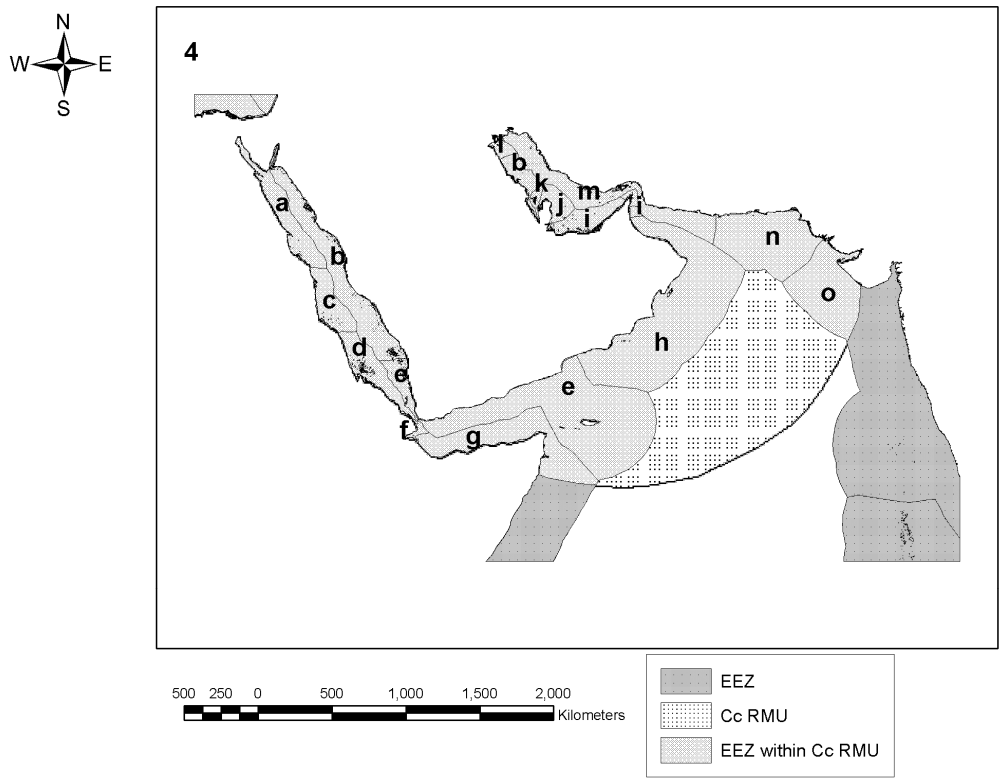

Figure 5. Overlay of the North-west Indian Ocean loggerhead turtle RMU (mesh), with the exclusive economic zones (grey) of inclusive territories.

Geographic spread of foraging sites

Overall there are EEZs of 15 nations that lie within the ecological range of the north-west Indian Ocean management unit (Figure 5). Loggerhead turtles from the management unit have been recorded in the coastal waters of six nations (UAE, Oman, Pakistan, Yemen, Eritrea and Djibouti). A combination of fisheries bycatch data, sightings and expert opinion indicate that loggerhead turtles from this management unit migrate and utilise waters to the south into northern Somalia, north/east into the waters of Iran, India and possible the Maldives and east to other nations within the Persian Gulf.

Geographic spread of nesting

In the north-west Indian Ocean, Oman hosts the vast majority (over 10,000 females nesting per year, and some figures indicate over 15,000 females per year) of loggerhead nesting on Masirah Island, the Al Halaniyat Islands, and on mainland beaches south of Masirah Island all the way to the Oman-Yemen border (Figure 6; IUCN 1989a, 1989b; Salm 1991). Nesting has also been recorded on Socotra, an island off the coast of Yemen, and some nesting is thought to occur on mainland Yemen beaches of the Arabian Sea (Pilcher and Saad 2000).

Oman: Nesting occurs on the Al Halaniyat Islands, mainland Omani beaches south of Masirah Island and north of Khor Khafort, and on the Oman-Yemen border (IUCN 1989a).

Yemen: Nesting occurs in the Abalhan Protected Area, Socotra Man Island and Biosphere Reserve, on the mainland Arabian coastline (Pilcher and Saad 2000).

Somalia: Unquantified records.

Figure 6. Map of major and minor nesting sites and locations of tag/satellite tag endpoints within the North-west Indian Ocean population

Trends in nesting data

Nesting trends are unknown for the north-west Indian Ocean population apart from Masirah Island in Oman, which has not recently been evaluated. It has been calculated that Masirah Island saw 30,000 nesting females in 2005 (REFERENCE SWOT).

Migration and distribution of foraging areas

Limited information exists on the foraging habitats for the north-west Indian Ocean population; however, foraging individuals have been reported off the southern coastline of Oman (Salm *et al*. 1993). Satellite telemetry studies conducted in Oman have revealed new information about post-nesting migrations of loggerheads nesting on Masirah Island (Environment Society of Oman and Ministry of Environment and Climate Change, Oman, unpublished data). Results reveal extensive use of the waters off the Arabian Peninsula, with the majority of telemetered turtles (15 of 20) travelling southwest, following the shoreline of southern Oman and Yemen, and circling well offshore in nearby oceanic waters. A minority travelled north as far as the western Persian (Arabian) Gulf (3 of 20) or followed the shoreline of southern Oman and Yemen as far west as the Gulf of Aden and the Bab-el-Mandab (2 of 20). These preliminary data suggest that post nesting migrations and adult female foraging areas may be centred within the region (Environment Society of Oman and Ministry of Environment and Climate Change, Oman, unpublished data).

Low density feeding also occurs in Bahrain waters (IOSEA signatory state report).

Threats to the population (by threat)

Type of threat	**Location** 1=nesting beach 2=migration zone 3=foraging area (local) 4=foraging area (widespread)	**Managed** 1=managed completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	**Quantified** 1=comprehensive documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data
Egg predation/collection	1	2	3
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Coastal development (industrial)	1	2	3
Bycatch in inter-nesting zone	2,3	4	3
Bycatch in migration zone	2,3,4	4	3
Bycatch in foraging habitat	3,4	4	3
Entanglement in discarded fishing gear	2,3,4	4	4
Impact to benthic ecology from fisheries	2,3,4	4	3
Solid pollution (e.g. plastics)	1,2,3,4	4	3
Water quality	2,3,4	4	3
Disease issues	1,2,3,4	4	2
Ecosystem level impacts	1,2,3,4	4	2
Other (list)			

Threats to the population

Eritrea: Incidental capture in fisheries is a low level threat for loggerhead turtles. Of 3342 turtles recorded as being incidentally caught in Eritrean shrimp trawls 30 were loggerhead turtles.

Oman: Predation of eggs, light pollution and coastal development are seen as then main threats in Oman.

Somalia: Pirate attacks and political instability in Somalia has caused safety concerns for outside conservation organisations such as NGOs, making it risky to conduct monitoring and research programmes in this region. No fishery protection vessels are present in Somalia, making by-catch in long-line fisheries and drowning in nets a high level threat for loggerheads.

There are no mentions of threats to loggerhead turtles in the IOSEA Signatory States reports for Bahrain, Iran, Jordan, Saudi Arabia, United Arab Emirates and Yemen.

Management and protection

Site name	Type	Index site Y/N	Relative importance (to the population)	Protection
Masirah Island, Oman	Nesting and foraging	Y	High	-Monitoring, protection, education, awareness programmes -Designation / management of protected areas, sanctuaries, exclusion zones etc. -1 km sectors of nesting habitat identified for monitoring purposes

Biological data breeding

Parameter	Value (if known)	Reference(s)
Pivotal temperature	unknown	
Remigration interval	2.6 - 3yrs	Hughes 1982
Clutches per season	3.6 - 4.4	Hughes 1974b; Rees et al. 2008; Ross 1998
Mean size of nesting adult (first breeding)	unknown	
Age at maturity	30 +/-5 SD	FWS 2008; Snover 2002

Biological data foraging

Parameter	Value (if known)	Reference(s)
Mean size at recruitment (to inshore foraging)	unknown	
Growth rates	unknown	
Survivorship estimates	unknown	

Summary from Wallace et al. 2010; 2011

Loggerheads in the Northern Indian Ocean were divided into two RMU's: the Northwest Indian Ocean RMU, and a putative Northeast Indian Ocean RMU. Wallace et al. (2010) combine these as a single RMU. In the Northwest, loggerheads were given a risk matrix score of 1.33, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 5,001-10,000, a low-medium likelihood of complete loss of nesting rookeries, and comprise more than two genetic stocks. Recent and long-term population trends could not be determined due to data deficiency. A threats matrix score of 1.67 was determined from expert opinion that loggerheads in the Northwest Indian RMU were highly threatened by fisheries bycatch, (mainly in longline, gillnet, trawl and IUU fisheries), and faced a low threat from take, pollution, and coastal development. The threat posed by climate change could not be determined due to data deficiency. Overall Wallace et al (2011) categorised this RMU as Low Risk-Low Threats. In the Northeast, loggerheads were given a risk matrix score of 2.17, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 101-1,000, a high likelihood of complete loss of nesting rookeries, and comprise more than two genetic stocks. Recent and long-term population trends could not be determined due to data deficiency. A threats matrix score of 3.00 was determined from expert opinion that loggerheads in the Northeast Indian RMU were highly threatened by fisheries bycatch (mainly in gillnet, and trawl fisheries), and coastal development (mainly from construction). The threat posed by take, climate change and pollution could not be determined due to data deficiency. Overall Wallace et al (2011) categorised this RMU as High Risk-High Threats (Figure 1), and concluded it was one of the world's most endangered RMU's (out of 58 RMU's including all turtle species).

Summary from NMFS

Unlike Wallace et al (2011), the NMFS only acknowledge one population of loggerheads in the Northern Indian Ocean, yet this is recognised as being highly threatened by fisheries bycatch (as both NEI and NWI are). The NMFS determine that fishing pressure in this region is likely to increase in the future, which is likely to increase loggerhead mortality. Similar to Wallace et al (2011), the NMFS were unable to obtain reliable data on population trends in this region, however nesting estimates and local observations suggest a marked population decline over the last 30 years. The NMFS also found it impossible to determine the magnitude of the threat of climate change for loggerheads in the Northern Indian Ocean. Further, consistent low threats across all the factors listed above may affect a significant portion of the early life-stages of loggerheads in this region, and therefore warrant attention. Particularly as these threats are considered likely to increase in the future. Higher mortality in the neritic environment is due to fishery bycatch. The US NMFA consider it unlikely that mortality due to bycatch can be adequately reduced or eliminated due to the existence of illegal, unregulated, and unreported fisheries, in addition to limitations in enforcement capabilities, geopolitical complexities, and not enough information regarding fishing efforts and distribution.

Other natural or manmade risk factors, including climate change and sea level rise, as well as fisheries bycatch, boat strike and marine debris, were considered to be of low risk to eggs/hatchlings, oceanic juveniles, oceanic adults and nesting females, but a medium risk factor for neritic juveniles and adults.

Given that impacts from fisheries and threats to nesting beaches are likely to increase in the future, in addition to the marked decline observed in nesting females in the last 30 years, the NMFS have determined that the North Indian Ocean DPS is in danger of extinction throughout its range. It is currently listed as 'Endangered'.

Central Indian Ocean management unit

Ecological range

The management unit which approximates ecological range, for the North-west Indian ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of five nations. Continued molecular research will determine its phylogenetic relationship with either the North-west Indian Ocean or the South-east Indo Pacific populations.

Geographic spread of foraging sites

There have been no studies to identify the foraging sites for the north-east Indian Ocean. It is likely that they utilise coastal waters of the Bay of Bengal (India, Sri Lanka, Myanmar and Thailand), plus the reef systems around the Maldives.

Geographic spread of nesting

The only verified loggerhead nesting on the Indian subcontinent occurs on mainland beaches of southern and southeastern Sri Lanka (Figure 7). There is no evidence for loggerhead turtle nesting occurring on either the western or northern coastline. Clutch counts remain unquantified, and only a small number of females use the beaches of Sri Lanka to nest each year (Kar and Bhaskar 1982, Dodd 1988). Loggerheads have been reported nesting in low density in Myanmar with 60 clutches counted in the 2004 nesting season, however misidentification of species may render these data inconsequential (Thorbjarnarson *et al.* 2000). Nesting has been reported in Bangladesh as well, however, there are no quantified nesting female or clutch counts for this location (SWOT).

Nesting reported at following locations:

- Butawa to Patanangala, Yala Nature Preserve, Southern Sri Lanka
- Bundala Modara to Kirindi Modara (Bundala NP), Southern Province
- Hambantota to Malala Modara, Southern Province (not confirmed)
- Ussangoda to Welipatanwila, Southern Province
- Tangalle
- Unawatuna
- Balapitiya
- Kosgoda/Bandarawatta

Figure 7. Map of major and minor nesting sites within the North-east Indian Ocean population

Trends in nesting data

There are no data to indicate population trends.

Migration and distribution of foraging areas

The information on loggerhead migration and the distribution of foraging habitats in the central Indian Ocean is minimal, however there have been reports of foraging turtles along the southern coastline of Oman (Salm *et al*. 1993) and the Gulf of Mannar which provides foraging habitat for both juveniles and post-nesting adults (Tripathy 2005, Kapurusinghe 2006).

Threats to the population (by threat)

Type of threat	**Location** 1=nesting beach 2=migration zone 3=foraging area (local) 4=foraging area (widespread)	**Managed** 1=managed completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	**Quantified** 1=comprehensive documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data
Egg predation/collection	1	2	3
Beach erosion	1	2	3
Increasing beach T	1	4	4
Coastal development (urban)	1,3	2	3
Coastal development (industrial)	1,3	2	3
Bycatch in inter-nesting zone	2,3	2	3
Bycatch in migration zone	2	4	3
Bycatch in foraging habitat	3,4	2	3
Entanglement in disgarded fishing gear	2,3,4	4	4
Impact to benthic ecology from fisheries	2,3,4	2	4
Solid pollution (e.g.	1,2,3,4	4	3

plastics)			
Water quality	2,3,4	2	4
Disease issues	1,2,3,4	2	3
Ecosystem level impacts	1,2,3,4	2	4
Other (list)			

Threats to the population

Sri Lanka: Egg collection and natural threats (such as predation and disease) in southern Sri Lanka (from Kalutata to Yala Nature Preserve) are considered medium to low level threats. Direct harvest in coastal waters, incidental bycatch, and nesting female exploitation are low intensity threats along with marine debris, boat strike, water quality and habitat degradation. These low intensity threats are reported to be absent in sections of southern Sri Lankan coastline (Bundala Modara to Kirindi, Modara (Bundala NP), Southern Province). Meanwhile, egg collection from Ussangoda to Welipatanwila, Southern Province is listed as a large threat, while habitat degradation and incidental capture are medium intensity threats. Coastal development and artificial lighting in Tangalle are considered severe theats to nesting turtles coming ashore. Vehicle disturbance and marine debris in Unawatuna are considered severe threats in this location.

There are no mentions of threats to loggerhead turtles in the IOSEA Signatory States reports for Bangladesh, India, Myanmar, Maldives, Pakistan or Thailand.

Management and protection

Site name	Type	Index site Y/N	Relative importance (to the population)	Protection
Butawa to Patanangala, Yala Nature Preserve, Southern Sri Lanka	Nesting and foraging	Y	unknown	- In-situ nest protection by Department of Wildlife Conservation - Designation / management of protected areas, sanctuaries, exclusion zones etc.
Bundala Modara to Kirindi Modara (Bundala NP), Southern Province	Nesting, foraging and developmental stages	Y	unknown	- In-situ nest protection by Department of Wildlife Conservation - Designation / management of protected areas, sanctuaries, exclusion zones etc.
Hambantota to Malala Modara, Southern	Nesting	?	unknown	- Education / awareness programmes

Province				
Unawatuna	nesting	Y	unknown	- Vehicle / access restrictions - Designation / management of protected areas, sanctuaries, exclusion zones etc.

Biological data breeding

Parameter	**Value (if known)**	**Reference(s)**
Pivotal temperature	unknown	
Remigration interval	unknown	
Clutches per season	unknown	
Mean size of nesting adult (first breeding)	unknown	
Age at maturity	30 +/-5 SD	Snover 2002

Biological data foraging

Parameter	**Value (if known)**	**Reference(s)**
Mean size at recruitment (to inshore foraging)	unknown	
Growth rates	unknown	
Survivorship estimates	unknown	

North Pacific Ocean management unit

Ecological range

The management unit which approximates ecological range, for the North Pacific ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of 18 nations (Figure 8).

Geographic spread of foraging

Similar to the South Pacific Ocean management unit, there is considerable knowledge about foraging distribution of loggerhead turtles in the north Pacific Ocean. A combination of fisheries bycatch data, sightings and expert opinion indicate that loggerhead turtles from this management unit migrate and utilise waters throughout the north Pacific Ocean. Overall there are EEZs of nine nations that lie within the ecological range of the north Pacific Ocean management unit (Figure 8) and loggerhead turtles from the management unit have been recorded in the coastal waters of eight of them (Japan, Philippines, China, Viet Nam, South Korea, USA and Mexico). All but Mexico are range states of the IOSEA MoU, with China and Sth Korea not yet signatory states.

Geographic spread of nesting

Loggerhead nesting within the North Pacific area occurs only in Japan (Figure 9). Nesting beaches can be separated into five geographic locations (Kamezaki et al. 2003), the Nansei Shoto Archipelago, Kyushu, Shikoku, the Kii Penisula, and east-central Honshu, distributed between 24°N and 37°N:

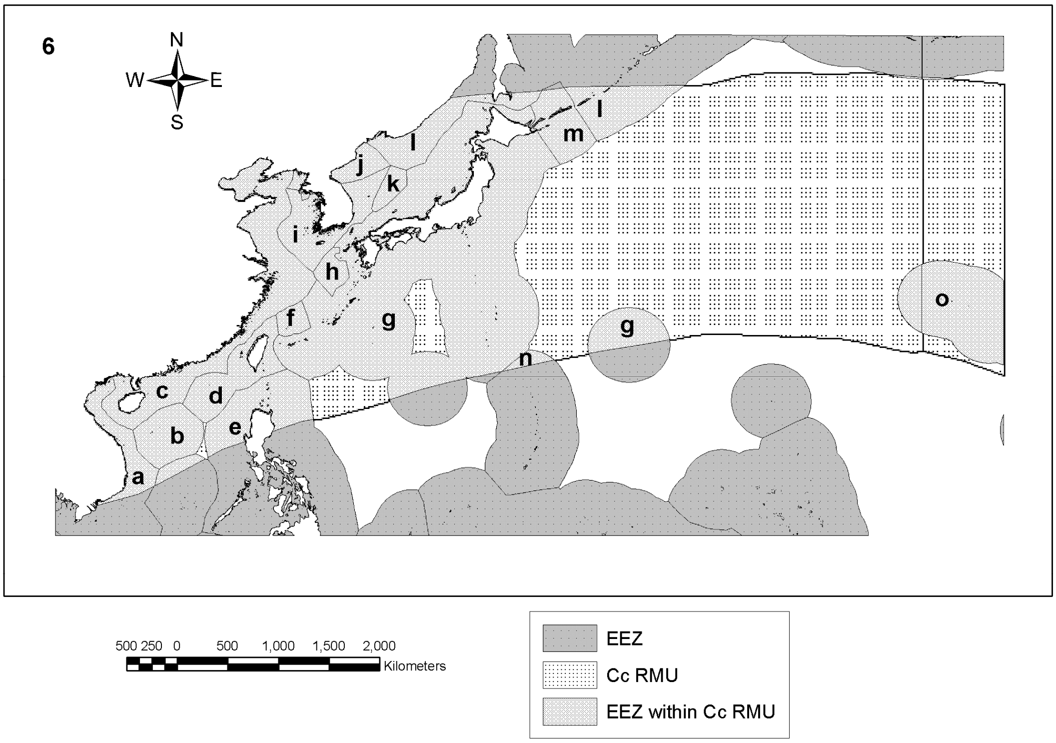
Nansei Shoto Archipelago: Found between Kyushu and Taiwan, this archipelago is comprised of numerous islands. Approximately 30% of loggerhead nesting occurs on Yakushima Island (Kamezaki, 1989), and minor nesting occurs on the Pacific-facing side of many islands in the Amami, Miyako and Yaeyama island groups (Kamezaki, 1989, 1991). Within the North Pacific, the Yaeyama Islands appear to be the southernmost limit of loggerhead nesting.

Kyushu: Nesting occurs in the south of the island, along both the western and eastern coasts. Fukiagehama, found in the west, is the most well-known nesting location. Loggerheads also nest at Nagasakibana Beach, in the south, and at Miyazaki, Nobeoka, Nichinan and Shibushi beaches in the east.

Shikoku: Nesting occurs across the Ashizuri Cape, the Muroto Cape and along the southeastern beaches.

Kii Peninsula: The majority of loggerhead nesting takes place at Minabe Senri Beach.

East Central Honshu: Enshunada Beach, stretching 130km, is the major nesting site for loggerheads on Honshu. Minor nesting also occurs on smaller beaches around the Chita Peninsula, Izu Peninsula, Izuoshima Island, Nijima Island and Boso Peninsula.



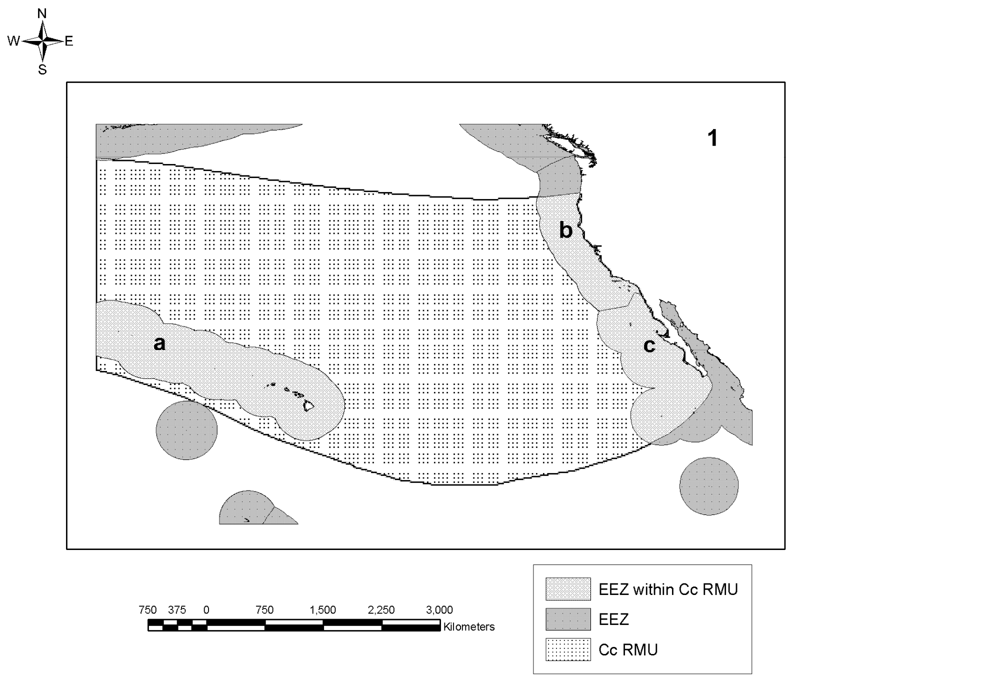


Figure 9. Overlay of the North Pacific Ocean loggerhead turtle RMU (mesh), with the exclusive economic zones (grey) of inclusive nations. The RMU is split into two panels to better reflect the size of the RMU (i.e. cross Pacific Ocean).

Figure 9. Map of nesting sites within the North Pacific Ocean management unit

Trends in nesting data

Nesting census data are available from most Japanese nesting beaches (Figure 10). Since the early 1990's there has been a decline in the annual nesting population, resulting in the north Pacific Ocean loggerhead management unit being accorded an Endangered status in the 1994 IUCN Red List (Kamezaki et al. 2003). Lowest numbers were recorded in the years 1997-1999. Given multiple re-nesting, current nesting figures suggest less than 1000 females breed annually within this DPS.

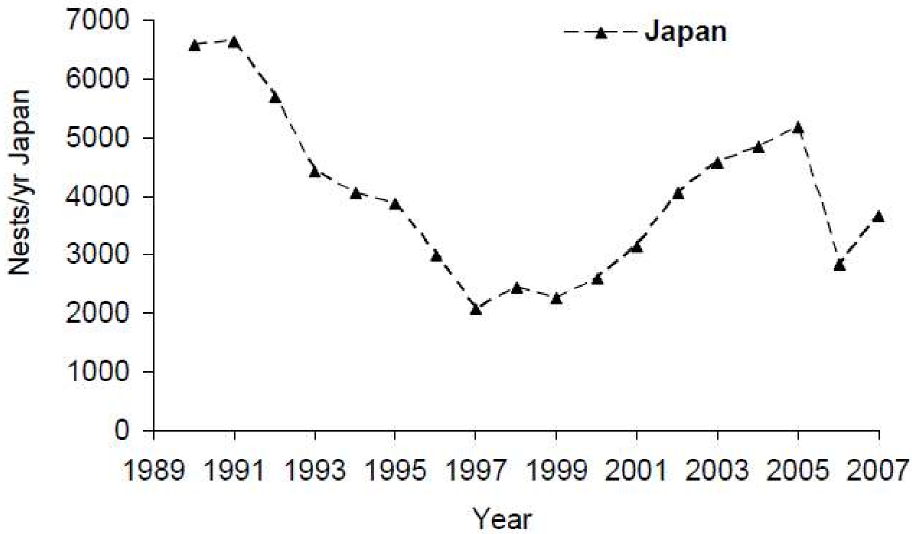


Figure 10. Loggerhead nest abundance in Japan over time (re-created from PIFSC Internal Report IR-08-010, June 2008)

Migration and distribution of foraging areas

Tag returns and satellite tracking has confirmed that post nesting females leave nesting areas in Japan as hatchlings, and migrate across the pacific, via the Hawaiian archipelago, to reach developmental and foraging habitats in the eastern Pacific (Uchida and Teruya 1988; Bowen et al. 1995). Following many years offshore from California, USA and Baja California, Mexico, the loggerheads return to Japanese nesting areas for breeding (Resendiz et al. 1998; Nichols et al. 2000).

Threats to the population (by threat)

Type of threat	**Location** 1=nesting beach 2=migration zone 3=foraging area (local) 4=foraging area (widespread)	**Managed** 1=managed completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	**Quantified** 1=comprehensive documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data
Egg predation/collection	1	2,3	2
Beach erosion	1	2	4
Increasing beach T	1	4	4
Coastal development (urban)	1	2	4
Coastal development (industrial)	1,3	2	4
Bycatch in inter-nesting zone	2,3	4	3
Bycatch in migration zone	2	4	3
Bycatch in foraging habitat	3,4	2	3
Entanglement in discarded fishing gear	2,3,4	4	3
Impact to benthic ecology from fisheries	2,3,4	2	3
Solid pollution (e.g. plastics)	1,2,3,4	2	3
Water quality	2,3,4	2	3
Disease issues	1,2,3,4	2	2
Ecosystem level impacts	1,2,3,4	4	3
Other (list)			

Threats to the population

Japan: Fisheries bycatch mortality may pose the greatest threat to this population (Kamezaki et al. 2003). Gill and pound nets are widely used along the Japanese coast, and anchovy trawl fisheries occur offshore from major loggerhead rookeries. The dramatic decline in nesting appears to have coincided with the increase in long-line and drift-net fisheries in the North Pacific, yet the lack of bycatch mortality data has prevented quantification of the extent of this problem. Beach erosion is a serious problem in Japan, due to the combination of coastal armouring and extreme weather during the winter (typhoon season). In 2004 and 2005, the Western Pacific Regional Fishery Management Council provided funding assistance to the Sea Turtle Association of Japan to allow management activities aimed at maximising hatchling production in erosion-prone locations. Hundreds of nests were relocated and an estimated 149,478 hatchlings produced that would otherwise have been lost (Matzuzawa, 2005). Egg predation from raccoon dogs and weasels is a minor threat, however quantitative data is lacking. Turtle eggs were a traditional food source in Japan, however this has substantially decreased through education efforts.

Viet Nam: Low level fisheries bycatch of loggerhead turtles has been recorded in central Viet Nam (Hamann et al. 2006). These turtles could be from the north Pacific Ocean population.

Baja California: The direct harvest of loggerheads occurs here at high levels, with juveniles and subadults being taken most frequently.

The development of several Liquid Natural Gas Facilities have been proposed off southern California and Baja California, Mexico. This could result in the degradation of the pelagic habitat in the eastern North Pacific due to oil trans-shipment (Western Pacific Regional Management Council, 2005).

There are no mentions of threats to loggerhead turtles in the IOSEA Signatory States reports for Philippines, Malaysia or Indonesia.

Climate change: Chaloupka et al. (2008) demonstrate that the frequency of nesting is related to sea surface temperatures, such that in warmer years fewer turtles nest. This has implications for climate change with predictions that the Pacific Ocean will increase in temperature by 1 to 5C over the next 20 to 100 years (IPCC 2007).

Management and protection

Site name	Type	Index site Y/N	Relative importance (to the population)	Protection
Yakushima, Nansei Shoto Archipelago	Nesting	??	High (30% of pop)	Monitoring, tagging
Nishinohama Beach/Ibaruma Beach/Osaki Beach/Gusuhu be Beach, Nansei Shoto Archipelago	Nesting		High	Monitoring
Kyushu	Nesting		High	Monitoring, education, leading to Regulations for Sea Turtle Conservation in 1988
Shikoku	Nesting		High	Monitoring, education

Kii Peninsula	Nesting		High	Monitoring, tagging, satellite tagging
Honshu	Nesting		High	Monitoring

Biological data breeding

Parameter	Value (if known)	Reference(s)
Pivotal temperature	29.7°C	Matsuzawa et al. 1998
Remigration interval	2.7 years	Hatase et al. 2004
Clutches per season	Several (max 5)	Hatase et al 2002, Sato et al. 1998
Mean size of nesting adult (first breeding)	SCL 784 ± 31 mm (oceanic foragers) SCL 840 ± 40 mm (neritic foragers)	Hatase et al. 2010
Age at maturity	Estimated 25yrs	Van Houtan & Halley, 2011

Biological data foraging

Parameter	Value (if known)	Reference(s)
Mean size at recruitment (to inshore foraging)	unknown	
Growth rates	2.5 ± 4.0 mm/year	Hatase et al. 2004
Survivorship estimates	Not known	Peckham et al 2008

Summary from Wallace et al. 2010; 2011

Loggerheads in the North Pacific RMU were given a risk matrix score of 2.00, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 1,001-5000 females, an increasing recent population trend, a decreasing long-term population trend, a low likelihood of complete loss of nesting rookeries, and comprise only one genetic stock. A threats matrix score of 2.67 was determined from expert opinion that loggerheads in the North Pacific RMU were highly threatened by fisheries bycatch, (mainly in longline and gillnet fisheries), faced a medium threat from take, and faced a high threat from coastal development (mainly beach armouring). The threat posed by both pollution and climate change could not be determined due to data deficiency. Overall Wallace et al (2011) categorised this RMU as High Risk-High Threats (see Figure 1), and concluded it was one of the world's most endangered RMU's (out of 58 RMU's including all turtle species).

Summary from NMFS

NMFS findings (Connant et al. 2009, Fed Reg, 2011) aligned with those of Wallace et al (2011), with coastal fisheries in Baja California, Mexico, and Japan (Kamezaki et al. 2003, Peckham et al. 2007) found to be the most significant threat to loggerheads in this region – particularly for neritic juveniles and neritic adults. Coastal development was also similarly highlighted as a major threat to loggerhead survival, mainly from seawall construction (Suganuma 2002, Kamezaki et al. 2003, Kudo et al. 2003). In addition the NMFS found beach debris to be an important cause of hatchling and nesting adult deaths, and also noted that in recent years there has been low hatching success has at many important nesting beaches.

North Pacific US NMFS Threat Summary:
The threat to critical habitats were considered to be of medium risk for eggs and hatchlings, but only low of very low risk for other life-cycle stages. This is because coastal development and coastal armouring is continuing on nesting beaches in Japan. The risk of overutilisation for commercial, scientific, educational or recreational purposes, as well as risk of disease or predation, was considered to be low to very low for all life stages. Other natural or manmade risk factors, including climate change and sea level rise, as well as fisheries bycatch, boat strike and marine debris, were considered to be of medium risk to eggs/hatchlings, neritic juveniles, and neritic adults, whilst other life stages were only considered at low to very low risk from these factors. This is due mainly to bycatch mortality from the coastal pound net fisheries in Japanese waters, as well as coastal fisheries near Baja California, Mexico, and other undescribed fisheries which potentially impact loggerheads elsewhere in the North Pacific. The BRT consider it unlikely that mortality due to bycatch can be adequately reduced or eliminated due to the existence of illegal, unregulated, and unreported fisheries, in addition to limitations in enforcement capabilities and not enough information regarding fishing efforts and distribution. Sea level rise as a result of climate change is also considered to become a substantial threat if coastal armouring continues without consideration. This contrasts with the findings of Wallace et al (2011) who found there to be insufficient data to determine any climate change impacts on loggerheads in this region.

Although the nesting population in this region has increased recently, current nesting levels are small compared to those that occurred prior to the 1950's. Moreover, despite the recent increase, the population of loggerheads in the North Pacific is considered to be small. Given that the North Pacific Ocean DPS shows evidence of a long-term decline, and is at significant risk from fisheries bycatch and coastal development, making further population declines likely, the NMFS have determined that the North Pacific Ocean DPS is in danger of extinction throughout its range. It is currently listed as 'Endangered'.

South-east Indian Ocean management unit

Ecological range

The management unit which approximates ecological range, for the south-east Indian ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of six nations (Figure 11).

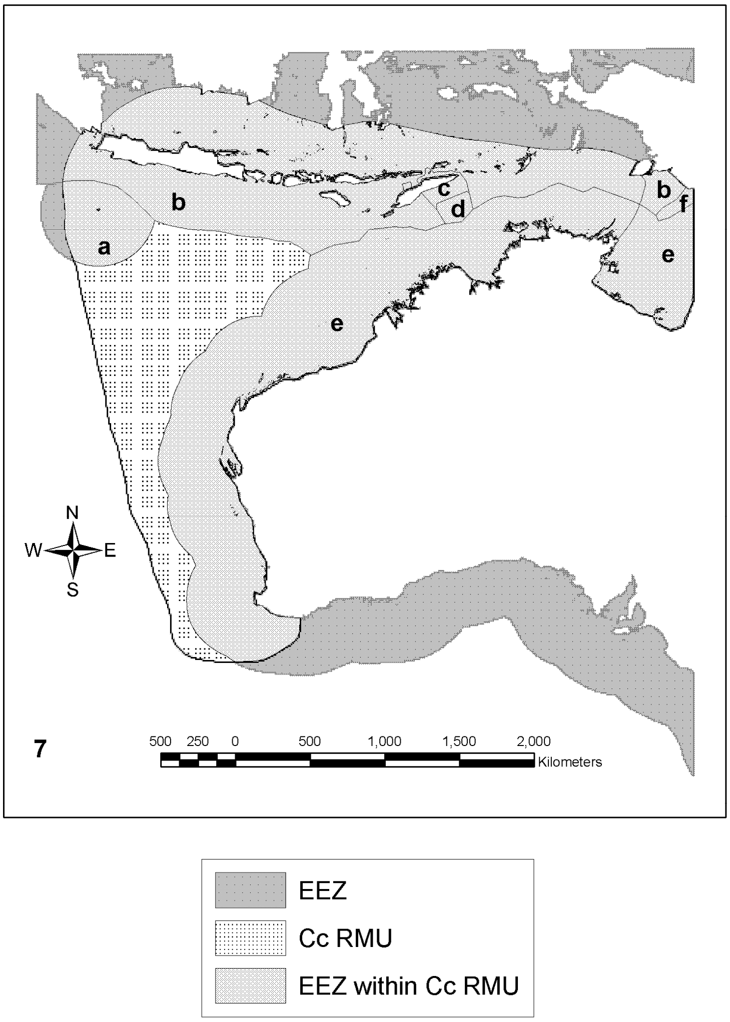


Figure 11. Overlay of the South-east Indian Ocean loggerhead turtle RMU (mesh), with the exclusive economic zones (grey) of inclusive nations.

Geographic spread of foraging

Loggerhead turtles from the south-east Indian Ocean management unit forage in the coastal waters of Australia and Indonesia. It is also possible that they use the coastal waters of Timor Leste and Papua New Guinea for foraging and/or migration. Within Australia they utilise the coastal zone from ~ 26S (Shark Bay in Western Australia) northwards and across the northern coast of Australia as far west as western Torres Strait (141E). Little is known about the foraging ecology of this management unit (see review by Limpus 2009).

Geographic spread of nesting

Loggerhead nesting in the southeast Indian Ocean is confined to Western Australia (Figure 12; Dodd 1988). Nesting occurs along the coast of WA, from the Shark Bay World Heritage Area (26.5°S) in the south to the North West Cape and Muiron Islands (21.5°S) further north (Baldwin et al. 2003).

Major nest sites include the northern beaches of Dirk Hartog Island, the Muiron Islands and sections of the Ningaloo Marine Park on the mainland (Limpus 2009). Minor nesting occurs over a wider area – including the Ashmore Reef National Nature Reserve (Guinea 1995).

Figure 12. Map of major and minor nesting sites and tag recoveries within the South-east Indian Ocean population

Trends in nesting data

Long-term nesting census data does not exist for this population. Nesting data was not collected until the early 1990's, and there are insufficient data for trends in loggerhead nesting to be determined (Limpus, 2009). However, the annual nesting population for this stock is considered to consist of several thousand females, with approximately 1000 – 3000 nesting annually at Dirk Hartog Island (Baldwin et al. 2003; WA DEC personal communication).

Migration and distribution of foraging areas

Distribution of foraging areas for the Western Australian population has been determined from the recovery of tagged loggerheads. Feeding areas for these loggerheads are located offshore from the WA nesting sites and extend northwards from Shark Bay to locations off the Arnhem Land coast of the Australian Northern Territory and into Indonesia's Java Sea (Prince, 1998; Baldwin *et al.* 2003). The foraging area off Arnhem Land is likely shared between loggerheads from Western Australia and Eastern Australian rookeries (Limpus et al. 1992; Limpus, 2009).

Threats to the population (by threat)

Type of threat	**Location** 1=nesting beach	**Managed** 1=managed	**Quantified** 1=comprehensive

	2=migration zone 3=foraging area (local) 4=foraging area (widespread)	completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data
Egg predation/collection	1	2	2
Beach erosion	1		
Increasing beach T	1	4	2
Coastal development (urban)	1	2	2
Coastal development (industrial)	1,3	2	2
Bycatch in inter-nesting zone	2,3	2	2
Bycatch in migration zone	2	2	3
Bycatch in foraging habitat	3,4	2	3
Entanglement in discarded fishing gear	2,3,4	2	3
Impact to benthic ecology from fisheries			
Solid pollution (e.g. plastics)	1,2,3,4	2	4
Water quality			
Disease issues	1,2,3,4	2	2
Ecosystem level impacts	1,2,3,4	2	2
Light Horizon Disorientation	1	2	2
Other (list)			

Threats to the population

Australia: The major threats to this population involve the nesting habitat. In the past, the European red fox (*Vulpes vulpes*) has preyed extensively on loggerhead nests (Mack, 2000) and this is considered to be a potential explanatory factor for the reduction in loggerhead nesting along the mainland (the islands where loggerheads nest do not have foxes) (Baldwin et al. 2003). In addition, vehicular traffic over the beaches has been common in this region. Vehicles driven over nesting areas can compact nests causing egg mortality, and hatchlings may be trapped in tyre tracks whilst traversing the beach (Limpus, 2009). The magnitude of the impact fox predation and vehicular traffic has had on this population has not been quantified, yet it is likely that egg loss has gone beyond a level which can be sustained (Limpus, 2009).

Unfortunately, the beaches affected by these issues are assumed to be the major female producing rookeries for this population, meaning that the impacts of fox predation and vehicle traffic on population dynamics is likely to be more detrimental than might be expected (Limpus, 2009).

Industrial development along the coast has the potential to be a significant threat to this population. Altered light horizons from coastal development can disorient hatchlings increasing mortality from predation and dehydration (Witherington and Martin, 2000), and can deter nesting females. At present no studies have quantified the extent of this problem with respect to hatchling disorientation for this population (Limpus, 2009), but analyses of light pollution using satellite data indicate that 15% of this nesting population is potentially affected by light pollution (Kamrowski et al. in prep). This is of further concern since the affected nest sites identified in this analysis include the mainland coast of Ningaloo, the region identified as being important for producing female loggerheads.

Further threats to this population include fisheries interactions from long-lines, trawling and lobster fisheries. To date, these interactions have not been quantified, but data indicate that crayfish pots in south Western Australia are responsible for the mortality of small numbers of loggerheads, and large immature loggerheads are vulnerable to long-line fisheries from Japan offshore from WA and in Indonesian waters (Limpus, 2009).

There are no mentions of threats to loggerhead turtles in the IOSEA Signatory States reports for Indonesia or Papua New Guinea.

<u>Management and protection</u>

Site name	Type	Index site Y/N	Relative importance (to the population)	Protection
Dirk Hartog Island	Nesting and foraging	Y	High	- Shark Bay World Heritage Area provides protection during foraging - Compulsory use of TED's on prawn and scallop trawls in WA
Ningaloo Coast			High	- Monitoring, protection, education, awareness programmes - Designation / management of protected areas, sanctuaries, exclusion zones etc. - Fox baiting programme - Vehicle access restrictions during summer - Compulsory use of TED's on

				prawn and scallop trawls in WA
Muiron Islands			High	- Designation / management of protected areas, sanctuaries, exclusion zones etc. - Compulsory use of TED's on prawn and scallop trawls in WA

Biological data breeding

Parameter	**Value (if known)**	**Reference(s)**
Pivotal temperature	Unknown	Limpus (2009)
Remigration interval	Unknown	
Clutches per season	Unknown	
Mean size of nesting adult (first breeding)	Unknown	
Age at maturity	Unknown	

Biological data foraging

Parameter	**Value (if known)**	**Reference(s)**
Mean size at recruitment (to inshore foraging)	Unknown	
Growth rates	Unknown	
Survivorship estimates	Unknown	

Summary from Wallace et al 2010; 2011

Loggerheads in the Southeast Indian RMU were given a risk matrix score of 2.00, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 1,001-5000 females, a low likelihood of complete loss of nesting rookeries, and comprise only one genetic stock. Recent and long-term population trends could not be determined due to data deficiency. A threats matrix score of 1.67 was determined from expert opinion that loggerheads in the Southeast Indian Ocean RMU faced a medium threat from fisheries bycatch and coastal development, and a low threat from take. The threat posed by both pollution and climate change could not be determined due to data deficiency. Overall Wallace et al (2011) categorised this RMU as High Risk-Low Threat.

Summary from US NMFS:

Similar to Wallace et al (2011) the US NMFS determined that population data in this region was insufficient to determine recent or long-term trends, but inferred from available evidence that population declines are likely to occur in the future, with the greatest threat to loggerheads in this region coming from fisheries bycatch of juvenile and adult loggerheads throughout the region. The US NMFS also found it impossible to determine the magnitude of the threat of climate change for loggerheads in the Southeast Indian Ocean.

The BRT consider it unlikely that mortality due to bycatch can be adequately reduced or eliminated due to the existence of illegal, unregulated, and unreported fisheries, in addition to limitations in enforcement capabilities, geopolitical complexities, and not enough information regarding fishing efforts and distribution. The BRT also conclude that uncertainty regarding loggerhead status in this region is considerable, but that significant conservation strategies have been implemented.

However, it must be noted that the US NMFS consider that cumulatively human activities may impact a large proportion of eggs and hatchlings (~30%). Given the uncertainty that exists regarding the status of loggerheads in this region, the US NMFS have determined that the Southeast Indo-Pacific Ocean DPS of the loggerhead sea turtle is not currently in danger of extinction, but is likely to become so in the foreseeable future throughout its range. It is currently listed as 'Threatened'.

South Pacific Ocean management unit

Ecological range

The management unit which approximates ecological range, for the North-west Indian ocean population was calculated based on existing data from molecular studies, migration behaviour, tag recoveries and expert opinion and its spatial extent matches its RMU (Wallace et al. 2010). The boundary of its ecological range indicates that turtles from the population occur within the Exclusive Economic Zones of 23 nations (Figure 13).

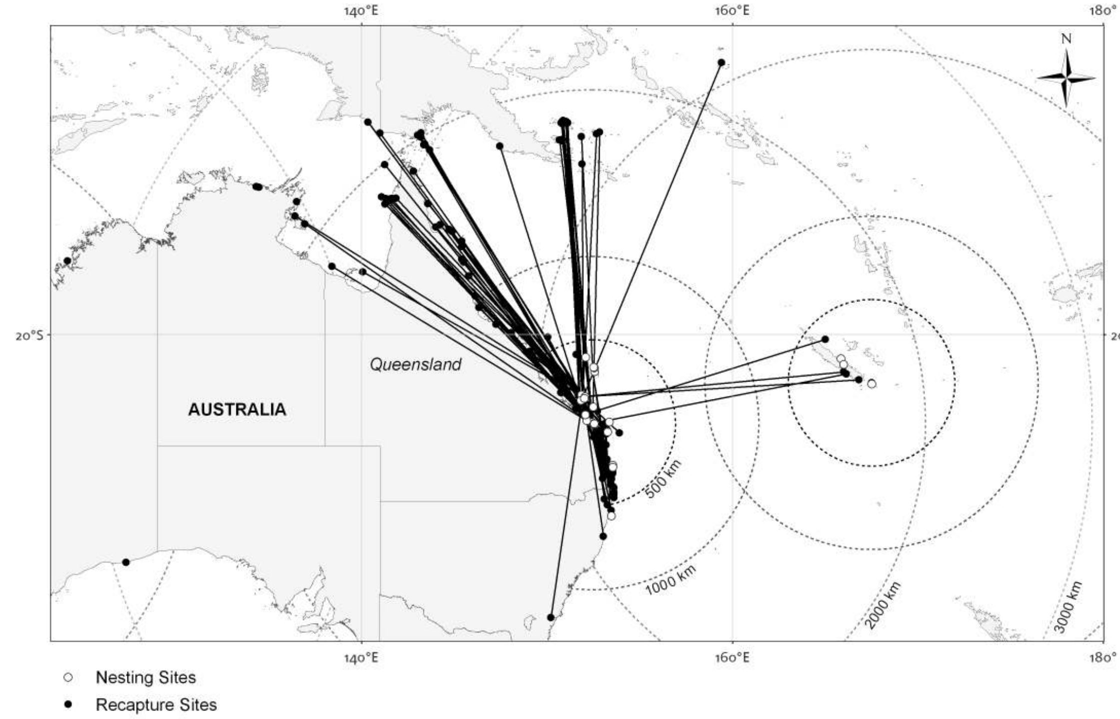
Geographic spread of foraging

Similar to the north Pacific Ocean management unit, there is considerable knowledge about foraging distribution of loggerhead turtles in the south Pacific Ocean, especially in eastern Australia. A combination of fisheries bycatch data, sightings and expert opinion indicate that loggerhead turtles from this management unit migrate and utilise waters throughout the south Pacific Ocean. Overall there are EEZs of 23 nations that lie within the ecological range of the south Pacific Ocean management unit (Figure 13) and loggerhead turtles from the management unit have been confirmed (tag recoveries, satellite telemetry and/or genetics) in the coastal waters of five of them (Australia, Papua New Guinea, New Caledonia, Solomon Islands and Peru). In eastern Australia considerable data has been collected on foraging loggerhead turtles – such as home range studies, diet and foraging ecology and population dynamics (see review by Limpus 2009).

Geographic spread of nesting

Loggerhead breeding in the south Pacific occurs mainly in eastern Australia (Figure 14). There are three principal breeding areas: the southeast coast of Queensland, the Capricorn-Bunker Islands in the southern Great Barrier Reef and the Islands of the Swain Reefs (Limpus, 2009). A small nesting population also occurs in southern New Caledonia and Vanuatu (Pritchard, 1982; Atuary, 1994).

Figure 13. Overlay of the North-west Indian Ocean loggerhead turtle RMU (mesh), with the exclusive economic zones (grey) of inclusive nations. The RMU is split into two panels to better reflect the size of the RMU (i.e. cross Pacific Ocean).



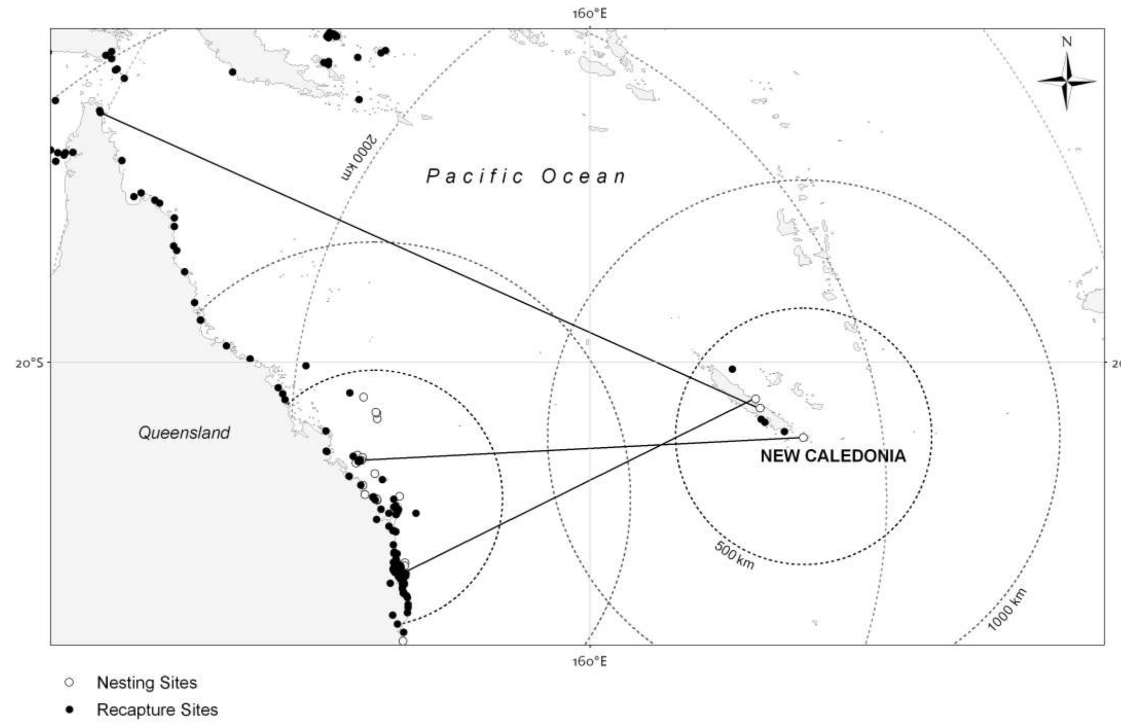


Figure 14. Major and minor nesting sites and tag recoveries within the South Pacific Ocean

population

Trends in nesting data

This population has been monitored at many locations, with long-term data collected from the Bundaberg coast since 1968, and Heron Island since 1974 (Limpus and Limpus, 2003). In the 1970's the eastern Australian nesting population was estimated to be approximately 3500 females annually (Limpus and Riemer, 1994), however this has declined substantially and current estimates put the nesting population at around 500 females (Limpus, 2009).

Migration and distribution of foraging areas

Tagged loggerheads from south east Queensland have been located in foraging areas to the south in New South Wales, east to New Caledonia, and north to the Solomon Islands, Papua New Guinea, the Australian Gulf of Carpentaria (where their feeding distribution overlaps with western Australian loggerheads; Limpus et al. 1992) and Indonesian waters (Limpus, 2009). A small number of tagged turtles from the New Caledonia breeding stock have been recorded foraging off eastern Australian, in the Heron Reef lagoon in the southern Great Barrier Reef and in Moreton Bay (Limpus and Limpus, 2003; Limpus, 2009).

Threats to the population (by threat)

Type of threat	**Location** 1=nesting beach 2=migration zone 3=foraging area (local) 4=foraging area (widespread)	**Managed** 1=managed completely 2=managed at some sites 3=nesting sites mostly protected 4=no, or little, effective management	**Quantified** 1=comprehensive documentation across population 2= comprehensive documentation for some of the population 3=anecdotal only 4=no reliable data
Egg predation/collection	1	2,3	2 (not NC?)
Beach erosion			
Increasing beach T	1	2	2
Coastal development (urban)	1	2	2
Coastal development (industrial)	1,3	2	2
Bycatch in inter-nesting zone	2,3	2	2
Bycatch in migration zone	2	2	2
Bycatch in foraging	3,4	2	2

habitat			
Entanglement in discarded fishing gear	2,3,4	2	3
Impact to benthic ecology from fisheries			
Solid pollution (e.g. plastics)	1,2,3,4	2	3
Water quality			
Disease issues	1,2,3,4	2	2
Ecosystem level impacts	1,2,3,4	2	2
Light Horizon Disorientation	1	2	2
Other (list)			

Threats to the population (by nation within the migration zone)

Australia: Fisheries bycatch is considered to be the biggest cause of mortality for loggerheads in the south pacific (Poiner and Harris, 1996). Oceanic gill-net fisheries potentially killed numerous loggerhead post-hatchlings when operational (Weatherall et al. 1993), and oceanic long-lines in the south pacific potentially cause high levels of post-hatchling loggerhead mortality today (Chaloupka, 2003).

Predation by the European red fox (*Vulpes vulpes*) destroyed large numbers of nests along the mainland coast of east Australia in the 1970's and 1980's (Limpus, 1985). Whilst baiting has controlled this problem at many of the affected nesting locations at present, minor nesting areas between the Burnett River and Deepwater Creek remain unprotected (Limpus, 2009).

Harvest of loggerhead turtles has been documented in a number of south pacific countries, including Fiji (Guinea, 1993), New Caledonia (LImpus et al. 1992) and Australia (Limpus, 1985). Consumption of loggerheads has not been as intense as for green and hawksbill turtles in this ocean basin (limpus and Limpus, 2003), and the loggerhead take within Australia is considered to be of minor significance to the population (Limpus and Reiner, 1994). Consumption rates in New Caledonia and Fiji, however, have not been quantified (Pritchard, 1982; Guinea, 1993).

Other threats in eastern Australia include boat strikes, ingestion of plastic waste, entanglement and bycatch from shark control programs, all of which are thought to cause the deaths of up to 60 loggerhead turtles each year (Limpus, 2009).

There are no mentions of threats to loggerhead turtles in the IOSEA Signatory States reports for Indonesia or Papua New Guinea.

Management and protection

Site name	Type	Index	Relative	Protection

		site Y/N	importance (to the population)	
Woongarra Coast (inc Mon Repos)	Nesting and foraging	Y	High	- Long-term monitoring, protection, education, awareness programmes - Designation / management of protected areas, sanctuaries, exclusion zones etc. - Seasonal control of tourist activities - Relocation of at-risk nests to protected area - Fox baiting programmes - Vehicle and access restrictions - Seasonal closure to trawling - Compulsory use of TED's on all trawls in QLD
Capricorn-Bunker Islands	Nesting and foraging		High	- Long-term monitoring - Designation / management of protected areas, sanctuaries, exclusion zones etc. - Compulsory use of TED's on all trawls in QLD
Swain Reef Islands	Nesting and foraging		High	- Long-term monitoring - Designation / management of protected areas, sanctuaries, exclusion zones etc. - Compulsory use of TED's on all trawls in QLD

Biological data breeding

Parameter	Value (if known)	Reference(s)
Pivotal temperature	28.6°C	Limpus et al (1985)
Remigration interval	3.82 yrs	Limpus (1985)
Clutches per season	3.41	Limpus (1985)
Mean size of nesting adult (first breeding)	CCL 93.7 $\pm$ 4.3 cm	Limpus (1991)
Age at maturity	29 + years	Limpus (2009)

Biological data foraging

Parameter	Value (if known)	Reference(s)
Mean size at recruitment (to inshore foraging)	CCL 78.6 $\pm$ SD 4 cm	Limpus & Limpus (2003)
Growth rates	Slow. Three decades	Limpus (2009)

	from hatchlings to breeding adults	
Survivorship estimates	0.782	Heppel et al (1996)

Summary from Wallace et al 2010; 2011

Loggerheads in the South Pacific RMU were given a risk matrix score of 2.30, obtained from expert opinion that loggerheads in this region have an annual nesting abundance of 101-1,000 females, an increasing recent population trend, a decreasing long-term population trend, a medium likelihood of complete loss of nesting rookeries, and comprise only one genetic stock. A threats matrix score of 2.00 was determined from expert opinion that loggerheads in the South Pacific RMU were highly threatened by both fisheries bycatch (mainly in longline and trawl fisheries) and climate change (mainly due to increased temperatures and sea level rise), faced a medium threat from coastal development, and a low threat from take. The threat posed by pollution could not be determined due to data deficiency. Overall Wallace et al (2011) categorised this RMU as High Risk-High Threats (Figure 1).

Summary from US NMFS

In line with Wallace et al (2011), the NMFS (Connant et al. 2009, Fed Reg, 2011) found that that greatest threat to loggerheads in the South Pacific region was bycatch in oceanic fisheries (Limpus and Reimer 1994; Poiner and Harris 1996; Robins et al. 2002a, b; Kelez et al. 2003; Alfaro-Shigueto et al. 2006; Donoso and Dutton 2006; Alfaro-Shigueto et al. 2008b; Limpus 2009) – making oceanic juveniles and adults particularly susceptible life-stages.

In contrast to Wallace et al (2011), the threat posed by take was considered by the NMFS to be a medium threat to nesting females, due to aboriginal harvest of approximately 40 adult females annually (Limpus 2009). Moreover, although climate change is recognised as having the potential to affect loggerheads in this region, unlike Wallace et al (2011), the NMFS found it was not possible to determine the magnitude of this threat.

In eastern Australia, the number of females breeding annually declined by approximately 86% between the mid-1970s and 1999. Fisheries bycatch of juvenile and adult loggerheads, occurring throughout the South Pacific Ocean, was the major driver of this decline. The US NMFS consider it unlikely that mortality due to bycatch can be adequately reduced or eliminated due to the existence of illegal, unregulated, and unreported fisheries, in addition to limitations in enforcement capabilities, geopolitical complexities, and not enough information regarding fishing efforts and distribution.

Given that the South Pacific Ocean DPS shows evidence of a marked decline (~86%) in nesting females since the mid-1970s, in addition to recent nest count data which indicates the population is still at risk, the US NMFS have determined that the South Pacific Ocean DPS is in danger of extinction throughout its range. It is currently listed as 'Endangered'.