RESEARCH PLAN

FOR

THE HAWAIIAN GREEN TURTLE, *Chelonia mydas*

Marine Turtle Research Program
Protected Species Division
NOAA, Pacific Islands Fisheries Science Center

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1. Statement of Research Goals

The goal of this research plan is for the Marine Turtle Research Program (MTRP) to continue to undertake research activities and obtain scientific information in support of achieving the biological recovery and sustained management of the Hawaiian green turtle stock (*Chelonia mydas*). To progress towards stock recovery, it is necessary to conduct research specifically designed to obtain data on: 1) assessment and monitoring, 2) ecology and natural history, and 3) natural and anthropogenic impediments to recovery. This document is intended to serve as a guide that defines research actions believed necessary to achieve the biological recovery of the Hawaiian green turtle stock.

2. Background

A. Species Inventories

This plan will focus on green turtles (*Chelonia mydas*) since over 97% of the sea turtles encountered within the Hawaiian Archipelago are of this species. The green turtle in Hawaii is currently listed as *threatened* under the US Endangered Species Act (ESA) (NMFS and USFWS 1998). The hawksbill turtle (*Eretmochelys imbricata*) occurs at low levels in Hawaii and is opportunistically studied during green turtle research activities. This research plan will not address hawksbill turtles; however, they will continue to be opportunistically monitored during MTRP green turtle research activities. A separate research plan, being prepared by the Marine Turtle Assessment Program of the PIFSC, will address hawksbill turtles in Hawaii. Three other species of marine turtle forage and migrate through pelagic waters in the Hawaiian Archipelago (loggerhead - *Caretta caretta*, leatherback - *Dermochelys coriacea*, and olive ridley - *Lepidochelys olivacea*). These species do not nest in Hawaii or reside in Hawaiian coastal waters, and therefore, they will not be considered in this research plan.

B. Species Description

The green turtle, *Chelonia mydas*, is globally distributed throughout tropical seas and subtropical waters with temperatures above 20° C (NMFS and USFWS, 1998). The green turtle is the largest of the cheloniids, or hard-shelled sea turtles. Characteristics that distinguish the green from other species of sea turtles include a smooth carapace with four pairs of lateral scutes, a single pair of prefrontal scales on the head, and a lower jaw-edge that is coarsely serrated, corresponding to strong grooves and ridges on the inner surface of the upper jaw (Carr 1952; Hirth 1971; Pritchard and Trebbau 1984).

C. Stock Structure

The green turtle in Hawaii is a genetically distinct stock. Analysis of mitochondrial DNA demonstrates the genetic discontinuity of the Hawaii population from other green turtle populations in the Pacific (Bowen et al. 1992, Balazs and Chaloupka 2004b).

Furthermore, protection and management are not complicated by international migrations. This stock forages and nests within the jurisdiction of one country. Foraging grounds are primarily located in the waters surrounding the Main Hawaiian Islands (MHI), whereas nesting primarily occurs on sandy beaches 500 miles to the northwest of Honolulu in the Northwestern Hawaiian Islands (NWHI), with 90% of all nesting occurring at French Frigate Shoals (FFS) (Balazs 1976).

D. Population Status

The green turtle has been the focus of marine turtle research and monitoring in the Hawaiian Islands since the 1970s. This population was heavily-exploited through the early 1970s. In 1974, the State of Hawaii put an end to the commercial harvest of green turtles, however, harvest for home consumption was still allowed. The green turtle was listed as *threatened* under the US Endangered Species Act (ESA) in 1978 and afforded full protection under US law. The ESA listing for the species came about because of over-exploitation for commercial and other purposes, the lack of adequate regulatory mechanisms and effective enforcement, evidence of declining numbers, and habitat loss and degradation (NMFS and USFWS, 1998). All populations throughout the species' Pacific Range were declared *threatened*, except for the population nesting on the Pacific coast of Mexico which was declared *endangered*. After decades of protective efforts, green turtles in the Hawaiian Islands are demonstrating encouraging signs of population recovery as indicated by a long-term, steady increase in the number of nesting females in the NWHI as well as increases in the number of immature green turtles residing in foraging pastures of the MHI (Balazs 1996, Balazs and Chaloupka 2004a, Balazs and Chaloupka 2006, Chaloupka and Balazs 2007). However, outside of Hawaii, green turtle populations have seriously declined throughout most of the Pacific Islands (NMFS and USFWS 1998). In places where green turtles are not protected by laws, unregulated harvest by humans for meat and eggs is the most serious threat to the species survival. Other threats include habitat loss, incidental capture in fishing gear, boat collisions, and the tumor disease, fibropapillomatosis (NMFS and USFWS 1998).

3. Assessment and Monitoring

A. Nesting Habitat

Monitoring, tagging, and census of nesting females at East Island, French Frigate Shoals in the Northwestern Hawaiian Islands have been on-going since 1973. These initial nesting surveys documented low numbers of nesting females at FFS. Since the 1980s, the population has steadily increased and continues to demonstrate signs of recovery (Balazs and Chaloupka 2004a, Balazs and Chaloupka 2006, Chaloupka and Balazs 2007).

B. Foraging and Resting Habitat

Research on juvenile green turtles in nearshore oceanic foraging and resting habitats in the MHI began in 1976. This long-term study of green turtles directly responds to

recommendations listed in the Recovery Plan for U.S. Pacific Populations of the Green Turtle (*Chelonia mydas*). It specifically addresses recovery action item 2.1.2 "Determine distribution, abundance, and status in the marine environment." Study sites are located on Oahu, Molokai, Lanai, and Hawaii.

4. Ecology and Natural History

A. Nesting Habitat

The 1974 – 1975 nesting surveys provided baseline information on the distribution of nesting activity, the distribution of arrival times (first nesting event of each year), the number of clutches produced per female within a season, the duration of each nesting episode (number of days nesting was attempted before successful oviposition), and the internesting interval (number of days between clutches). Results from those surveys showed that 90% of all green turtle nesting activity in Hawaii occurs at French Frigate Shoals and 50% of all nesting activity at FFS occurs on East Island. Based on those results, East Island was selected as an index site to monitor nesting activity of Hawaiian green turtles.

Partial-season surveys spanning several weeks during peak nesting season were designed to monitor all nesters coming ashore. Typically, partial-season surveys are conducted each year by trained personnel to count and tag nesters. A series of full-season saturation surveys were conducted from 1988-1992, where complete coverage of the nesting season at East Island was achieved (Wetherall et al. 1998). The saturation surveys provide detailed information on the nesting biology of Hawaiian green turtles and updated values for basic biological parameters. Additional information on remigration intervals, site fidelity, survival rates, and reproductive longevity is obtained through tag recoveries.

B. Foraging and Resting Habitat

The purpose of conducting ocean capture research on green turtles in foraging and resting habitats is to determine stock structure, abundance, size ranges, growth rates, health/disease (FP) status, diving behavior, habitat use, foraging ecology, local movements, and migration. Since 1976, the MTRP has spent considerable effort capturing and studying green turtles in neritic habitats. Results of this research have led to a better understanding of the biology and ecology of this stock.

The green turtle in Hawaii is a genetically distinct stock. Analysis of mtDNA demonstrates the genetic discontinuity of the Hawaii population from other green turtle populations in the Pacific (Bowen et al. 1992, LeRoux et al. 2003, Balazs and Chaloupka 2004b).

The growth dynamics of immature Hawaiian green turtles have been modeled. This stock is characterized by slow growth rates displaying significant spatial and temporal variation and an immature growth spurt (Balazs and Chaloupka 2004b). The effect of disease

(fibropapillomatosis) on growth rates is only evident in the most severely afflicted individuals. These animals grow slower than turtles with low to moderate disease affliction (Chaloupka and Balazs 2005). Additionally, bones from dead stranded turtles were used to determine age and growth using skeletochronology. Results from research using this technique show that recruitment to neritic habitats is estimated at 4 to 10 years and growth rates are relatively constant for nearshore animals between 10 and 30 years of age (Zug et al. 2002).

Numerous studies on health and disease have provided insight into the tumor disease fibropapillomatosis (Balazs et al. 1997, Casey et al. 1997, Bennett et al. 2000, Lu et al. 2000, Quackenbush et al. 2001, Aguirre et al. 2002, Greenblatt et al. 2004, Work et al. 2004, Keuper-Bennet et al. 2005), the effect of the disease on the health and immune status of individuals (Work and Balazs 1999, Aguirre and Balazs 2000, Work et al. 2000, Work et al. 2001, Work et al. 2003, Chaloupka and Balazs 2005), and the associated secondary infections that are present in this population of green turtles (Aguirre et al. 1998, Graczyk et al. 1997, Work et al. 2005). Furthermore, a recent study indicates that in some foraging populations in the Hawaiian Islands the prevalence of the disease has declined over the past 10 years (Chaloupka et al. In Press).

Studies on behavior (Davis et al. 2000, Quaintance et al. 2003, Quaintance et al. 2005, Rice et al. 2002, Rice et al. 2005), foraging ecology (Russell and Balazs 1994, Balazs et al. 2003, McCutcheon et al. 2003, Russell et al. 2003), habitat use (Brill et al. 1995, Rice et al. 2000, Harrington et al. 2002), and interactions with other species (Losey et al. 1994, Lu et al. 2000) have provided information on the ecology of green turtles in Hawaii's coastal waters and the impact green turtles can have on the environment (Balazs et al. 1993, Bennett et al. 2002). The destruction of corals at a site off Honokowai, Maui was shown through years of video and still images to be the direct result of resting and foraging Hawaiian green turtles (Bennett and Bennett 2002).

Research on the pelagic ecology of juvenile green turtles was begun in 2006 in collaboration with Sea Life Park by Dolphin Discovery. Several pelagic-sized (smaller than 35 cm carapace length), captive-hatched and raised green turtles were equipped with satellite transmitters and released into pelagic waters off the MHI. This project is the first step in understanding the pelagic ecology of Hawaiian green turtles during the early stages of their life. The diet of oceanic green turtles has been documented through stomach content analysis of animals incidentally caught in the Hawaii-based longline fishery (Parker and Balazs *In Press*).

5. Impediments to Recovery

The Hawaiian green turtle population is a relatively small stock compared to other major stocks (i.e. Tortuguero, Costa Rica > 20,000 nesters, Raine Island, Australia > 80,000 nesters) with currently used nesting habitat comprising a relatively small total land area (i.e. several small, sand islets). Therefore, any catastrophic event, whether natural or human-induced, has the potential to greatly impact the status of this population. Low

levels of green turtle nesting have been documented in the MHI in recent years, suggesting the MHI may serve as a refuge for nesting turtles if habitat loss in the NWHI becomes an imminent threat to successful reproduction.

A. Natural Impediments to Recovery

1) Reproduction

As climate change alters the state of the planet, animals such as sea turtles, whose reproductive success is determined by the environment, may be directly impacted. The sex of hatchling sea turtles is determined by nest temperatures. Increasing beach temperatures may lead to skewed sex ratios and ultimately a female biased population. Additionally, if beach temperatures increase significantly, the overall success of each nest may decrease due to embryonic mortality at high temperatures. Either of these scenarios would be detrimental to the status of this stock.

2) Habitat Loss

The principal nesting beaches for this stock are low-lying, small, sand islets located several hundred miles from the developed Hawaiian Islands. Habitat loss due to sea level rise may impose the greatest risk to the continued existence of this population. Most of the land at the primary nesting grounds of FFS is less than 2 m above sea level. Significant loss of habitat has already occurred at FFS from 1963 – 2004 (Antonelis et al. 2006) and projected loss of habitat due to sea level rise for East Island is between 3% and 33% for a rise in sea level of +9 to +88 cm, whereas land loss at some of the other islets at FFS (Trig, Gin, Little Gin) may be as great as 99%. Laysan and Lisianski Islands may provide refuge for nesting turtles since their elevation is higher (Baker et al. 2006) provided other environmental parameters (sand temperature and ocean currents) are conducive to the survival of hatchlings.

3) Food availability

Competition for herbivorous food resources among green turtles may lead to reduced growth rates and increased time to maturity. This population exhibits slow and declining rates of growth at several sites in the MHI (Balazs and Chaloupka 2004b). As this population continues to recover, competition for resources will increase, not only between turtles but also between turtles, herbivorous fishes, and other reef creatures. Green turtles are extremely resilient in harsh conditions (as are many reptilian species), so the overall impact of reduced food resources may not ultimately lead to death, however it may lead to even slower growth rates and greater age to maturity which could impact the recovery rate of the population.

4) Predation

Green turtles are preyed upon by sharks, finfish, and presumably sea birds in the marine environment. The protected status of the NWHI and the resulting elimination of fishing

pressures will allow all species and stocks to recover to higher population levels. This in turn may lead to higher predation rates of hatchlings by finfishes off the nesting beaches and higher rates of interactions between sharks and adult turtles in the inter-nesting habitat resulting in injury and potentially death.

5) Disease

The tumor disease, fibropapillomatosis (FP), is an ongoing threat to green turtles in the Hawaiian Archipelago. While some individuals may contract the disease and eventually overcome it, many others are plagued with large tumors that interfere with their ability to see and forage, and eventually lead to death. At some sites in the MHI the disease has declined in both severity and prevalence (Chaloupka et al. Submitted Manuscript). At other sites, such as around the island of Maui, the disease still affects a large proportion of the population, but the overall trend is decreasing.

B. Anthropogenic Impediments to Recovery

1) Commercial harvest

The Hawaiian green turtle population was listed as a *threatened* species under the US Endangered Species Act in 1978 primarily because the stock had been over-harvested. Even though this stock is currently increasing, it has demonstrated in the past that over-harvesting will cause the stock to crash because the population is relatively small and individuals are particularly slow growing, taking 35 years or more to reach maturity. The potential for future re-instatement of a regulated low-level harvest will require delisting of the species under the ESA; an action that may not be initiated until the natural threats are more clearly understood. That action may lead to unaccountable levels of unregulated harvest which would undoubtedly have a negative affect on the population's status.

2) Incidental Take

The incidental capture of green turtles in commercial and recreational fishing gear is a continuing concern. The interaction between green turtles and recreational fishing gear is the second most common cause of strandings in the MHI (7%), the disease, fibropapillomatosis is the most common cause (28%) (Chaloupka et al. submitted manuscript). Discarded monofilament fishing line, fishing hooks, and gillnets pose serious threats to green turtles including injury, flipper amputation, and death. The cause of approximately half of all strandings is undetermined Since drowning is very difficult to determine, it is possible that the total impact of fishing gear interactions is greater than we currently believe since many turtles that drown in fishing gear may be assigned to undetermined or other causes (Chaloupka et al. submitted manuscript). New regulations on gillnet fishing have been imposed in the MHI which should reduce the number of turtles incidentally caught and killed in gillnets.

3) Marine Debris

The entanglement in and ingestion of marine debris is a potential threat to this population. Such debris includes discarded or abandoned fishing gear such as nets and lines as well as plastics such as bags, 6-pack rings, tar balls, styrofoam and other refuse that might ensnare or be consumed by a green turtle. Entanglement in discarded nets and lines, as well as ingestion of plastics and other discarded debris may lead to injury or death.

4) Habitat Degredation

Green turtles depend upon algae, sea grass and/or coral reef habitats for food and refuge. The destruction and/or degradation of these habitats are widespread and serious threats to the recovery of sea turtle stocks. Degradation of these habitats occurs through pollution, over-fishing, disease, anchoring, climate change, and other anthropogenic factors (Jackson et al. 2001, Rogers and Garrison 2001, Orth et al. 2006).

6. Research Tools

A. Nesting surveys to assess abundance, trends, survival, threats, etc.

Nesting surveys are the most common method used to monitor marine turtle populations. Appropriately designed nesting beach surveys can provide information on the size of the adult female population, hatchling production, and interannual variability in production (Schroeder and Murphy 1999). Threats to these life-stages (nesting females and hatchlings) can be quantified such as 1) nest destruction from predation, inundation, and other females attempting to nest; 2) habitat loss from beach erosion and sea level rise; and 3) hatchling predation on land and in the water.

Nesting surveys have been on-going at East Island, FFS for 34 consecutive years and provide an index of abundance for the Hawaiian green turtle stock. Expanding survey efforts to other islets in FFS and throughout the NWHI will increase our understanding of the current distribution of nesting activity, individual site-fidelity and overall dynamics of this recovering population.

Trained biological technicians conduct annual nesting surveys at East Island. New turtles are tagged, measured, and sampled (tissue for genetic analysis and health – FP tumors), and tags of previously tagged turtles are recorded.

Satellite tags and/or time-depth recorders are deployed on nesting green turtles to determine habitat use, migration routes between breeding and foraging grounds (Balazs and Ellis 2000), daily and seasonal use of foraging and resting habitat, and localized movements of breeding males and gravid females between nesting and breeding sites and associated basking sites.

Temperature data loggers are deployed in the substrate of East Island to provide data relevant to temperature-dependent sex determination and sex ratios of green turtle

hatchlings. Dead hatchlings found in the nest or on the beach are salvaged and preserved for sex determination via histopathology.

B. Foraging and resting habitat surveys to assess abundance, trends, survival, growth, etc.

Although studying sea turtles in the water is difficult, research directed towards sea turtles on foraging and aquatic resting grounds can provide a wealth of information on the abundance, trends, survival and growth of juvenile and adult turtles. Well-designed monitoring studies may include aerial or boat-based transect surveys to estimate abundance and capture/tagging work to provide information on individuals, habitat use, growth, diet, health and disease, survival, residency, etc. A primary goal of foraging ground research is to integrate data from genetic analysis, flipper tagging, and satellite telemetry to identify nesting beach origins of turtles occurring in the Hawaiian Islands and contribute to the overall understanding of sea turtle stock structure in the Pacific Ocean.

A variety of research techniques are employed by the MTRP during foraging habitat research activities: 1) flipper tagging, passive integrated transponder (PIT) tagging, and shell etchings (mototool) to identify individual turtles, 2) morphometric analysis to determine the size, mass, sex, and health of each captured animal, 3) genetic analysis of tissue samples collected from each turtle to determine nesting beach origin, 4) biotelemetry (radio, acoustic, satellite, archival) to determine movements and habitat use, 5) blood sampling for genetic analysis or to assess health status of individuals, 6) diet sampling using esophageal lavage, and 7) stable isotope analysis of tissue samples for foraging ecology research.

Turtles are captured for these studies by various methods including: hand/scoop net capture in shallow coastal and reef waters, hand capture/snorkeling, hand capture while diving from a slow moving boat, entanglement net capture, scoop net capture, and bullpen net capture (Balazs et al. 1987, Balazs et al. 1998). All of these methods have been successfully and safely employed to study and tag green turtles in coastal waters of the Hawaiian Islands. Turtles are released at or very close to the capture site.

C. Stranding Research

The stranding research program of the MTRP has responded to sick, injured, or dead sea turtles in Hawaii since 1982. Necropsies of stranded turtles provide information on species distribution, stock structure, sex ratio, health and disease, diet, age and growth, and cause of mortality and have been the source of data for numerous scientific publications (Work and Balazs 2002, Work et al. 2004, Work et al. 2005, Zug et al. 2002).

7. Research Plan

A. Research Plan Objectives

The purpose of this plan is to outline research and data analysis needed to further our understanding of the Hawaiian green turtle stock and move towards the recovery and delisting of the species.

The Recovery Plan for US Pacific Populations of the Green Turtle, the Fibropapilloma Research Plan, and an External Program Review of the MTRP in 2002 have served as guiding documents for past research and the formulation of new research ideas. In May 2006, the Center for Independent Experts (CIE) conducted a review of the methodology used by the MTRP to assess the abundance and trends of the Hawaiian green turtle stock. This formal review resulted in two written reports providing recommendations and constructive comments for future research initiatives. The recommendations are used here as a basis for improving data collection and analysis, and for ensuring the techniques are transparent and unequivocal. The refinement of research techniques will also provide an excellent opportunity to incorporate an adaptive research philosophy that will allow for modifications of protocols over time as changes occur in Hawaiian green turtle distribution and abundance.

The MTRP has taken into consideration the recommendations of the CIE reviewers and identified (1) “essential” research elements – research resulting in peer-reviewed publications providing a scientific basis for the Pacific Islands Regional Office (PIRO) and NOAA Headquarters to evaluate the current recovery status of the stock and (2) “high priority” research elements – projects deemed necessary for the continued establishment of the Hawaiian green turtle stock as one of the most comprehensively studied worldwide, and for this program to continue to serve as a "model" of useful knowledge for comparison with green turtle stocks under study elsewhere for conservation, recovery, and creation of sound management practices.

The MTRP has conducted research dedicated to understanding the basic biology of the Hawaiian green turtle for the past 35 years; however, much of the basic demographic data (distribution of nesting, site fidelity, and clutch frequency) has not been updated since the early 1990s. Other parameters such as fecundity, survival rates, recruitment rates, and abundance estimates have not yet been formally investigated. To better understand the dynamics of this recovering population, basic demographic data should systematically be updated to reflect the current status of the stock and new scientific methods should be employed to acquire data on parameters that have not previously been established.

B. Step Down Outline and Narrative for Research Plan

1 Monitor status and trend of Hawaiian green turtle nesting stock

1.1 Continue annual partial-season surveys of nesters at East Island, FFS

The MTRP will continue long-term and expanded monitoring, sampling, and validation of nesting numbers at French Frigate Shoals including the

incorporation of the experimental use of remote controlled satellite-linked camera viewing, and incorporate a means for periodic analytical updates.

1.2 Expand survey efforts at FFS and throughout NWHI to identify other important nesting beaches, determine number of nesters, and determine population trends

Periodic surveys of all NWHI nesting and basking are needed to ensure that concentrations of turtles are not changing and to possibly ascertain how the loss of habitat (e.g., Whaleskate) has or might impact the distribution of nesting.

1.3 Conduct periodic multi-year saturation surveys of nesters at East Island, FFS to re-assess various life history parameters

Full season surveys of nesting activity are needed at East Island to reassess the methodology developed during 1988-92 to estimate total census counts from partial surveys. Such validation studies should be done soon and for two consecutive years. Also, setting a standard protocol for reevaluation of the technique, if necessary, should be conducted every 10 years.

1.4 Analyze long-term nesting data and conduct a formal stock assessment of the Hawaiian green turtle stock

The MTRP will work with PIFSC scientists to conduct a second stock assessment of the Hawaiian green turtle population. The MTRP and PIFSC scientists will identify elements needed to complete the assessment by mining existing data and designing studies to collect additional information.

1.5 Analyze long-term basking turtle census data from the NWHI for trends in abundance and distribution

The MTRP will work with PSD staff to analyze the results of long-term basking turtle censuses in the Northwestern Hawaiian Islands to determine if the spatial distribution and abundance of basking turtles has changed over time.

1.6 Evaluate nest success and predation rates of hatchlings

The evaluation of egg clutch hatching success, hatchling emergence, and dispersal success (near shore levels of hatchling predation) is recommended as they would yield important information for stock assessment, conservation, and management.

1.7 Continue temperature-dependent sex determination study on captive Hawaiian green turtles

The MTRP will collaborate with researchers at the University of Alabama, Birmingham and staff from Sea Life Park to continue a temperature-dependent

sex determination study on captive Hawaiian green turtles and ascertain the pivotal incubation temperature for the stock. This study will provide insight into the proportions of male and female hatchlings produced in the wild and the potential impacts of climate change on hatchling sex ratios.

2 Determine stock structure of Hawaiian green turtle population

2.1 Determine genetic relationships of green turtles in the Hawaiian Islands

The MTRP will support SWFSC staff in the completion and peer-reviewed publication of a genetics study to ascertain Distinct Population Status for the Hawaiian green turtle stock.

3 Investigate distribution, abundance, and status in the neritic marine environment

3.1 Model the distribution and abundance of hatchlings and post-hatchlings in pelagic habitats

The MTRP will work with PIFSC staff to develop and build a model simulating the dispersal of hatchling turtles produced at French Frigate Shoals, augmented with data from the satellite tracking of small juveniles in pelagic habitats.

3.2 Determine the distribution, abundance, survivorship, recruitment rates, and residency times of juveniles and adults in coastal habitats

The MTRP will continue long-term monitoring and sampling at long-term coastal foraging pastures and incorporate a means for periodic analytical updates. Current methodologies may not be fully applicable to obtaining recruitment rates, survival, abundance estimates or trends in juveniles. A structural scientific approach will be used for site selection, sampling protocols, and analysis of data.

3.3 Evaluate the natural and anthropogenic impacts of various threats to green turtles on foraging grounds

The MTRP will continue stranding research to ascertain causes of mortality and trends, and incorporate a means for periodic analytical updates.

3.4 Study the impacts of diseases on green turtles

The MTRP will continue to study the impacts of disease on Hawaiian green turtles through collaborative firbropapillomatosis research with USGS Veterinarian and Wildlife Disease Specialist Dr. Thierry Work. Biological samples will be collected from live, dead and euthanized stranded turtles, diseased turtles captured during ocean-capture research, and from nesting females at East Island, FFS.

4 Ecosystem approach to managing the Hawaiian green turtle stock

4.1 Evaluate the carrying capacity of green turtle foraging habitats

The MTRP will collaborate with Jeff Polovina (EOD), scientists at the SEFSC, and University of British Columbia PhD candidate, Collete Wabnitz, to design and build an ecosystem-based Carrying Capacity Model (CCM) for coastal foraging pasture habitats. The carrying capacity of foraging habitats will be assessed by 1) quantifying and assessing body condition and overall fitness in foraging pastures including proximal terrestrial basking phenomenon, 2) conducting censuses by boat or helicopter of selected shallow water foraging pasture sites, such as Palaau, Molokai, and 3) conducting foraging pasture assessments for algal standing crop and species diversity, including dietary use by turtles of native and non-native species introduced in recent decades, and utilize stable isotope techniques to study the foraging ecology of the population.

4.2 Evaluate the carrying capacity of green turtle nesting habitat

The MTRP will pursue collaboration with SWFSC scientists to design and build an ecosystem-based Carrying Capacity Model (CCM) for nesting habitat at French Frigate Shoals. The long-term nesting dataset for East Island, FFS will be utilized to analyze the carrying capacity of the nesting habitat.

5 Other research elements

5.1 Conduct an economics study to estimate the value of Hawaiian green turtles

The MTRP will work with PIFSC staff to conduct an economics study to estimate the "value" of the Hawaiian green turtle to the diverse interests of the Hawaii community, such as the Hawaiian culture, tourism, and conservation education.

5.2 Build capacity within the Pacific Islands Region

The MTRP assists in the building of sea turtle conservation and research programs throughout the region by participating in cooperative research and providing training opportunities and assistance to Pacific Islanders and Pacific Rim personnel. Building capacity within the Pacific Islands Region is needed to achieve the recovery of marine turtle stocks throughout the region.

5.3 Build capacity within the MTRP

Building capacity within the MTRP staff is highly desirable to achieve many of these research tasks. Training of MTRP and funding/recruitment of additional personnel with analytical expertise (Program Mark, GIS, statistical methods, etc.) will increase the MTRPs ability to analyze and update its long-term data sets and increase the number of peer-reviewed publications from MTRP staff members.

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9. Implementation Schedule

The Implementation Schedule outlines research actions and estimated costs for Hawaiian green turtle research, as set forth in this research plan. This schedule indicates task priority, task description, duration of tasks, and estimated costs. The actions identified in the implementation schedule, when accomplished, should protect habitat for the species, stabilize existing populations, and increase the population size and numbers. Monetary needs are identified to reach this point.

Priorities in column 3 of the Implementation Schedule are assigned as follows:

Priority 1

> An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2

> An action that must be taken to prevent significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3

> All other actions necessary to provide for full recovery of the species.

Implementation Schedule / Research Plan for the Hawaiian Green Turtle Stock

Plan Action	Priority	Action Duration	Estimated Fiscal Year Costs $K										Notes
			Current	FY2	FY3	FY4	FY5	FY6	FY7	FY8	FY9	FY 10	
Assessment and Monitoring													
1 Monitor status and trend of Hawaiian green turtle nesting stock													
1.1 Continue annual partial-season surveys of nesters at East Island, FFS	1	ongoing	60	60	60	60	60	60	60	60	60	60	
1.2 Expand survey efforts to identify other important nesting beaches, determine number of nesters, and determine population trends	1	annual	30	30	30	30	30	30	30	30	30	30	Recommended by CIE
1.3 Conduct periodic multi-year saturation surveys of nesters at East Island, FFS to re-assess various parameters	2	2 years every 10 years		60	60								Recommended by CIE
1.4 Analyze long-term nesting data and conduct a formal stock assessment of the Hawaiian green turtle stock	1	1 year											Marine Turtle Assessment Program – no cost
1.5 Analyze long-term basking turtle census data from the NWHI for trends in abundance and distribution	3	1 year											Marine Turtle Assessment Program – no cost
1.6 Evaluate nest success and predation rates of hatchlings at East Island, FFS	1	2 years every 10 years											Included in action 1.3
1.7 Continue temperature-dependent sex determination study	2	ongoing	20	20	20	20	20	20	20	20	20	20	

Implementation Schedule / Research Plan for the Hawaiian Green Turtle Stock												
Plan Action	Priority	Action Duration	Estimated Fiscal Year Costs $K									Notes
			Current	FY2	FY3	FY4	FY5	FY6	FY7	FY8	FY9	FY 10	
2 Determine stock structure												
2.1 Determine genetic relationships of green turtles in the Hawaiian Islands	1	ongoing	20	20	20	20	20	20	20	20	20	20	
Ecology and Natural History												
3 Investigate distribution, abundance, and status in neritic marine environment												
3.1 Model the distribution and abundance of hatchlings and post-hatchlings in pelagic habitats	1	2 years		40	40								Recommended by CIE
3.2 Determine distribution, abundance, survivorship, recruitment rates, and residency times of juveniles and adults in coastal habitats	1	ongoing	310	310	310	310	310	310	310	310	310	310	
3.3 Evaluate impacts of threats on foraging grounds through stranding research	2	ongoing	400	400	400	400	400	400	400	400	400	400	Recommended by CIE
3.4 Study impacts of diseases through ocean capture research and stranding research	1	ongoing											Included in 3.2 and 3.3
4 Ecosystem-approach to managing stock												
4.1 Evaluate carrying capacity of foraging habitats	1	10 years	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Recommended by CIE

Implementation Schedule / Research Plan for the Hawaiian Green Turtle Stock												
Plan Action	Priority	Action Duration	Estimated Fiscal Year Costs $K									Notes
			Current	FY2	FY3	FY4	FY5	FY6	FY7	FY8	FY9	FY 10	
4.2 Evaluate carrying capacity of nesting habitat at East Island, FFS	1	2 years		40	40								Collaborate with SWFSC
5 Other research elements													
5.1 Conduct an economics study to estimate the value of Hawaiian green turtles	3	2 years		20	20								
5.2 Build capacity within the Pacific Islands Region	3	ongoing	5	5	5	5	5	5	5	5	5	5	
5.3 Build capacity within the MTRP	3	ongoing	5	5	5	5	5	5	5	5	5	5	
TOTAL			850	1,010	1,010	850	850	850	850	850	850	850	