RED LIST ASSESSMENT
Hawaiian Green Sea Turtle: Regional Assessment

1a. Scientific name:

Chelonia mydas (Linnaeus, 1758)

1b. Synonym/s:

None

1c. English Common Name:

Hawaiian green turtle

1d. Other Common Name:

Tartaruga-Verde, Aruanã (Portugese), Green Turtle (English), Tortuga Verde, Tortuga Blanca (Spanish); Honu (Hawaiian)

2a. Order	**2b. Family**
Testudines	Cheloniidae

3. Distribution

The distribution for this sub-population comprises only the Hawaiian Archipelago. While the green turtle is distributed circumglobally and nests in over 80 countries, the Hawaiian green turtle comprises a discrete and genetically distinct population segment, which is endemic to the Hawaiian archipelago (Dutton et al. 2008). It has also been identified recently as a Regional Management Unit, and so fits the definition of a subpopulation for IUCN Red List assessment purposes (Wallace et al. 2010).The isolated archipelago stretches approximately 2400 km from Hawaii Island (Big Island) in the Southeast to Kure Atoll in the Northwest. Hawaiian green turtles are found throughout the entire island chain (Figs. 1 & 2). Stock mixture analysis shows that the Hawaiian foraging ground populations comprise one distinct genetic stock derived from the nesting population at French Frigate Shoals (FFS) (Dutton et al. 2008). Only three turtles with haplotypes not found at FFS have been identified, indicating that Hawaiian foraging grounds might occasionally, albeit rarely, be visited by animals from rookeries outside the Hawaiian Archipelago. While a small number of Hawaiian turtles have been recorded outside of Hawaii (e.g. one in Japan, one in the Philippines, one in the Marshall Islands), there is no evidence that the normal range of Hawaiian green turtles extends beyond the central Pacific region. These findings indicate that the numerous foraging aggregations around the Hawaiian Islands can be considered part of a distinct regional population for management. The finding that turtles in foraging grounds scattered across over 2,000 km belong to one genetic stock allows Hawaiian green turtles to be assessed separately from other Pacific stocks with respect to risk (Dutton et al. 2008). The total amount of area of occupancy (excluding the open ocean post-hatchling phase) is estimated to be about 1400 km^2, which represents the nearshore waters and reef habitats around the islands, although this is very likely an underestimate given the range of habitats sea turtles inhabit (Figs. 1 & 2). Given the genetic isolation of the Hawaiian green turtle it is classified as an independent Regional Management Unit (Wallace et al. 2010) by the MTSG, and is considered an IUCN Red List subpopulation.

Countries of Occurrence: Native: United States of America—Hawaiian Islands

FAO Fisheries Areas: Native: Pacific—Eastern Central, Pacific—Northwest

3a. Red List Assessment

3b. Red List Criteria (For threatened taxa (i.e., those assessed as CR, EN or VU) record which criteria are met (e.g., A2c+3c; B1ab(iii); D) alongside the appropriate Category. For NT taxa, record criteria nearly met):

	3a. Category	3b. Criteria
	Extinct (EX)	
	Extinct in the Wild (EW)	
	Critically Endangered (CR)	
	Endangered (EN)	
	Vulnerable (VU)	
	Near Threatened (NT)	
X	Least Concern (LC)	
	Data Deficient (DD)	
	Not Evaluated (NE)	

4. Rationale for the Red List Assessment

Analysis of published peer-reviewed literature indicates that the endemic and genetically-isolated Hawaiian green turtle is approaching full recovery to pre-exploitation levels, continues to grow, and anthropogenic hazards do not appear to be restricting population recovery (Balazs & Chaloupka 2004, Chaloupka et al. 2007; see Section 9e below on Threats).

Assessments of green turtle population abundance are based on monitoring the number of female nesters at East Island, French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands (NWHI). Survival of this species is heavily dependent on successful nesting at FFS (Niethammer 1997). More than 90% of Hawaii green turtle nesting occurs on FFS, a crescent-shaped low-lying atoll, 35 km long and 26 km in diameter, located in the centre of the Hawaiian Island chain. Made up of ten small sand islands, only six are used for nesting purposes (Balazs, 1976). In recent years, low level nesting events have been documented on islands other than FFS, and there are increasing nesting events in the main Hawaiian islands (Parker & Balazs 2011) but ca. 50% of nesting occurs on the 0.46 km^2 East Island. Restricted location is a concern for the Hawaiian green turtle as they primarily utilize one rookery (Balazs 1976; Balazs 1980; Niethammer et al. 1997; Balazs & Chaloupka 2004a), but Tiwari et al. (2010) suggest that East Island is still well below carrying capacity to support nesting green turtles even given the robust recovery and increase in nesting females over the years. While the small nesting site is below carrying capacity (i.e. the number of nesting females could increase substantially within the existing area), the impact of erosion and habitat loss throughout the NWHI can not be ignored. Nesting habitat loss may occur through climatic impacts and heightened erosion, but anthropogenic impacts at this site have now been mostly eliminated through the protection of the site as a US National Monument. Natural sand accretion may replace eroded habitat (see Baker et al. 2006), there are other suitable nesting sites throughout the archipelago, and the natural history of the species is that it colonises new nesting habitat with sea level rise and fall. East Island, which hosts most turtle nesting in the FFS, was projected to lose 15% of its area with an Intergovernmental Panel on Climate Change (IPCC)-projected 48 cm increase in sea level, and up to 26% of its area under the extreme predictions of 88 cm rise in sea level. These predictions are based on IPCC suggested rises up to 2100 (Church et al. 2001), or roughly three green sea turtle generations. There are no accurate predictions beyond this 2100 cut-off. This reduced nesting habitat would continue to support large numbers of turtles if predictions on carrying capacity by Tiwari et al. (2010) hold true, and if sand accretion offsets the beach loss resulting from sea level rise (see Baker et al. 2006).

While foraging ground research has been ongoing for may years, levels of effort have differed and thus predictive models are here derived from nesting census data, which has been carefully documented at FFS for 39 years. Annual nesting surveys conducted at FFS are one of the few reliable long-term studies in the world where such trends can be detected (Balazs & Chaloupka 2004a, Chaloupka et al. 2007; Fig. 3). No long-term trend data in juvenile recruitment are available, but based on the long-term nesting studies, the Hawaiian green turtle population is considered to be increasing at a rate of 5.7% per annum (Chaloupka et al. 2008), and while the population was compromised due to hunting in the past, it continues to recover. In several places within the Hawaiian islands it is likely the turtles have reached carrying capacity (Chaloupka & Balazs 2007, Wabnitz et al. 2010, but see Snover 2008). Snover (2008) argued that Chaloupka & Balazs (2007) used an incomplete dataset in their analysis and underestimated the period required to reach carrying capacity.

Within the past 100 years, the Hawaiian green turtle population was over-exploited for its meat (Witzell 1994; Chaloupka & Balazs 2007), and was depleted to around 20% of pre-exploitation abundance. However, exploitation stopped in the 1960s and since then nesting abundance has been increasing linearly at approximately 5.7% (Balazs & Chaloupka 2004a). It is estimated that Hawaiian green turtles are currently at 83% of their pre-exploitation numbers (Balazs & Chaloupka 2004a), representing a long-term population decline of around 17%. The Hawaiian green sea turtle stock may have been around 320,000 turtles prior to exploitation (Chaloupka & Balazs, 2007). Based on those estimates, there may be some 265,600 turtles or more in this population with 61,000 resident in Hawaiian coastal habitats (Chaloupka & Balazs, 2007). This is higher than the IUCN Red List Vulnerable threshold of <10,000 under C or D criteria concerning population size. Given there was traditional use of turtles prior to commercial exploitation it is possible pre-exploitation levels did not represent full ecological carrying-capacity, although it is unknown to what extent, both spatial and quantitative, this was the case. It is likely that even with the traditional harvests, the population was functionally at carrying capacity.

Even though green turtles are protected through State and Federal laws, occasional illegal harvesting of green turtles still occurs in Hawaii (Balazs 1980, Balazs 2011, pers. comm.), but this does not appear to have negatively impacted their recovery. Another major threat is fibropapillomatosis (FP), which causes debilitating tumours of the skin and internal organs. FP is the most significant cause of stranding and mortality in green turtles in Hawaii, accounting for 28% of strandings and an 88% mortality rate of stranded turtles (Chaloupka et al. 2008). While the disease has declined significantly in recent years (Chaloupka et al. 2009), it persists in the population at varying spatial scales (Van Houtan et al. 2010). Van Houtan et al. (2010) also suggest a possible relationship between the expression of FP in green turtles and the State's land use, waste management practices, and invasive macroalgae. Other threats include coastal development and urbanization, fishing line ingestion or entanglement from recreational shore based fisheries, entanglement in gillnets, vessel collisions, and miscellaneous hazards such as spear wounds (see Section 9e below on Threats).

In calculating the Extent of Occupancy (EOO) for the Hawaiian green turtle, we took into account the area contained within the shortest continuous assumed boundary which encompasses all known present occurrence for the Hawaiian green turtle, which includes the main Hawaiian islands extending all the way up to the NW Hawaiian islands. Given the Papahānaumokuākea Marine National Monument covering the NW Hawaiian islands and the surrounding waters encompasses some 360,000 km^2, and a minimum convex polygon around the Main Hawaiian islands alone comprises some 41,000 km^2, we confirmed that the Hawaiian green turtle EOO is > 20,000 km^2.

In calculating the Hawaiian green turtles' Area of Occupancy (AOO) we considered nesting habitat as the smallest area essential to the survival of the population. Using the 2 x 2 km IUCN minimum grid size to calculate AOO, we estimated that there is at least 453 km^2 of currently used nesting habitat throughout the archipelago. This estimate was derived by taking the total linear distance of each current known nesting beach for Hawaiian greens in the archipelago (113 linear total km of beach length for nesting site locations provided by Parker & Balazs (2011) and multiplying by 4 (for each 2 x 2 km square grid). While this would trigger a VU assessment under criterion B2, there is no continuing decline or fluctuation in AOO or the population, making this criterion inapplicable in this case.

A formal quantitative analysis of the probability of extinction of Hawaiian green turtles has not been conducted. Chaloupka & Balazs (2007) suggested that nesters may be nearing carrying capacity at nearly 500 nesters per annum at East Island, FFS. Snover (2008) and nesting recent data (over 800 nests in 2011; Balazs, pers. comm.) suggest however that this trend is still increasing. Tiwari et al. (2010) concluded the beach at East Island was well below carrying capacity and was capable of supporting a larger nesting population. Baker et al. (2006) modelled potential effects of sea level rise on terrestrial habitats in the NWHI up to 2100. The study estimated terrestrial area that would be lost if islands maintained their current topography but did not account for either erosion or accretion. The study showed that East Island would survive the highest projected IMCC sea level rise (0.89m) with a 26-33% reduction in size. This would likely have substantial impacts on the turtle population, but would not cause extinction. Turtles colonise new nesting habitats as others are lost to sea level rise and fall, and this may aid their survival in the archipelago. A number of periodically-submerged sandbars exist at FFS, but no information exists on the formation of new islands.

While the Hawaiian green turtle stock is still subject to variable levels of anthropogenic threat, the causes for the population decline are understood, and most of these have been addressed, reversed and/or ceased. Neither the EOO nor the AOO is fluctuating in a manner which impacts turtles negatively. The number of locations is not fluctuating, and the number of mature individuals is no longer declining – indeed it is linearly increasing (Balazs and Chaloupka, 2004a), suggesting other population segments (post-hatchling, juvenile, sub-adult) are similarly increasing.

The population of *Chelonia mydas* in the Hawaiian islands is effectively isolated from other *Chelonia* populations (Dutton et al. 2008). In accordance with the *Guidelines for Application of IUCN Red List Criteria at Regional Levels, version 3.0* (IUCN, 2003), the criteria and thresholds of the Red List criteria version 3.1 are directly applicable.

The Hawaiian green turtle should not be classified as Critically Endangered (CE) as it has not suffered an overall population reduction of 80% over the last three generations based on published counts of nesting females, an appropriate index for marine turtles. Nesting females are similarly not projected to decline by 80% in the coming three generations. Both EOO and AOO are much greater than 100 km^2 and are not declining. It is not a severely fragmented population and is present at many locations throughout the Hawaiian island chain. While there is a risk of erosion and therefore nesting habitat loss, there is similarly the opportunity for accretion and new nesting habitat development, much as has sustained marine turtles through thousands of years of sea level rise and fall. There are no extreme fluctuations in EOO or AOO, or number of mature individuals, which is known to be greater than 250 (a CE criterion threshold). The population of turtles in the Hawaiian islands is increasing at ca. 5.7% per annum, and we do not believe it is facing an extremely high risk of extinction in the wild in the immediate future.

Similarly, the Hawaiian green turtle should not be considered as Endangered (E) as it has not undergone a population reduction of 50% over the last three generations based on counts of nesting females, and neither are these projected to decline by such an amount in the coming three generations. EOO is >5000 km^2 and while AOO is >500 km^2, neither EOO or AOO are declining substantially, and variations in extent and quality of habitat do not appear to be impacting the increasing population. The population (estimated at >2500 mature individuals) is increasing at ca. 5.7% per annum. There is no quantitative analysis suggesting a probability of extinction in the wild of least 20% within five generations and the Hawaiian green turtle is not facing a very high risk of extinction in the wild in the near future.

The Hawaiian green turtle should also not be classified as Vulnerable (VU) as it is not facing a high risk of extinction in the wild in the medium-term future The population has suffered an overall decline of some 17%, below the 30% threshold for consideration as VU, and by some accounts still has a substantial amount of potential population increase (Snover 2008). Levels of exploitation are considered very low (occasional traditional harvests) and these harvests have not inhibited a strong population recovery. The population is expected to continue to increase in the coming three generations. The population likely does not comprise more than 10,000 mature individuals but is not predicted to decline in the coming three generations, there are no extreme fluctuations in population size, and there are no small subpopulations. EOO is much greater than 20,000 km^2 and while we recognize that AOO is less than 2000 km^2, Tiwari et al. (2010) suggest this area is far below carrying capacity (i.e. the number of nesting females could increase substantially within the existing estimate of 450 km^2), and there are numerous other suitable nesting sites, many in very close proximity to existing beaches where nesting has been recorded, and of similar composition, and the natural history of the species is that it colonises new nesting habitat with sea level rise and fall. While we acknowledge that we have no way of predicting how this will occur under varying rates of impact, such as accelerated erosion and nesting habitat loss, recent increases in nesting amongst the main Hawaiian islands (Parker & Balazs 2011) supports this assumption. Along with erosion there may also be the opportunity for accretion, and we do not believe the restricted nesting habitat alone to justify a VU classification. Certainly, the population is not characterised by an acute restriction in its area of occupancy (<100 km^2) or in the number of nesting locations, although some 90% of nesting does occur in on place. This site is not prone to the effects of human activities although it is subject to natural (and possibly heightened) climatic impacts. These facts do not support a high risk of extinction for the Hawaiian green in the wild in the medium-term future.

The Hawaii green turtle also des not qualify as Near Threatened, primarily because it is an increasing population which overall has suffered only a 17% reduction in numbers, but also as it does not trigger sufficient criteria to meet the Vulnerable category. The population has not declined by the requisite 20-25% in the last 3 generations (indeed it is increasing) and does not meet the area requirements under criterion B for EOO and/or AOO whereby the population also would need to be severely fragmented and suffer extreme fluctuations.

Based on the above, and not withstanding the limited Area of Occupancy, we propose the Hawaiian green turtle should be considered as **Least Concern (LC)**.

5. Reason for Change from previous Red List assessment

X	Genuine change in status of species		New or better information available
	Incorrect information used previously		Taxonomic change affecting the species
	Previously incorrect application of the Red List Criteria		

6. Current Population Trend (cross (**x**) one of the following):

X	Increasing		Decreasing		Stable		Unknown

7. Date of Assessment (day/month/year): **01 12 2011**

8a. Name/s of the Assessor/s

Nicolas Pilcher, Milani Chaloupka, Erin Woods

8b. Names of the Evaluators - to be filled in By Red List Authority ONLY

Red List Evaluators: Alan Bolten, Paolo Casale, Kirstin Dobbs, Peter Dutton, Karen Eckert, Colin Limpus, Jeff Miller, Jeanne Mortimer, Jack Musick, Ronel Nel, Peter Pritchard, Peter Paul van Dijk

Red List Authority: IUCN Marine Turtle Specialist Group

9. Text documentation

9a. Taxonomy:

Testudines, Cheloniidae, *Chelonia mydas*

9b. Geographic Range

Hawaiian green turtles are found throughout the entire Hawaiian archipelago. Like other green turtle populations, they are migratory, but in this case the population is limited to the Hawaiian island chain. The entire Hawaiian archipelago can be considered one large rookery comprising 54 discreet sites on 17 islands (Parker & Balazs 2011). French Frigate Shoals (FFS), in the Northwestern Hawaiian Islands, is the primary rookery, located in the centre of the 2400 km island chain. FFS accounts for >90% of all nesting activity with approximately 50% occurring on East Island (Balazs & Chaloupka 2004a). There are numerous foraging grounds found throughout the archipelago. Adult female turtles resident in these foraging grounds migrate every 3-4 years to their preferred nesting grounds at FFS (Chaloupka & Balazs 2004).

9c. Population

The geographic isolation of the Hawaiian Island chain has led to a distinct genetic stock derived from a single nesting population at French Frigate Shoals (Dutton et al. 2008). Genetic studies using mitochondrial DNA (mtDNA) analysis identify FFS as an Evolutionary Significant Unit (ESU) and demographically discreet Management Unit (Bowen et al. 1992, Bowen & Avise 1995, Dutton et al. 2008). Recent analysis using nuclear DNA corroborates this (Roden et al. 2010). mtDNA analysis shows that green turtles found foraging throughout the Hawaiian Islands originate from the FFS rookery and indicates that juvenile and adult green turtles foraging and breeding throughout the Hawaiian Archipelago comprise a singe stock (Dutton et al. 2008). Turtles from outside the archipelago infrequently stray to the Hawaiian Islands, as three turtles have been recorded with haplotypes not associated with Hawaii turtles. Two of these were foraging turtles and one was a turtle which had lost both front flippers, and which may have drifted to Hawaii from the Eastern Tropical Pacific (Dutton et al. 2008). It is unknown of there is any interbreeding, but these rare haplotypes have not been recorded at the nesting site (Dutton et al. 2008).

9d. Habitat and Ecology

Green turtles are the largest of the hard-shelled sea turtles, reaching lengths of 100 cm in carapace length (straight and curved carapace length) and weighting 150 kg. Juvenile green turtles (10 years and older) exhibit a relatively constant growth rate until about 28 to 30 years or approximately 80 cm straight carapace length (Zug et al. 2002; Balazs & Chaloupka 2004b). Hatchlings emerge from nesting beaches and enter a post-hatchling oceanic phase. It is estimated that the oceanic developmental phase is approximately 6 years, but ranges from 4 to 10 years (Zug et al. 2002). Following the oceanic phase, juveniles recruit to coastal or neritic habitats mostly around the islands in the southeastern part of the archipelago (Zug et al. 2002). Nesting females average 92 cm SCL (Balazs 1980; Zug et al. 2002). Females can lay up to 6 clutches and an average of 1.8 clutches / season, with an average of 100 eggs per clutch, during a nesting season (Balazs 1980; NMFS 1998). The eggs incubate for 54 – 88 days, with an average of 66 days (Neithammer et al. 1997), after which hatchlings emerge (Balazs 1980). Adult Hawaiian green turtles live and forage in the Main Hawaiian Islands. Every 3 or 4 years, females migrate to French Frigate Shoals to nest (Balazs & Chaloupka 2004a). There is direct evidence of non-random dispersal and habitat use, with Hawaiian green turtles returning to natal beaches as they mature, as evidenced through their genetic isolation. The extent to which Hawaiian green turtles disperse to foraging areas in either the eastern or western Pacific is unknown (only a small number of Hawaiian turtles have been recorded outside of the islands) and there is no evidence from limited studies to date that the range of Hawaiian green turtles extends beyond the central Pacific region (Dethmers et al. 2006; Dutton et al. 2008). Foraging grounds range from coral reefs to seagrass beds to algal-dominated hard substrates throughout the Hawaiian Archipelago (Balazs & Chaloupka, 2004).

Long-term studies of green turtles in nearshore waters of the Hawaiian Islands have been underway to obtain comprehensive information on growth rates, food sources, habitat use, developmental and reproductive migrations, underwater behaviour, health status, and population trends. Pelagic juveniles recruit to Hawaiian neritic foraging grounds from ca. 35 cm SCL or 5 kg (~6 years of age), and grow at foraging-ground specific rates resulting in different size- and age-specific growth rates of 0-2.5 cm/yr. Based on this, expected age-at-maturity was estimated to be ca. 35–40 years for four south-eastern populations, and possibly >50 years for the northern population at Midway (Balazs & Chaloupka 2004). Skeletochronological data supported these findings, with mean growth rates of Hawaiian green sea turtles are 4–5 cm/yr in early juveniles, declining to ~2 cm/yr by age 10 yr, then again to less than 1 cm/yr as turtles neared age 30 yr (Zug et al. 2002). Based on long-term mark-recapture data, Hawaiian green turtles mature at 14-32 years of age (Hargrove & Balazs 2011). In one study in Kiholo Bay several hundred turtles have provided growth increments ranging from 3 months to 14.4 years and an overall mean growth rate of 1.7 cm/yr (Balazs et al. 2000). Sex ratios of immature turtles at captured in-water at three sites in the Hawaiian islands did not differ statistically from a 1:1 ratio and was homogenous relative to location and turtle size (Wibbels et al. 1993).

Similarly, much has been learnt of reproductive biology of turtles on land. Turtles deposit a mean of 104 eggs per clutch with a range of 38 t o 145 eggs, and larger females lay more eggs per clutch (Balazs 1980). Mean incubation periods are recorded as 54-88 days with a ~70% emergence rate (Balazs 1980). Niethammer et al. (1997) has since determined that the nesting peaked between mid-June and early August and hatchling emergence peaked between mid-August and early October. Mean incubation period was 66.0 days, with a mean clutch size of 92.4 eggs and a mean hatching success of 78.6% when averaged over success of individual nests and 81.1% when calculated as percentage of total number of eggs.

Hawaiian green turtles feed on native and introduced algae that commonly occur throughout the Hawaiian Islands in roughly equal amounts (Russell & Balazs 2009), with an active selection for non-native species in many case even when native species are present (Arthur and Balazs 2009). Turtle growth rates are similar amongst forage habitat types (Balazs & Chaloupka 2004b) even with the introduction of an alien species of algae (Arthur and Balazs 2009, Russel & Balazs

1994). Of approximately 400 species of algae present in the Hawaiian archipelago, nine species account for the majority of green turtle diet, including invasive algae species in Kaneohe Bay, for example, which have stifled reef growth for many years (Arthur and Balazs 2009; Russell & Balazs 2009). The transition in choice over native species is a process that takes ten to twenty years, but the choice of the nutritionally-rich non-native species appears to be an important contributing factor to the recovery of the Hawaiian green turtle stock (Russell & Balazs 2009) as well as a potential link to aetiology of FP (Arthur et al. 2008; Van Houtan 2010).

9e. Threats

Green turtles were a source of food for some Native Hawaiians but consumption was limited by a *kapu*, or prohibition system, that controlled when, where, and by whom sea turtles could be harvested and consumed (Balazs 1980, Rudrud 2010). Turtle shell was used as an instrument for scraping bark, hair combs, and jewellery (Malo 1951). Human exploitation was once the greatest threat to the Hawaiian green sea turtle. Hawaiian green turtles were exploited in the 19^{th} century during the expeditions to the Northwestern Hawaiian Islands (Amerson 1971). Turtles were also taken at foraging grounds from the mid-1800s. Commercial exploitation began in the mid-1940s (Amerson 1971) and due to restaurant demand and tourism, and concomitant affluence and presence of turtles in markets had increased significantly in the 1960s and early 1970s (Witzell 1994; Chaloupka & Balazs 2007). Take of nesting females and their eggs ceased in the early 1960s because US Fish and Wildlife Service had a permanent presence at FFS and commercial take of green turtles in Hawaii was prohibited in 1974 under a regulation passed by the Hawaii State Division of Fish and Game (Balazs 1976; Neithammer et al. 1997). Despite the cessation of legal take and protection under State and Federal laws, occasional illegal take of green turtles still occurs in Hawaii (Balazs 1980).

Modification of coastal waterways has caused shallow water coral reefs to degrade (Wolanski et al. 2009). Foraging habitats are particularly vulnerable to the effects of coastal development and urbanization. Nesting habitats in the Northwestern Hawaiian Islands face no direct anthropogenic threat, as they are protected. Disturbance of basking, swimming or foraging turtles occurs. Turtles are also subject to fishing line ingestion or entanglement from recreational shore based fisheries (Nitta & Henderson 1993, Chaloupka et al. 2008), and miscellaneous hazards such as spear wounds. Human activity may alter the natural behaviour of green turtles.

A prominent and highly regulated pelagic longline fishery industry exists in Hawaii. The majority of sea turtles landed dead in this fishery are immature loggerheads, leatherback, and olive ridleys (Work & Balazs 2002; Work & Balazs 2010), with more turtles caught in shallow fisheries than deep-set fisheries (Gilman et al. 2006). Sea turtle bycatch in Hawaii-based longline fisheries have been reduced by nearly 90% in recent years due to additional regulatory measures implemented in 2004. The National Marine Fisheries Service has recorded very low levels of Hawaiian green turtles as bycatch (6 out of 14 green turtles; NMFS 2005), and Hawaiian green turtles are generally at low risk of incidental capture in pelagic longline fisheries operating in the North Pacific (Work & Balazs 2010).

Recreational fishing also poses a threat to Hawaiian green turtles, especially interaction with inshore fisheries (Nitta & Henderson 1993). Hook-and-line fishing gear induced trauma accounts for roughly 7% (n=261 of 3732 green turtle strandings between 1982 and 2003) of turtle stranding in Hawaii and gillnet fishing gear-induced trauma causes about 5% of stranding (Chaloupka et al. 2008). There is a high mortality rate (>50%) associated with strandings caused by fishing gear (Chaloupka et al. 2008).

Green turtles also face the threat of vessel collisions. Small boat collisions account for 2.5% of strandings or approximately 10 – 14 turtles per year (Chaloupka et al. 2008). Boat strikes often result in a dead stranded turtle (Chaloupka et al. 2008). With increased tourism, it is likely there will be elevated threats to turtles through vessel collisions and potential behavioural impacts as humans and turtles interact. At present however, human/turtle interactions do not appear to drive any substantial behavioural changes.

Marine pollution abrades and scours living coral polyps and destroys coral skeletons, which affects reef structure (Donohue et al. 2001). Significant amounts of marine pollution are deposited in the Hawaiian Archipelago due to oceanic circulation patterns (Donohue et al. 2001). While ingestion of marine debris has been documented to impact to marine turtles elsewhere (Stamper et al. 2009), death or debilitation due to marine debris ingestion is not a major threat in Hawaii. Less than 0.5% of the 3732 turtles which were examined by as part of the stranding work by NOAA Fisheries in Hawaii were deemed to have stranded due to marine debris (Chaloupka et al. 2008).

Increases in sea surface temperature and intensity and number of severe storms are potential climate change-induced threats facing sea turtles. Migratory patterns and life history of sea turtles correlate with ocean temperatures (Weishampel et al. 2010). Ambient temperatures may lead to changes in the initiation and duration of nesting (Weishampel et al. 2010). Green turtles may initiate nesting earlier and increase nesting season length with warmer sea surface temperature (SST) (Weishampel et al. 2010). Sea level rise threatens to erode coastal habitat, including nesting habitat. The majority of nesting occurs on French Frigate Shoals, a low-lying atoll vulnerable to increases in sea level (Baker et al. 2006). However, there is evidence of long term accretion of islands, so that this effect may be somewhat mitigated (Webb & Kench 2010). Warming temperatures may lead to a skewed sex-ratio with far greater number of females than males (Davenport 1997; Hays et al. 2003), although recent work suggests warming temperatures may also lead to more clutches being produced, with the additional clutches incubating at sub-optimal or male-producing temperatures, leading to a proportional increase in male production (documented for *Trachemys scripta*: Tucker et al. 2008).

Fibropapillomatosis (FP) causes debilitating tumours of the skin and internal organs (Work et al. 2009). FP is the most significant cause of stranding and mortality in green turtles in Hawaii, accounting for 28% (1044 of 3732 green turtle strandings between 1982 and 2003) of strandings. Stranded turtles with FP show a 88% mortality rate (Chaloupka et al. 2008). Despite the high incidence of death, Hawaiian green turtles have the capacity to recover from the disease as evidenced by steady declines in prevalence of disease (Chaloupka et al. 2009). The disease was nearly absent in the early 1980s, but increased rapidly following a late 1980s outbreak, peaking during the mid-1990s with a prevalence rate of nearly 50%, and has declined steadily ever since, The prevalence of FP has been linked to land use practices (van Houtan et al. 2010), who demonstrated strong epidemiological links between disease rates, nitrogen-footprints, and invasive macroalgae. In 2007 prevalence of FP was estimated to have dropped be around 9.4% (Chaloupka et al. 2009), and the population continues to increase despite presence of the disease (Balazs & Chaloupka 2004a; Chaloupka & Balazs, 2005).

9f. Conservation Actions

Both Federal Legislation and State of Hawaii law protect the Hawaiian green sea turtle. The green turtle was listed in 1974 under State Division of Fish and Game Regulation 36 (Balazs 1976, Bennett & Keuper-Bennett 2008), and under the Endangered Species Act (ESA) in 1978. Under Hawaii State law, the green turtle received full legal protection consistent to Federal ESA listing, when it was added to the protected list of wildlife of the State of Hawaii under Chapter 194 (Balazs 1983). The primary nesting habitat, French Frigate Shoals, receives protection as it is located within the Northwestern Hawaiian Islands Marine National Monument (NWHIMNM, also called Papahānaumokuākea Marine National Monument). NWHIMNM received World Heritage status in 2010. The marine protected area is managed by both State and Federal agencies.

The Federally-managed Hawaii-based longline fishery operates under a number of regulatory measures to reduce turtle bycatch. These measures include mandatory uses of circle hooks and mackerel-type bait, mandatory annual attendance of a protected species workshop by longline vessel operators, mandatory handling measures to dehook and revive comatose turtles, and annual interaction limits for loggerhead and leatherback turtles. These bycatch reduction measures have significantly reduced bycatch by up to 90% (Gilman et al. 2007), with 100% coverage in the shallow-set fishery and 20% observer coverage in the deep-set sector of the longline fishery. Internationally, the Hawaiian population is part of the listing of *Chelonia mydas* in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), prohibiting all forms of international trade in the species or its parts or derivatives for commercial purposes; the United States is a party to CITES and to the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC).

g. Utilization

Infrequent takes of subadults and adults for consumption is reported to continue in the Hawaiian island chain, although this has not impacted the recovery and growing trend of the population.

10. Literature References

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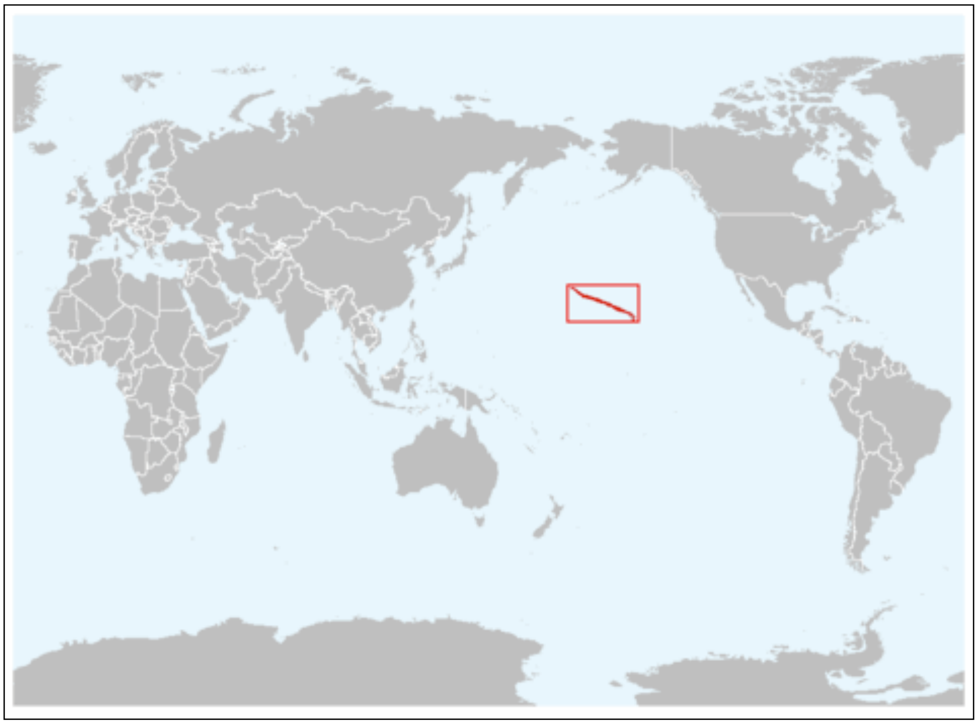

Figure 1: Location of Hawaiian Archipelago

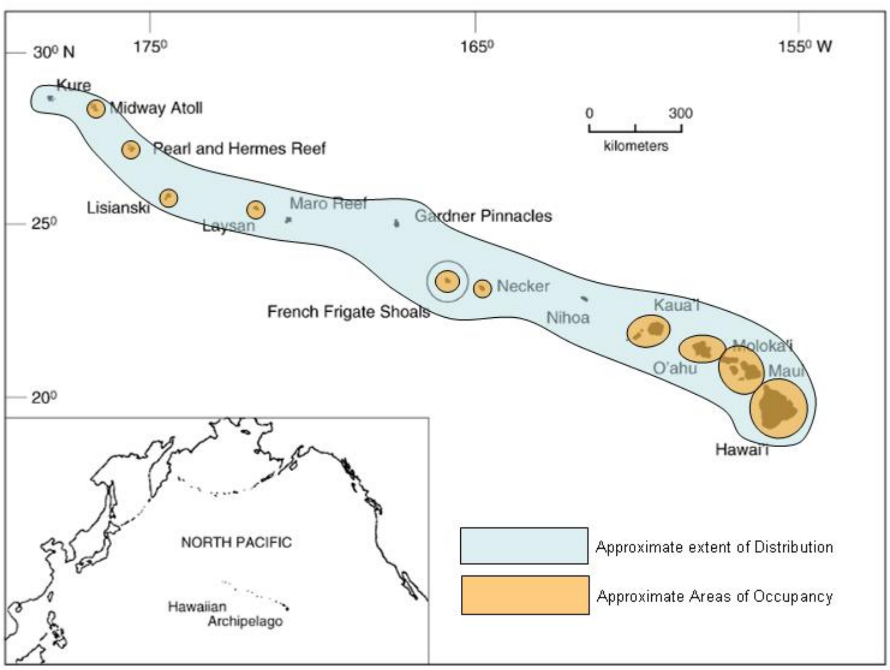

Figure 2: Detailed map of the Hawaiian Archipelago (from Balazs & Chaloupka 2004b)

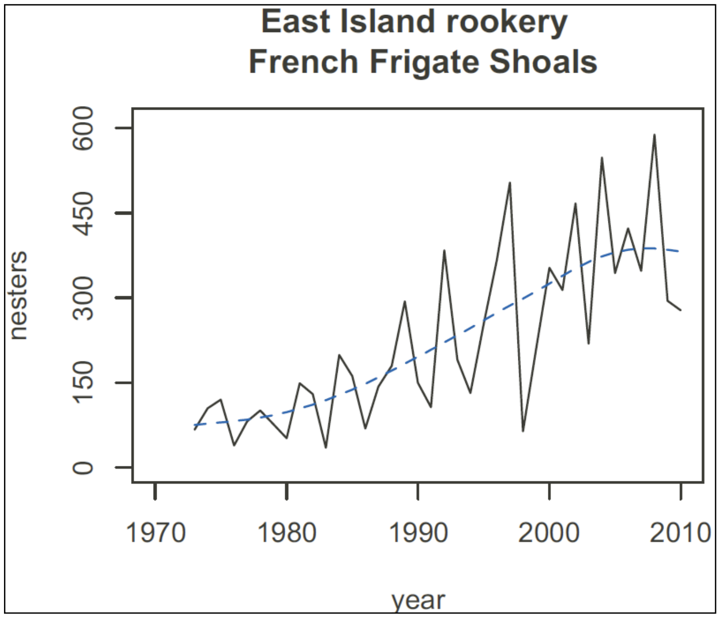

Figure 3: Time series and trend (dashed line) of annual number of green turtles recorded nesting at East Island rookery (French Frigate Shoals) from 1973-2010. See Balazs & Chalopuka 2004a and Chaloupka and Balazs 2007. Solid curve is recorded annual nesting, dashed curve is smoothing spline fit of underlying trend.