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Papers presented at the

EXPERT CONSULTATION ON INTERACTIONS BETWEEN SEA TURTLES AND FISHERIES WITHIN AN ECOSYSTEM CONTEXT

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ABSTRACT

An Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context was convened by FAO and held in Rome, Italy, from 9 to 12 March 2004. The meeting was attended by 11 experts from seven countries, covering expertise related to sea turtle biology and conservation, fishing gear technology, fisheries management and socio-economics. The Expert Consultation was organized to provide technical input to the Technical Consultation to take place in Bangkok, Thailand, later in 2004, as agreed at the twenty-fifth session of the Committee on Fisheries (COFI), held in Rome, Italy, from 24 to 28 February 2003. This document includes all the contributions prepared by the participating experts as background information to the Expert Consultation.

The first four papers provide an overview of available information on biology, distribution and main sources of natural and man-induced sea turtle mortality for the Atlantic, Pacific and Indian Oceans and the Mediterranean Sea, respectively.

Gear technology developments to reduce impacts on sea turtles are reviewed in papers 5 to 7. Special emphasis is given to the Turtle Excluder Devices (TEDs) and mitigation measures in pelagic longline fishing. Management experiences in reducing sea turtle bycatch in coastal fisheries, including implementation of technology standards and area/time closures, are covered by paper 8.

Examples of conservation efforts aimed at preserving nesting beach habitats and at preventing direct take of sea turtles and their eggs are presented for two locations in Indonesia (paper 9). The examples show the importance of community empowerment in the implementation of conservation measures.

Finally, paper 10 describes an important case study from the State of Orissa (India). Here olive ridley turtles congregate in large numbers in the shallow coastal waters that also happen to be the richest fishing grounds and the source of livelihoods for traditional fishing communities in that region. Experiences made in implementing various management measures to reduce sea turtle mortality due to fishing are presented, with particular emphasis on the consequences that these have had on traditional fishing communities.

Status of sea turtle stocks in the Pacific

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Abstract

Six species of sea turtles occur in the Pacific Ocean (green turtles, loggerheads, leatherbacks, hawksbills, olive ridleys and flatbacks). All species, except flatbacks, have transboundary distributions. The status of most sea turtle stocks in the Pacific Ocean is poorly understood. Some stocks are increasing, such as in eastern Australia and Hawaii. However, there is evidence that many stocks have been reduced significantly, which is mainly a result of overharvesting of eggs, subsistence or commercial harvest of large turtles and nesting habitat destruction. Incidental capture in coastal and pelagic fisheries can also be an important source of mortality for some stocks. Abundance trends for the six Pacific species of sea turtles are reviewed, using the best available quantitative information.

INTRODUCTION

The status of the sea turtle stocks in the Pacific Ocean basin is poorly understood (Spotila *et al.*, 1996; Meylan and Donnelly, 1999; Chaloupka and Limpus, 2001; Seminoff, 2002). Many stocks have been reduced significantly, which is mainly a result of overharvesting of eggs (Meylan and Donnelly, 1999; Chaloupka, 2001; Seminoff, 2002), subsistence or commercial harvest of large turtles (Horikoshi *et al.*, 1994; Meylan and Donnelly, 1999; Trinidad and Wilson, 2000; Gardner and Nichols, 2001; Limpus *et al.*, 2004) and nesting habitat destruction (Sharma, 2000; Matsuzawa *et al.*, 2002). Other sources of mortality can have local importance, such as fibropapilloma disease (Chaloupka and Balazs, n.d.) or tiger shark attack (Heithaus, Frid and Dill, 2002; Balazs and Chaloupka, unpubl. strandings data for Hawaii). Incidental capture in coastal and pelagic fisheries can also be an important source of mortality for some stocks (Chan, Liew and Mazlan, 1988; Cheng and Chen, 1997; Chaloupka, 2003b).

Most assessments of the status and trends of sea turtle populations have been based on monitoring the seasonal beach nesting activity of adult females (Chaloupka and Limpus, 2001). But monitoring only female nesting activity provides insufficient information for stock assessment because: (1) females skip breeding seasons, and (2) no information is provided on demographic structure because the immature, adult male and non-breeding female components are not sampled (Chaloupka and Limpus, 2001).

Reliable estimates of sea turtle abundance that would be suitable for stock assessment and conservation management planning depend on sampling the entire demographic structure of a population resident in the foraging grounds. Yet such foraging ground abundance estimates are only known for three Pacific sea turtle stocks – the southern Great Barrier Reef green turtle metapopulation (Chaloupka and Limpus, 2001; Chaloupka, 2002b), the Australian loggerhead metapopulation (Chaloupka and Limpus, 2001) and the Hawaiian green turtle metapopulation (Balazs and Chaloupka, 2004).

All previous regional assessments of sea turtle abundance have been based mainly on anecdotal or qualitative information (Spotila *et al.*, 1996; Meylan and Donnelly, 1999; Seminoff, 2002). Here we review briefly the abundance trends for the six species of sea turtle (green turtles, loggerheads, leatherbacks, hawksbills, olive ridleys, flatbacks) that occur in the Pacific Ocean basin using the best available quantitative information. However, most data are based on nesting beach monitoring and so must be viewed with extreme caution. Moreover, little is known about the spatial and temporal trends in coastal or pelagic fishing effort in the Pacific (Wetherall *et al.*, 1993; Robins, 1995; Poiner and Harris, 1996; Lu, Lee and Liao, 1998; Slater *et al.*, 1998; McCracken, 2000; Chaloupka, 2003b; Tuck, Polacheck and Bulman, 2003). Hence there is very little quantitative information available to support any robust risk analysis of fisheries impacts on sea turtle population viability (Slater *et al*., 1998).

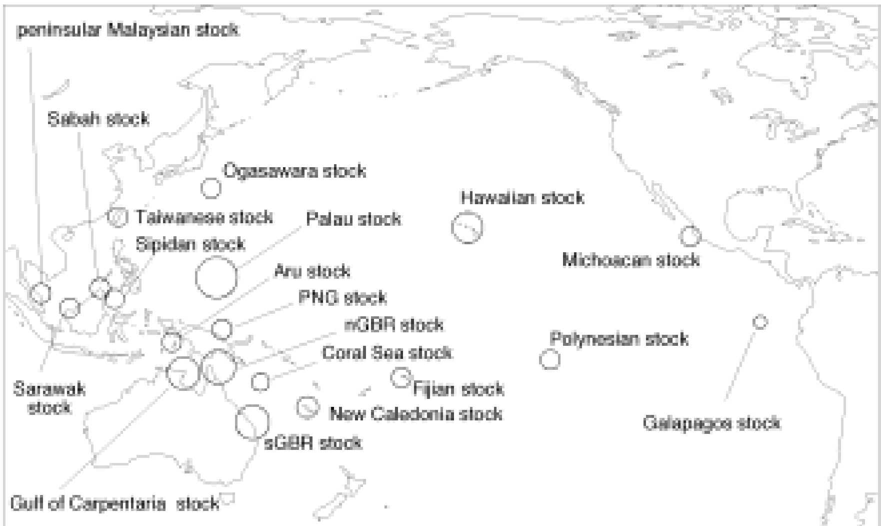

Figure 1. Location of the major regional rookeries for the Pacific green turtle stocks.
Source**:** Bowen, 1992; Dutton, Broderick and Fitzsimmons, 2002

Green turtles (*Chelonia mydas*)

Background

The green turtle comprises 20 management units or stocks in the Pacific (Dutton, Broderick and Fitzsimmons, 2002), which are shown in Figure 1. Many Pacific stocks are declining (Seminoff, 2002) but some are stable or increasing (Chaloupka and Limpus, 2001). Stable stocks include the Terengganu rookery (Liew, 2002), Ko Khram rookery (Charuchinda, Monanunsap and Chantrapornsyl, 2002), Sabah and Philippine Turtle Island rookeries in the Sulu Sea (Chaloupka, 2001; Basintal, 2002), Guam rookery (Cummings, 2002), Raine Island rookery of the northern Great Barrier Reef stock (Limpus *et al*., 2004), Heron Island rookery of the southern Great Barrier Reef stock (Chaloupka and Limpus, 2001), East Island rookery of the Hawaiian stock (Balazs and Chaloupka, 2004), Galapagos rookery (Seminoff, 2002) and the Playa Colola rookery of the Michoacan stock (Seminoff, 2002).

Table 1. Summary of nesting seasons for 20 Pacific green turtle stocks shown in Figure 1

Stock	Nesting location	Season (peak)	Source
sGBR	Heron Island	Oct–Jan	Chaloupka & Limpus (2001)
nGBR	Raine Island	Oct–Jan	Limpus *et al*. (2004)
Sipidan	Sipidan Island	year round (Oct–Jan)	Basintal (2002)
Sulu Sea	Philippine Turtle Islands	year round (Jul–Sep)	Chaloupka (2001)
Sarawak	Sarawak Turtle Islands	year round (Jul–Sep)	Chaloupka (2001)
Malaysia	Terengganu	year round (Jun–Jul)	Chaloupka (2001)
Taiwan (Prov. of China)	Wan-an Island	Jul–Aug	Cheng (2002)
Ogasawara	Ogasawara Islands	May–Aug	Suganuma (1985)
Hawaii	French Frigate Shoal	May–Jul	Balazs & Chaloupka (2004)
Michoacan	Playa Colola-Maruata	Sep–Jan	Alvarado-Diaz, Arias-Coyotl & Delgado-Trejo (2003)
Revillagigedo	Isla Clarion	Dec–April	Sarti, Roldan & Dutton (2002)
Galapagos	Isabella, St.Cruz, Fernandina	Dec–April	Zarate, Fernie & Dutton (2004)

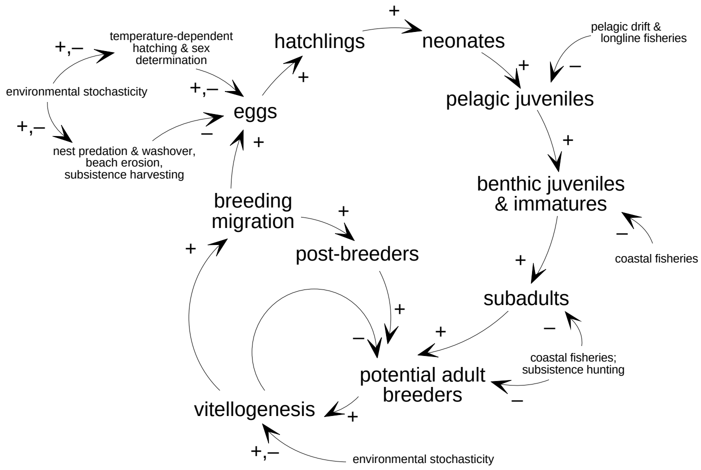

Figure 2. Lifecycle graph or causal loop model based on developmental phases and reproductive status (source: Puccia and Levins, 1985) for Pacific green turtles. The demographic structure and feedback mechanisms depicted here are included in the stochastic simulation model to explore Pacific green turtle metapopulation dynamics subjected to various hazards (e.g. nesting beach erosion, nest inundation by wave washover, egg and turtle harvesting, or incidental capture and drowning in coastal or pelagic fisheries) - see Chaloupka (2002a, 2004)

The main reason for the decline of some green turtle stocks in the Pacific Ocean is the overharvesting of eggs and large turtles (Horikoshi *et al.*, 1994; Limpus, Couper and Read, 1994; Chaloupka, 2002a; Seminoff *et al.*, 2003b – see Figure 3d). There is extensive demographic information available for the southern Great Barrier Reef stock (Limpus, Couper and Read, 1994; Limpus and Chaloupka, 1997; Chaloupka and Limpus, 2001; Chaloupka and Limpus, 2002; Chaloupka, 2002a; Chaloupka, 2002b). There is also extensive demographic information available for the Hawaiian stock including foraging ground abundance estimates (Balazs and Chaloupka, 2004; Balazs and Chaloupka, in press; Chaloupka and Balazs, n.d.). Some important demographic information such as survival probabilities and somatic growth dynamics is available for the Baja California population (Seminoff *et al.*, 2002; Seminoff *et al.*, 2003b). Demographic data are not available for any other Pacific green turtle stock.

A stochastic simulation model of the metapopulation dynamics of the Hawaiian stock was developed for National Oceanic and Atmospheric Administration (NOAA) Fisheries to help evaluate the impact of competing risks on green turtle population viability (Chaloupka, 2003, unpubl. – see Figure 2). A stochastic simulation model for the Australian stock was described in detail in Chaloupka (2002a) and a spatially explicit extension of that model was described in Chaloupka (2004). A more comprehensive stochastic simulation model was developed for the Great Barrier Reef Marine Park Authority to evaluate potential impacts of indigenous harvests on the viability of the southern Great Barrier Reef stock (Chaloupka, 2003a; see also Dobbs and Limpus, in press). A Bayesian surplus production stock assessment model has been developed recently for the Hawaiian green turtle metapopulation (Chaloupka, unpubl.).

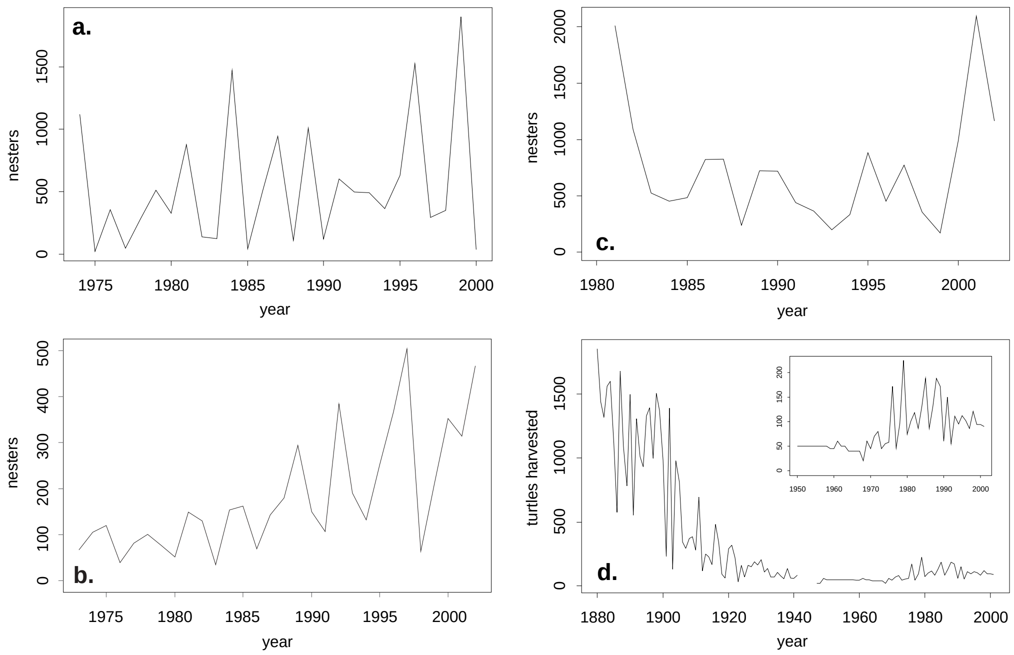

Figure 3. Trends in nesting abundance of three Pacific green turtle populations (a, b and c) and the harvest history of the Ogasawara population (d). Panel (a) shows the annual nesting census of green turtles at the Heron Island rookery, southern Great Barrier Reef (source**:** Chaloupka and Limpus, 2001; Limpus and Limpus, 2003). Panel (b) shows the annual nesting census of green turtles at the East Island rookery, French Frigate Shoals, Hawaii (source**:** Balazs and Chaloupka, 2004). Panel (c) shows the annual nesting census of green turtles at the Colola rookery, south Michoacan, Mexico (source**:** USA Biological Opinion, 2004). Panel (d) shows the number of adult green turtles harvested each year around the Ogasawara Islands, Japan (source**:** Horikoshi *et al*., 1994 with updates from Dr Suganuma, pers. comm.). The inset shows the same data for the period 1950–2000.

Hazards

Green sea turtles account for a small proportion of the incidental take in the Queensland east coast otter trawl (Robins, 1995; Slater *et al*., 1998) and Australian northern prawn fishery (Poiner and Harris, 1996). Green turtles are commonly caught in pelagic fisheries in the North Pacific (McCraken, 2000) and in some coastal fisheries off the California coast (Julian and Beeson, 1998).

Green turtles have also been the preferred target species for a wide range of subsistence harvests throughout the Pacific (Chaloupka, 2002a; Seminoff, 2002) and for egg collection (Chaloupka, 2001). The main hazards for the species are (Figure 2):

- egg harvesting;
- harvest of large turtles in the foraging grounds and on nesting beaches;
- nesting habitat destruction;
- incidental capture in coastal and pelagic fisheries.

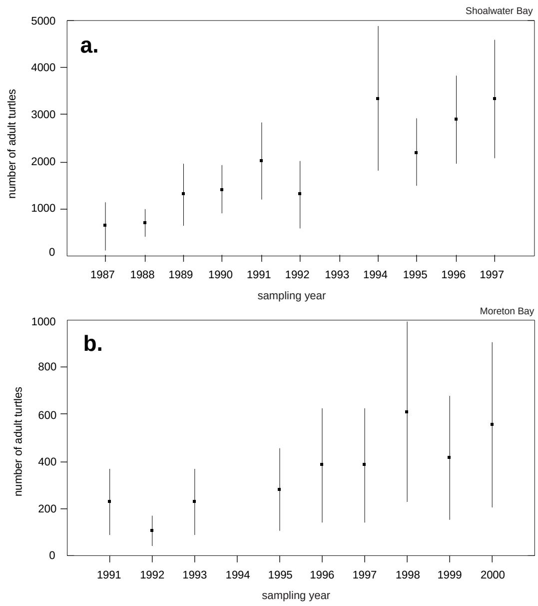

Figure 4. Trends in Horvitz-Thompson type population abundance (solid squares) for green turtles resident in two major foraging grounds of the southern Great Barrier Reef stock. Panel (a) shows adult abundance estimates for the Shoalwater Bay foraging ground population of the sGBR metapopulation. Panel (b) shows adult abundance estimates for the Moreton Bay foraging ground population of the sGBR metapopulation. Vertical bar = approximate 95 percent confidence interval. Source: Chaloupka, 2002b

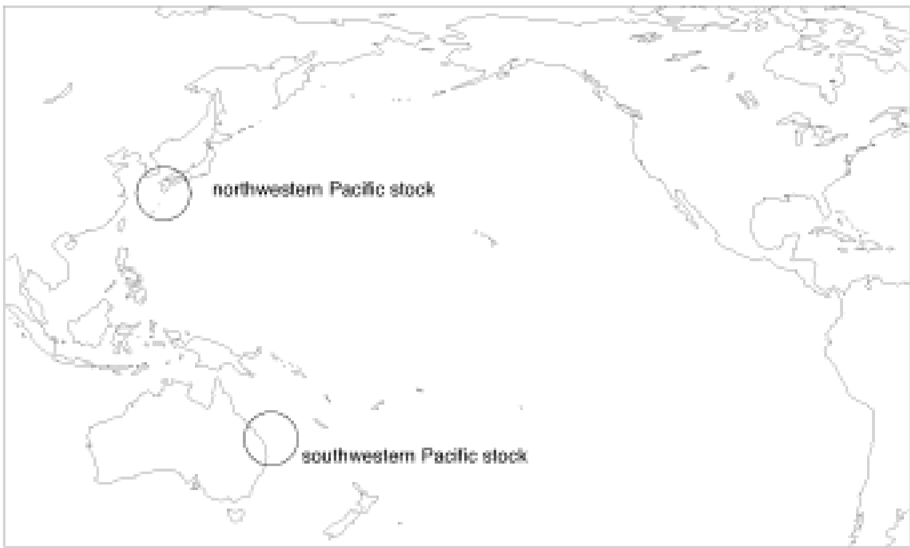

Figure 5. Location of the major regional rookeries for the Pacific loggerhead turtle stocks. Source: Bowen *et al.*, 1994; Kamezaki *et al.*, 2003; Limpus and Limpus, 2003

Loggerheads (*Caretta caretta*)

Background

The loggerhead sea turtles resident in Pacific waters comprise two distinct stocks (Figure 5). Ongoing genetic and tagging studies are beginning to define breeding stocks on a finer scale within these broad regions. Within Australia, the cluster of rookeries in the east and west is recognized as two distinct management units by genetic studies (see Dutton, Broderick and Fitzsimmons, 2002). Limpus and Limpus (2003) also suggest an additional unit, encompassing the small rookeries in New Caledonia (1 300 km distant from Australian nesting beaches). Similar genetic studies in Japan (Hatase *et al*., 2002) indicate the presence of at least four discernible management units and provide evidence that all loggerheads found in the northern Pacific originate in Japan. The transition from hatchling to young juvenile in this species occurs in the open ocean. Juvenile foraging areas occur off Baja California, Mexico, approximately 10–12 000 km from their nearest nesting beaches in Japan (Figure 6). Pacific loggerhead stocks have declined significantly over the last 50 years (Figure 7). This is apparent for all nesting populations (Figure 7a,c) and many foraging ground populations (Chaloupka and Limpus, 2001), but not for all foraging ground populations of the Australian stock (Figure 7b). There is extensive demographic information available for the Australian stock (Chaloupka and Limpus, 2002; Chaloupka, 2003b; Limpus and Limpus, 2003). There is very little demographic information available for the Japanese stock (Kamezaki and Matsui, 1997) but there are comprehensive nesting data available for this stock (Sato *et al*., 1997; Kamezaki *et al*., 2003). A stochastic simulation model of the population dynamics of the Japanese stock was developed for NOAA Fisheries to help evaluate the impact of competing risks on loggerhead population viability (Chaloupka, unpubl.). A stochastic simulation model for the Australian stock was described in detail in Chaloupka (2003b), which suggested the dramatic decline in the Australian loggerhead stock was a result of foxes feeding on nest contents at mainland rookeries and incidental capture in coastal and pelagic fisheries.

Table 2. Summary of nesting seasons for Pacific loggerhead turtle stocks shown in Figure 5

Stock	Nesting location	Season (peak)	Source
Southwest Pacific	New Caledonia, southern GBR/ Queensland	Oct–Mar (Dec)	Limpus & Limpus (2003)
Northwest Pacific	Southern Japan, Ryukyu Islands	Apr–Aug (Jul)	Kamezaki *et al*. (2003)

Hazards

Nearly 51 percent of sea turtles caught in the Queensland east coast otter trawl fishery were found to be loggerheads (Robins, 1995; Slater *et al*., 1998) while around 10 percent of the incidental capture of sea turtles in the Australian northern prawn fishery (Gulf of Carpentaria) was loggerheads (Poiner and Harris, 1996). Loggerheads are also commonly caught in pelagic fisheries in the northern Pacific (Wetherall *et al*., 1993; McCraken, 2000) and some coastal fisheries off the California coast (Julian and Beeson, 1998). The loggerheads caught in these high seas and coastal fisheries in the North Pacific all belong to the Japanese breeding stock (Figure 6). Recently, juvenile loggerheads of Australian stock origin have been found foraging in the southeast Pacific off the coast of Peru and Chile, suggesting that this stock is distributed across the entire southern Pacific Ocean (Dutton, in prep; see also Donoso *et al*., 2000, and Alfaro-Shigueto *et al*., in press) and is impacted by high seas and coastal fisheries operating in this region of the eastern Pacific (Donoso and Dutton, in press).

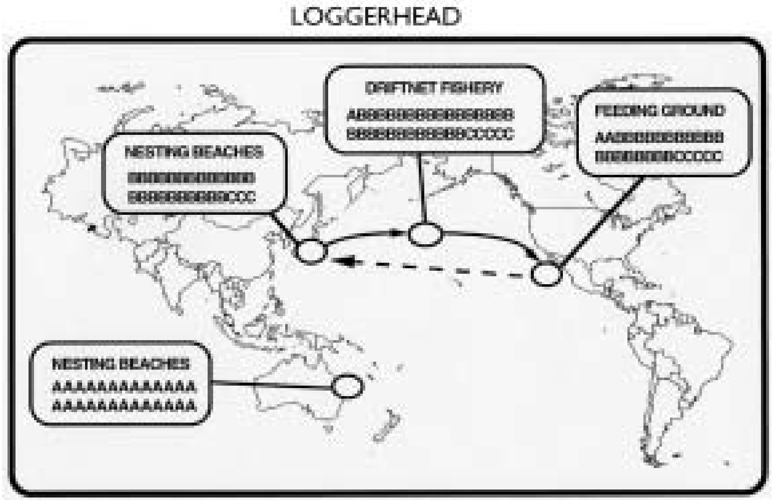

Figure 6. Genetic stock composition (based on mitochondrial DNA haplotypes) of loggerheads in the Pacific. Two regional nesting stocks are shown (Japan and Australia). The turtles in the North Pacific foraging areas belong to the Japanese nesting stock. Source: Bowen *et al*., 1995

The main hazards for loggerheads are (see also NMFS and USFWS, 1998a):

- incidental capture in coastal and pelagic fisheries;
- nesting habitat destruction, including beach armourment;
- feral animal predation on nests.

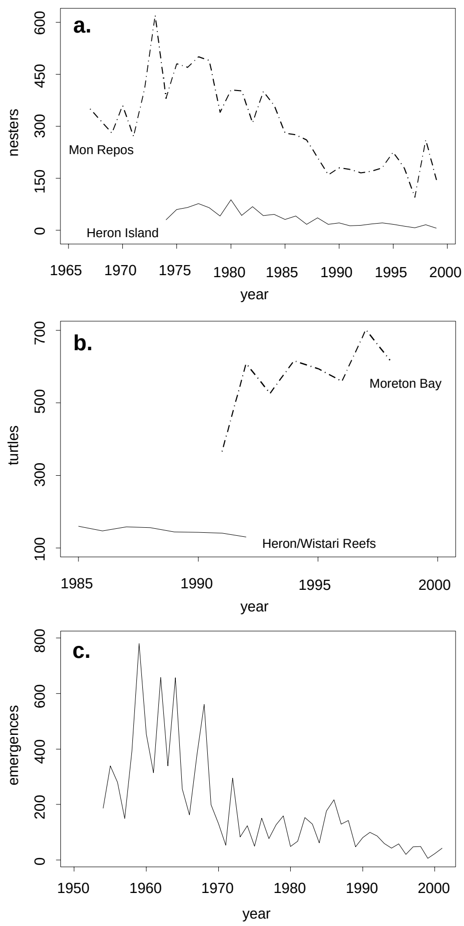

Figure 7. Trends in nesting abundance for the two Pacific loggerhead stocks. Panel (a) shows number of nesters recorded each year for the southwestern Pacific loggerhead rookeries at Mon Repos (source: Limpus and Limpus, 2003) and Heron Island (source: Chaloupka and Limpus, 2001). Panel (b) shows abundance estimates for loggerheads at two foraging ground populations of the southwestern Pacific stock based on Horvitz-Thompson type estimates using Cormack-Jolly-Seber capture probabilities (source: Chaloupka and Limpus, 2001). Panel (c) shows the number of female beach emergences or haul-outs recorded each year for the northwestern Pacific loggerhead rookery at Kamouda, Japan (source: Kamezaki *et al.*, 2003)

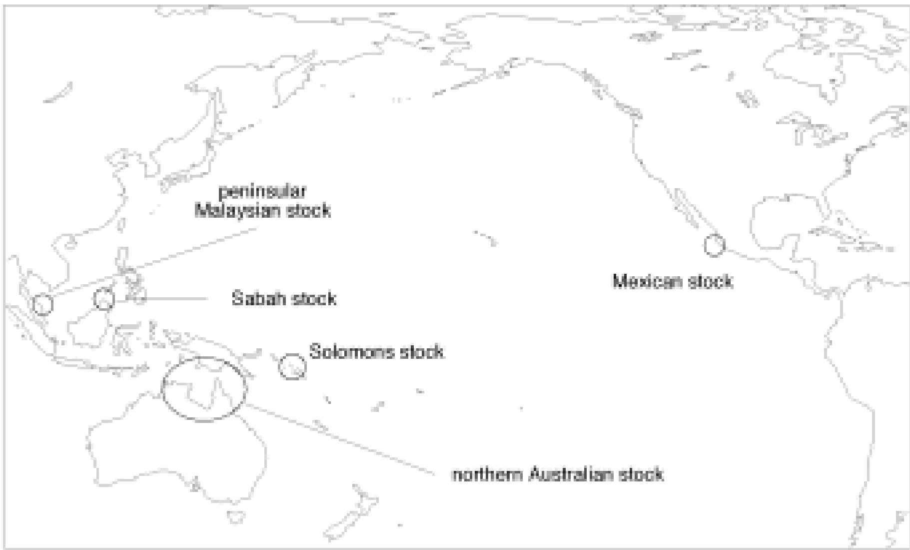

Figure 8. Location of the major regional rookeries for the Pacific hawksbill turtle stocks. Source: Broderick *et al*., 1994; Dutton, Broderick and Fitzsimmons, 2002

Hawksbills (*Eretmochelys imbricata)*

Background

The hawksbill turtle comprises five stocks or management units in the Pacific (Dutton, Broderick and Fitzsimmons, 2002), which are shown in Figure 8. The hawksbill is critically endangered with some Pacific stocks in decline (Meylan and Donnelly, 1999; Seminoff *et al*., 2003a). However, stable stocks include the Ko Khram rookery in the Gulf of Thailand (Charuchinda, Monanunsap and Chantrapornsyl, 2002) and the Sabah Turtle Islands rookery in the Sulu Sea (Basintal, 2002). The eastern Pacific stock was abundant but is now only occasionally found along the Baja and Pacific Mexico coast (Seminoff *et al*., 2003a). Long-term monitoring of nesting abundance is only available for the northern Australian stock (Figure 9a) and the Sabah stock (Figure 9b). The Australian stock has declined in recent years but there are no foraging ground abundance estimates for any Pacific population. There are only limited demographic data available for hawksbills (Chaloupka and Limpus, 1997; Pilcher and Ali, 1999). There are no reliable demographic models of hawksbill population dynamics (Chaloupka and Musick, 1997) but a stochastic simulation model is in development for the Western Pacific Regional Fishery Management Council (Hawaii).

Table 3. Summary of nesting seasons for Pacific hawksbill turtle stocks shown in Figure 8

Stock	Nesting location	Season	Source
Malaysian	Terengganu	Apr–Aug	Chan & Liew (1996)
Sabah	Gulisaan Island	Feb–Apr, Jun–Aug	Basintal (2002)
Australian	Milman Island	Dec–Apr	Loop, Miller & Limpus (1995)

A Bayesian surplus production stock assessment model has been developed for the Cuban hawksbill turtle population (Chaloupka, unpubl., for the IUCN review of the application of the Convention on International Trade in Endangered Species [CITES]), and this is being applied to the central Pacific hawksbill stock.

Hazards

Hawksbills appear to be rarely caught in either pelagic fisheries (Wetherall *et al*., 1993; McCracken, 2000) or coastal fisheries (Robins, 1995; Poiner and Harris, 1996; Slater *et al*., 1998). The main hazards for hawksbills are (Meylan and Donnelly, 1999; see also NMFS and USFWS, 1998c):

- commercial harvesting for *bekko* (tortoiseshell);
- egg harvesting;
- nesting habitat destruction.

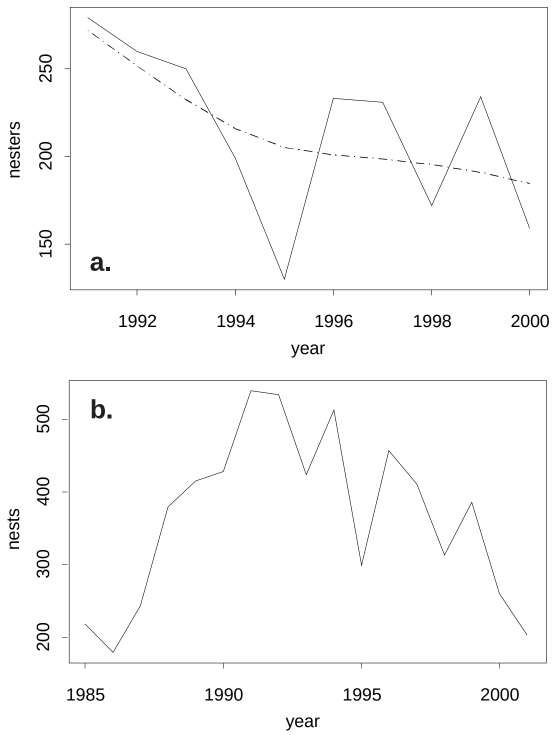

Figure 9. Trends in nesting abundance of two Pacific hawksbill populations. Panel (a) shows the estimated number of hawksbills nesting each year (solid curve) on Milman Island, northern Great Barrier Reef (source: Miller *et al*., in prep.). The underlying long-term trend in the nester series is shown by a robust cubic spline smooth fit (dashed curve), which suggests that the nester series declined most rapidly during the early 1990s and has since slowed. Panel (b) shows the estimated number of hawksbills nesting at the Gulisaan rookery in the Sabah Turtle Islands (source: Pilcher and Ali, 1999; Basintal, 2002)

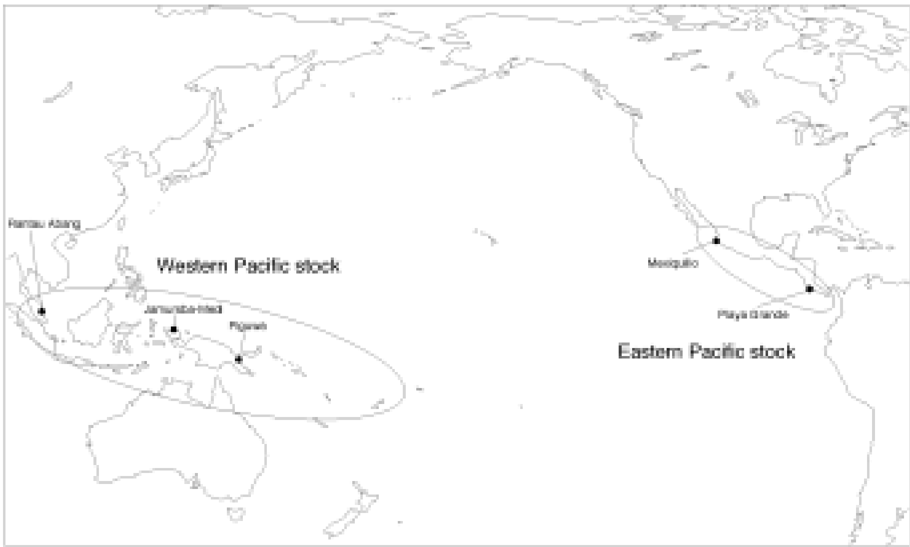

Figure 10. Location of the major rookeries for the Pacific leatherback turtle stocks. Source: Chua, 1988; Hirth, Kasu and Mala, 1993; Sarti *et al*., 1996; Spotila *et al*., 1996; Dutton *et al*., 1999; Suarez, Dutton and Bakarbessy, 2000

Leatherbacks (*Dermochelys coriacea*)

Background

The leatherback sea turtles resident in Pacific waters comprise two main distinct stocks (Figure 10), (with possibly a third "Indo-Pacific" stock whose status is unclear, in Malaysia). All stocks in the Pacific are apparently in decline (Sarti *et al*., 1996; Spotila *et al*., 1996) although perhaps not as seriously for the population that nests along the north Vogelkop coast of Papua near Jamursba-Medi (Hitipeuw and Maturbongs, 2002). However, there are no reliable estimates of the long-term status and trend in Pacific leatherback abundance. Many leatherbacks are apparently caught in coastal fisheries operating in Malaysian (Chan, Liew and Mazlan, 1988) and Californian waters (Julian and Beeson, 1998). Leatherbacks are also caught in pelagic fisheries in Chilean (Eckert and Sarti, 1997; Donoso and Dutton, 2000, and in press) and north Pacific waters (McCraken, 2000). A stochastic simulation model of the metapopulation dynamics of the western Pacific stock has been developed for NOAA Fisheries to help evaluate the impact of competing risks on leatherback metapopulation viability (Chaloupka, unpubl.).

Table 4. Summary of nesting seasons for Pacific leatherback turtle stocks shown in Figure 10

Stock	Nesting location	Season	Peak	Source
West Pacific	Terengganu (Malaysia)	Apr–Sep	Jul	Chua (1988)
	Jamursba-Medi (Papua)	Apr–Oct	Aug	Suarez, Dutton & Bakarbessy (2000)
	War Mon (Papua)	Nov–Feb	Dec	Suarez, Dutton & Bakarbessy (2000)
	Piguwa (Papua New Guinea, PNG)	Nov–Mar	Jan	Hirth, Kasu & Mala (1993)
	Kamiali-Huon Coast (PNG)	Nov–Mar	Dec	Dutton *et al*., unpubl
	Solomon Islands	Nov–Mar	Dec	Ramohia, Pita & da Wheya (2001)
East Pacific	Playa Mexiquillo (Mexico)	Oct–Mar	Dec	Eckert & Sarti (1997)
	Cahuitan (Mexico)	Oct–Mar	Dec	Sarti-Marinez (2002)
	Tierra Colorada (Mexico)	Oct–Mar	Dec	Sarti-Marinez (2002)
	Playa Grande (Costa Rica)	Oct–Mar	Dec	Steyermark *et al*. (1996)
	Playa Langosta (Costa Rica)	Oct–Mar	Dec	
	Chococente (Nicaragua)	Oct–Mar	Dec	Dutton *et al*., unpubl.

Although Atlantic populations appear to be stable or even increasing, leatherback populations are declining at all major Pacific basin nesting beaches, especially in the past two decades (NMFS and USFWS, 1998b; Spotila *et al*., 2000; Dutton, in press; Figure 14). The major decline of these nesting populations was probably brought about by a severe overharvest of eggs coupled with incidental mortality from fishing (Eckert and Sarti, 1997), especially the high seas driftnet fishery in the 1980s (Sarti *et al*., 1996).

Remaining breeding assemblages occur on both sides of the Pacific. In the western Pacific region they occur at low and scattered densities in Papua New Guinea, Solomon Islands, Fiji, Thailand, Vanuatu, China and Australia (east and northeast) (Limpus and McLachlan, 1996; Márquez, 1990; Hirth, Kasu and Mala, 1993). In the western Pacific the last remaining major rookery is limited to Papua (formerly Irian Jaya, Indonesia). Prior to 1990 a major rookery was located in Malaysia (Terengganu), but this population has collapsed in the last decade (Chan and Liew, 1996). In the eastern Pacific, the largest rookeries occur along the coasts of Mexico and Costa Rica. Scattered nesting has been reported in Panama, Colombia, Ecuador and Panama (Márquez, 1990; Spotila *et al*., 1996).

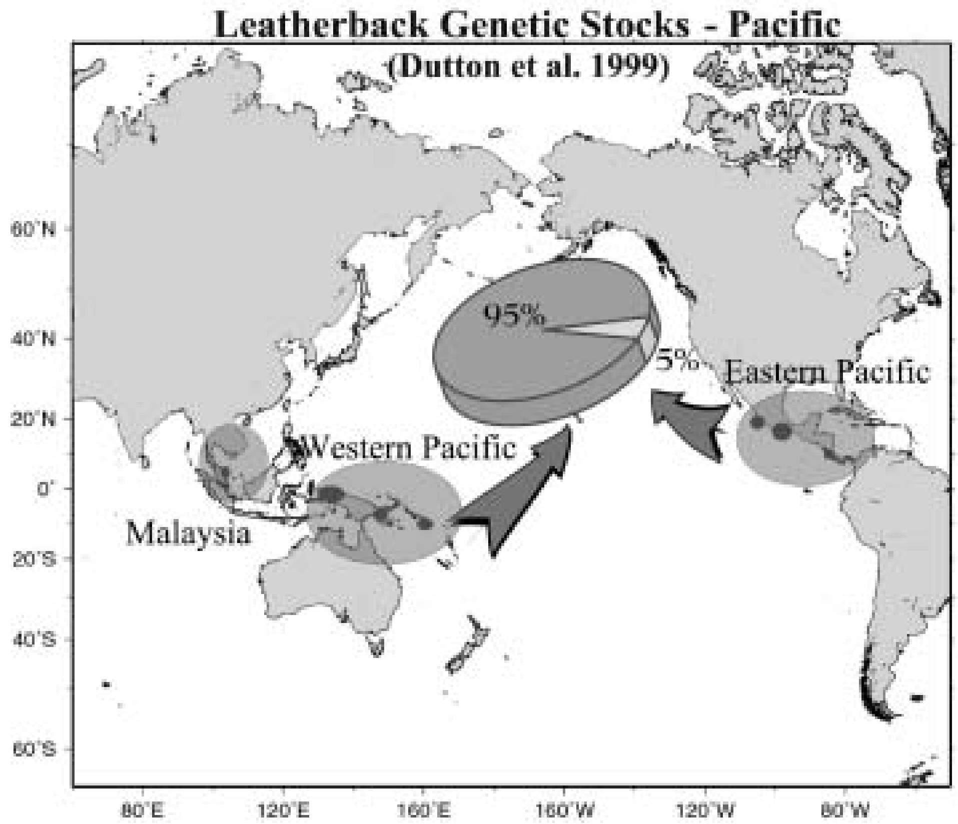

Figure 11. Stock composition of leatherbacks encountered in the north Pacific based on mitochondrial DNA (mtDNA) analysis (17 samples collected from the Hawaii-based longline fishery). The eastern Pacific genetic stock includes nesting populations in Costa Rica and Mexico, while the western Pacific stocks include populations in Papua (Indonesia), Papua New Guinea and the Solomon Islands, and a distinct stock in Malaysia. Source: Dutton *et al*., 1999

Mitochondrial DNA (mtDNA) sequences can be used to distinguish western Pacific from eastern Pacific genetic stocks (Figure 11). The eastern Pacific genetic stock includes Mexican and Costa Rican breeding assemblages, and the western Pacific stock contains populations in the Solomon Islands, Papua (Indonesia), and Papua New Guinea (Dutton, Broderick and Fitzsimmons, 2002). Genetic results, coupled with tag-recapture and satellite telemetry data suggest that the nesting stocks in the western Pacific primarily use the north Pacific for development and foraging, while animals from eastern Pacific stocks generally forage in the Southern Hemisphere, including the waters off Peru and Chile (Dutton, Broderick and Fitzsimmons, 2002). However, there are exceptions to this pattern, since animals of western Pacific stock origin have been found off Chile (Donoso *et al*., 2000), and likewise, some leatherbacks of eastern Pacific stock origin have been found in the north Pacific (Dutton, Broderick and Fitzsimmons, 2002).

Leatherbacks undertake some of the longest migrations of all sea turtles and can travel great distances between feeding and nesting areas (Figure 12). Although leatherbacks do not nest on the United States Pacific coast or territories, they forage in United States waters. Animals that are found in these forage areas are mainly from nesting beaches in the western Pacific, and undertake extraordinary migrations across the Pacific to return to nest in

Indonesia, Solomon Islands or Papua New Guinea (Dutton, Benson and Eckert, in press). This migratory behaviour exposes them to several United States and international high seas fisheries where they are taken as bycatch. While some eastern Pacific leatherbacks are found in the north Pacific, most animals that originate in Mexico and Costa Rica migrate south to feed in waters off Peru and Chile and further out in the southeastern Pacific (Dutton, Benson and Eckert, in press; Eckert 1999; Morreale *et al.*, 1996). The juvenile developmental areas remain unknown. Leatherbacks continue to be killed in the artisanal fisheries in Peru (Alfaro-Shigueto *et al.*, in press), and juveniles are caught in the Costa Rican artisanal fisheries (Arauz, unpubl.). Leatherbacks were killed in coastal swordfish gillnet fisheries in Chile (Eckert and Sarti, 1997). However, the size of this fishery has declined considerably since the early 1990s (Donoso and Dutton, in press). The extent of incidental take of leatherbacks by the international fleets that operate on the high seas in the eastern Pacific is unclear. The only data available are for the Chilean swordfish longline fishery, which indicate that leatherbacks are caught, although there have been no observed mortalities (Donoso and Dutton, in press).

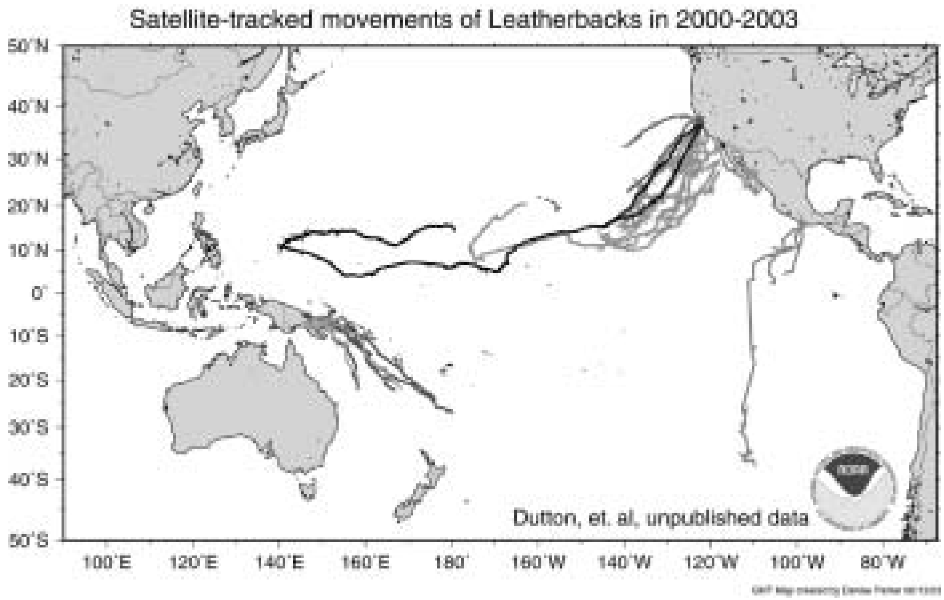

Figure 12. Satellite-tracked movements of adult leatherbacks in the Pacific. Tracks include turtles captured and released in a foraging area in Monterey Bay, California (Dutton, Eckert and Benson, unpubl.); females from nesting beaches in Papua New Guinea (Dutton, Benson, Rei and Ambio, unpubl.); and nesting females in Mexico (Sarti, Dutton and Eckert, unpubl.). Additional studies (not depicted here) have tracked southward post-nesting movements of female leatherbacks from Costa Rica passing by the Galapagos Islands (Morreale *et al.*, 1996), and females from Mexico that have travelled to waters off Peru and Chile (Eckert and Sarti, 1997)

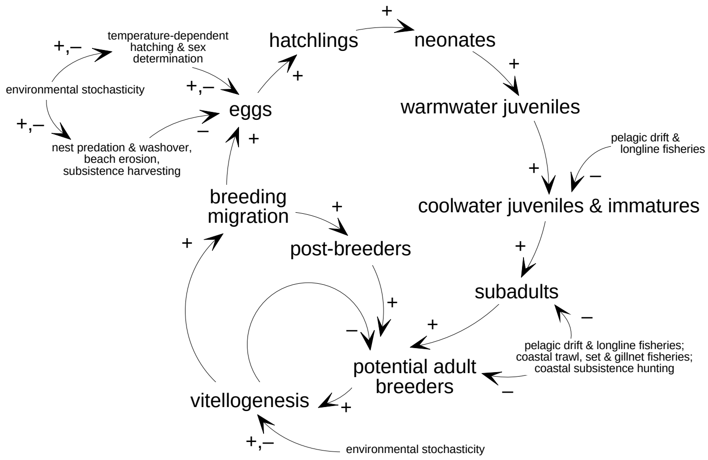

Figure 13. Developmental-phase-based and reproductive-status-based lifecycle graph or causal loop model (source: Puccia and Levins, 1985) for Pacific leatherback turtles constructed using information in Eckert (1999). The demographic structure and feedback mechanisms shown here are included in stochastic simulation models to explore western Pacific leatherback turtle metapopulation dynamics subject to various hazards, e.g. nesting beach erosion, nest inundation by wave washover, egg and turtle harvesting, or incidental capture and drowning in coastal or pelagic fisheries

Hazards

The main hazards for leatherbacks are (Figure 13, see also NMFS and USFWS, 1998b):

- egg harvesting;
- pig and veranid predation of eggs at coastal rookeries;
- incidental capture in coastal and pelagic fisheries;
- subsistence harvest of large turtles in the foraging grounds and on nesting beaches.

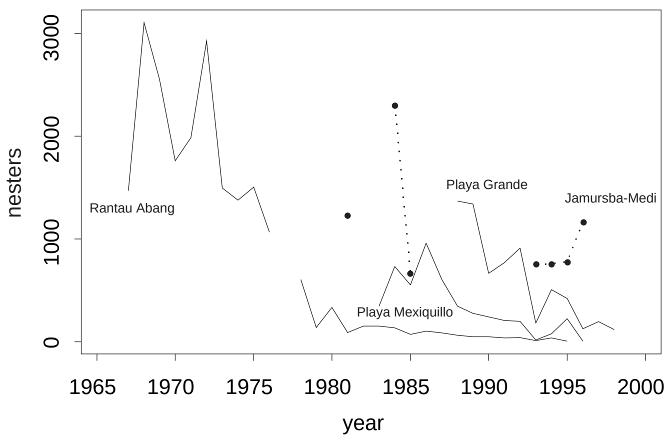

Figure 14. Trends in the nesting abundance of four major Pacific leatherback populations. The western Pacific stock comprises the Rantau Abang and Jamursba-Medi rookeries while the eastern Pacific stock comprises the Mexiquillo and Playa Grande rookeries. The data has been derived in various ways from Chua, 1988; Chan and Liew, 1996; Spotila *et al.*, 1996, 2000; Eckert and Sarti, 1997; Suarez, Dutton and Bakarbessy, 2000

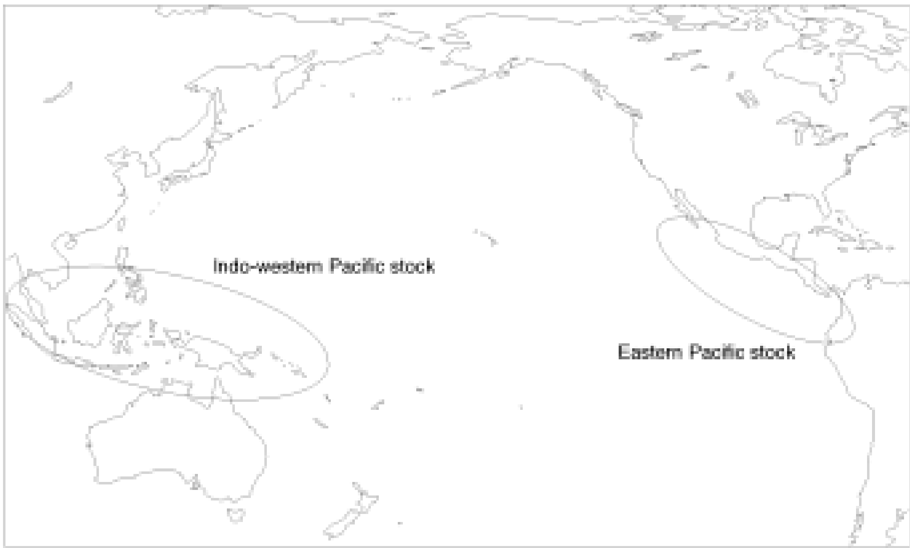

Figure 15. Location of the Pacific olive ridley turtle nesting stocks. Source: Bowen *et al*., 1998

Olive ridleys (*Lepidochelys olivacea*)

Background

The olive ridley turtle (*Lepidochelys olivacea*) has a circumtropical distribution and is probably the most abundant sea turtle species (Bowen *et al*., 1998). Olive ridleys resident in Pacific waters comprise two stocks (Figure 15) – an eastern Pacific stock that nests along the Pacific coast from Mexico to Colombia (Cliffton, Cornejo and Felger, 1982; Cornelius, 1982; Green and Ortiz-Crespo, 1982; Martinez and Paez, 2000) and a western Pacific stock that nests in coastal areas of southeastern Asia, New Guinea and northern Australia (Siow and Moll, 1982; Chantrapornsyl, 1992; Bowen *et al*., 1998; Putrawidjaja, 2000). Table 5 summarizes some of the nesting seasons for these two stocks.

Several major nesting populations of the eastern Pacific stock are increasing in abundance following protection from anthropogenic hazards (Figure 16) while some nesting populations in the eastern Pacific (Valverde, Cornelius and Mo, 1998) and Indo-western Pacific stocks are apparently in decline (Siow and Moll, 1982; Chantrapornsyl, 1992; Chantrapornsyl and Bhatia, 1993). The eastern Pacific stock was heavily exploited during the 1960s and 1970s for eggs, meat and skins (Green and Ortiz-Crespo, 1982; Trinidad and Wilson, 2000). Olive ridleys from both Pacific stocks are known to be caught incidentally in coastal fisheries (Cliffton, Cornejo and Felger, 1982; Robins, 1995; Poiner and Harris, 1996; Cheng and Chen, 1997; Slater *et al.*, 1998), which can be a major source of mortality (Poiner and Harris, 1996). Olive ridleys are also exposed to incidental capture in some Pacific pelagic longline fisheries (McCraken, 2000; Polovina *et al*., 2004). A stochastic simulation model of the population dynamics of the eastern Pacific stock has been developed for NOAA Fisheries to help evaluate the impact of various competing risks on olive ridley population viability (Chaloupka, unpubl.).

Table 5. Summary of nesting seasons for Pacific olive ridley turtle stocks shown in Figure 15

Stock	Nesting location	Season (peak)	Source
Eastern Pacific	Mexico	Jun–Dec (Aug–Oct)	Dash & Kar (1990)
	Costa Rica	year round (Aug–Nov)	Hughes & Richard (1974)
	Colombia	Aug–Dec (Aug–Dec)	Martinez & Paez (2000)
Indo-western Pacific	Northern Australia	Jun–Aug (Jun–Jul)	Limpus (2002 pers. comm.)
	Peninsula Malaysia	Oct–Jan	Siow & Moll (1982)
	West Thailand	Oct–Feb (Dec–Jan)	Chantrapornsyl (1992)
	Orissa	Dec–Apr (Dec–Apr)	Dash & Kar (1990)

Hazards

The main hazards for olive ridleys are (see also NMFS and USFWS, 1998d):

- egg harvesting;
- commercial harvest of large turtles in the foraging grounds and on nesting beaches;
- incidental capture in coastal and pelagic fisheries.

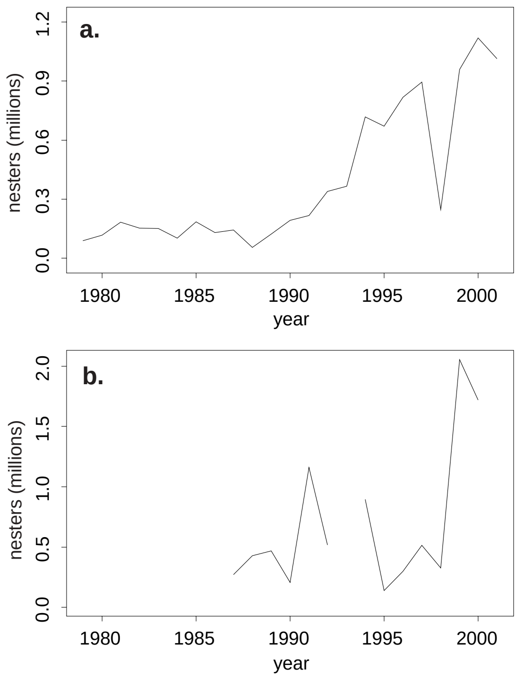

Figure 16. Trends in abundance of two major olive ridley nesting populations from the eastern Pacific stock. Panel (a) shows estimated nesting abundance at La Escobilla, Mexico. Panel (b) shows estimated nesting abundance at Ostional, Costa Rica — the nesting population at nearby Playa Nancite is apparently in decline (Valverde, Cornelius and Mo, 1998). Source: Chaves, 1998, 1999, 2002; Penaflores *et al*., 2000; F. Alberto Abreu, 2002, pers. comm.

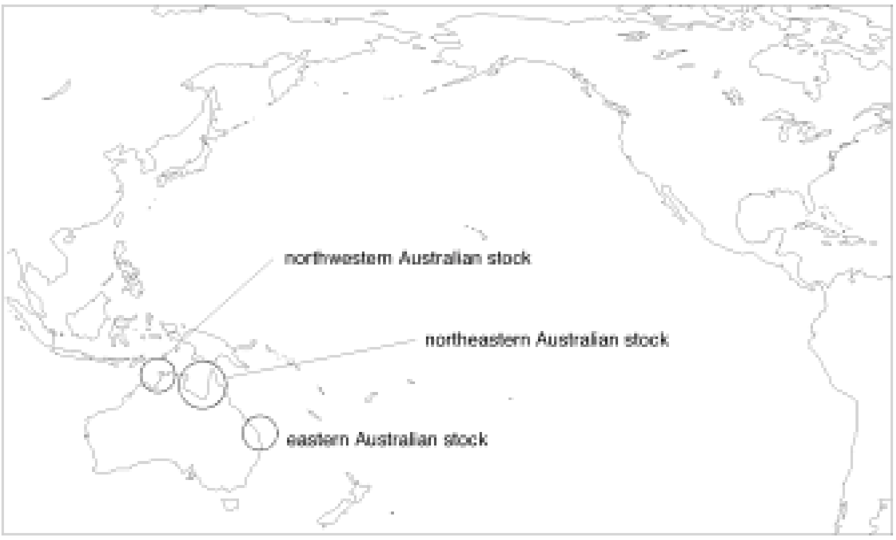

Figure 17. Location of the regional rookeries for the Pacific flatback turtle stocks. Source: Dutton, Broderick and Fitzsimmons, 2002; Limpus, 2002

Flatbacks (*Natator depressus*)

Background

The flatback is endemic to the northern Australian region with nesting restricted to Australia. Three management units are recognized in the Pacific (Dutton, Broderick and Fitzsimmons, 2002) – a northwestern Australian, a northeastern or Gulf of Carpentaria and an eastern Australian nesting stock (Figure 17). Crab Island in North Queensland (northeastern Australian stock) is the largest flatback rookery in the world (Limpus *et al*., 1983). Long-term monitoring of nesting abundance is only available for the eastern Australian stock that nests along central coastal Queensland (Mon Repos, Woongarra) and on offshore islands in the central Great Barrier Reef region such as Wild Duck (Limpus, 2002). All monitored nesting populations appear to be stable (see Figure 18) but there are no foraging ground abundance estimates for any population. There are only very limited demographic data available for the flatback turtle (Walker and Parmenter, 1990; Parmenter and Limpus, 1995; Limpus, 2002). There are no demographic models of flatback population dynamics available.

Table 6. Summary of nesting seasons for Pacific flatback turtle stocks shown in Figure 17

Stock	Nesting location	Season (peak)	Source
Northwestern Australian	Fog Bay	May–Jul	Guinea (1994)
Northeastern Australian	Crab Island	year round	Limpus *et al*. (1983)
Eastern Australian	Wild Duck Island	Oct–Jan	Slater *et al*. (1998)

Hazards

The eastern Australian stock might have been significantly reduced over the last century but there are no reliable data to confirm this view (Limpus, 2002). Extensive harvesting of eggs and turtles occurs in northern Australian waters (Limpus *et al*., 1983; Limpus, 2002). Nearly 60 percent of sea turtles caught in the Australian northern prawn fishery (Gulf of Carpentaria) are flatbacks (Poiner and Harris, 1996) while around 11 percent of the incidental capture of sea turtles in the Queensland east coast otter trawl fishery are flatbacks (Robins, 1995). The main hazards for flatbacks are:

- pig and veranid predation of eggs at coastal rookeries;
- egg harvesting;
- incidental capture in coastal otter trawl fisheries;
- indigenous harvest of large turtles in the foraging grounds and on nesting beaches.

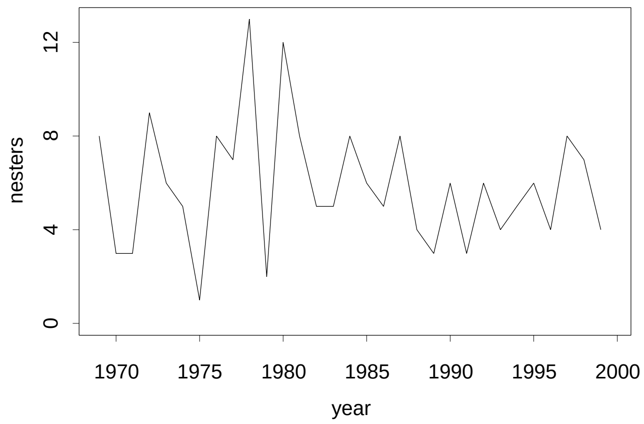

Figure 18. Trend in abundance of the Woongarra flatback nesting population from the eastern Australian stock. Source: Limpus, 2002

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