G. BALAZS
7/1/85

Ecological Assessment of Nearshore Habitat for the Hawaiian Green Sea Turtle, Chelonia mydas

The goal of this research is to acquire baseline data on the dependencies and interrelationships of the herbivorous green turtle to its habitat at select sites in the main Hawaiian Islands. As migrant breeders, nearly all reproduction by this species in Hawaii occurs at French Frigate Shoals in the northwestern segment of the archipelago. However during non-reproductive periods, which comprise the greatest portion of life, adults as well as the immature age classes reside in nearshore waters of the main island. Emphasis is being placed on characterizing what constitutes good resident habitat for foraging, shelter for resting, and thermoregulation. The similarities and differences of various habitat are being identified, along with the turtle's tolerance and adaptability to human and other types of habitat alteration.

The principal sites where studies are underway include: Kawela Bay on Oahu, an area scheduled soon for substantial resort development; Palaau on Molokai, where introduced mangroves have significantly altered the coastline; Kahului Bay on Maui, where warm water is discharged from a power plant; Keomuku on Lanai, a relatively pristine area where heavy commercial turtle fishing took place during past years; and Polihua on Lanai, where abundant nesting occurred up to 50 years ago. These study sites were selected on the basis of their present or past importance to turtles, based on interviews with local residents and historical documentation in the literature. Study methods include the extensive use of scuba for underwater surveys, and tangle nets to sample turtles for size frequency, abundance, food sources, sex ratios, and status of health. The turtles are

captured alive and released a short time later after being identified with alloy flipper tags.

Hawaiian green turtles of all sizes greater than 35 cm carapace length have been found to feed on select kinds of benthic algae (Pterocladia, Acanthopora, Ulva, and Codium), growing in shallow water, often right in the intertidal zone. Grazing occurs principally at night, resting takes place under ledges with soft sand or mud bottoms in deep water, frequently at the 18 m or more drop off that exists a short distance from shore around all the main islands of Hawaii. Resident habitats preferred by turtles are not evenly distributed, but rather occur at specific places where food requirements and acceptable shelter are in proximity. Fishing pressures during the recent past on this slow-to-mature species also appear to have affected the distribution and numbers of turtles.

Eq. A: hab. pl

Title: Ecological status of nearshore foraging habitat for the threatened green sea turtle in the Hawaiian Islands.

Overall objective: To acquire baseline data on the interrelationships of habitat and green turtle, Chelonia mydas, at select locations in coastal waters of the main Hawaiian Islands.

Specific objectives for Phase 1 (FY85):

1. Ascertain status and trends of selected priority habitat.
2. Quantify the relationship of priority habitat to green turtle productivity; characterize what constitutes superior foraging habitat.
3. Identify future research, management, and enhancement actions that may be required.
4. Began to determine what types and levels of man-induced alternations can occur to foraging habitat without significant loss to green turtle productivity.

Outline of major project steps:

1. Hire and train technicians.
2. Acquire equipment and supplies.
3. Preliminary on-site visitations.
4. Execute field studies--data acquisition.
5. Data processing
6. Report preparation.

Study areas:

1. Kahului Bay, Maui--emphasis on warm-water discharge from Maui electric plant.
2. Palaau, Molokai--extensive shallow reef flat previously altered

by the introduction of mangroves. Work here will be in collaboration with local resident fisherman who has done previous tagging under NMFS contract.

3. Polihua, Lanai--Historical site of an extirpated green turtle nesting colony possibly now undergoing recolonization; adjacent areas are said to host significant foraging aggregations of subadults.

4. Waimanalo Bay, Barbers Point, and Kawailoa, Oahu--Known sites of key foraging habitat believed to be suitable for intensive investigation.

5. Punaluu, Hawaii--One of the best areas of foraging habitat known in the Hawaiian Islands; follow-up work to earlier studies conducted at this site.

Green Turtle Habitat Study Underway

The National marine Fisheries Service Honolulu Laboratory has been acquiring baseline data on the dependencies and interrelationships of the herbivorous green turtle, Chelonia mydas, to its habitat at select sites in the main Hawaiian Islands. The green turtle is listed as a threatened species under the U.S. Endangered Species Act. Nearly all reproduction in Hawaii by this migrant breeder occurs at French Frigate Shoals in the Leeward Islands. During the nonreproductive periods which comprise the greatest portion of its life, adults as well as individuals in the immature age classes reside in nearshore waters of the main islands. Emphasis is being placed on characterizing what constitutes good resident habitat for foraging, shelter for resting, and thermoregulation. The similarities and differences of various habitat are being identified, along with the turtles tolerance and adaptability to human and other types of habitat alteration. These research activities will allow better evaluation of actual or proposed habitat alteration.

The principal sites where studies are underway include Kawela Bay on Oahu, an area scheduled for substantial resort development; Palaau on Molokai, where introduced mangroves have significantly altered the coastline; Kahului Bay on Maui, where warm water is discharged from a powerplant; Keomuku on Lanai, a relatively pristine area where heavy commercial turtle fishing took place during past years; and Polihua on Lanai, where abundant nesting occurred up to 50 years ago. These study sites were selected on the basis of their present or past importance to turtles, based on interviews with local residents, and historical documentation in the literature. Study methods include the extensive use

of scuba and tangle nets to sample turtles for size frequency, abundance, food sources, sex ratios, and status of health. The turtles are captured and released a short time later after they are tagged with allow flipper tags.

Hawaiian green turtles of all sizes greater than 35-cm carapace length feed on select benthic algae (Pterocladia, Acanthopora, Ulva, and Codium) growing in shallow water, often in the intertidal zone. The turtles graze principally at night. They rest under ledges with soft sand or mud bottoms in deep water, frequently at the 18-m or more drop-off that often exists a short distance from shore around all the main Hawaiian Islands. Resident habitats preferred by turtles are not evenly distributed, but, rather, are found at specific sites where food and acceptable shelter are nearby. Past fishing pressure on this slow-to-mature species also appears to have affected the distribution and numbers of turtles.

PROPOSED FISHERY HABITAT RESEARCH BY THE SOUTHWEST FISHERIES CENTER HONOLULU LABORATORY

Through the efforts of Senator Daniel K. Inouye, the United States Senate Appropriations Committee recently approved funds for "vital fisheries habitat research in the Pacific," and the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), has been charged with developing and executing this research program. The initial plans proposed for the research program were developed through discussions among scientists at the Honolulu Laboratory, and joint meetings with personnel of the Western Pacific Program Office, Southwest Region, NMFS.

The proposed research program is designed to consider basic fishery habitat concerns of importance and interest to NOAA-NMFS and the Hawaiian Archipelago. The immediate plan is to initiate research that is clearly relevant to current issues affecting fishery habitat in the Hawaiian Archipelago, including ongoing and potential marine activities such as dredging, ocean thermal energy conversion (OTEC) projects, and manganese mining; Longer-range research planning will take place during the first year, after key program personnel are recruited.

The research projects for fiscal year 1985-86 have been divided into four areas--those concerning OTEC, manganese crust mining, habitat enhancement and mitigation, and long-term ecological research. In addition a modest program would be initiated on habitat evaluation which would include defining areas and their resources throughout the Hawaiian Archipelago using video systems, deep-sea photography, and possibly submersibles to provide a more complete inventory of habitat types. Of particular interest would be to define the habitat of juveniles or critical nursery areas for commercially important species. Also, selected nearshore research will be conducted to identify characteristics of marine turtle habitat in the main Hawaiian Islands. The four areas of research are described in more detail below.

Research related to OTEC. The Honolulu Laboratory has had some involvement in OTEC developments, for example, in the preparation of background documents on OTEC in collaboration with the NOAA Ocean Minerals and Energy Office (OME). In the past year, the Laboratory started a project on thermal shock effects on larval fish.

The proposed 40-MW OTEC facility off Kahe Point, Oahu, would draw about 200 m^3/sec each of warm water from the surface and cold water from 700 m. The concerns here are the potential of entrainment, impingement, and thermal impacts on marine life, the attraction of fishes to the large pipelines, and also the effects of sand transport and construction on the habitat. A key research project would be a baseline study of the vertical distribution of ichthyoplankton (fish larvae) off Kahe Point. This area has high densities of fish (tuna) larvae, and understanding the vertical distribution of fish larvae will allow analysis of the potential of mortality caused by entrainment and impingement, and the effects of the effluent plume.

A second project is a study of the movement and migration of deep bottom fishes, which is particularly important to the OTEC study. The purpose of the project is to determine if certain commercially important fishes (snappers and a grouper) remain in a given habitat or move among habitats. For OTEC the importance of this information relates to whether these fishes are attracted to the deepwater pipe, which may act as an artificial reef. Current information on OTEC's impact on fisheries indicates that the attractiveness of the pipes may result in increased exploitation of fishes in restricted areas at the expense of adjacent areas. This study should also provide an understanding of the recruitment of bottom fishes to artificial habitats and the repopulation of impacted areas.

The final OTEC-related project will involve a modest continuation of the thermal stress work on larval and juvenile fishes. Much information exists on the effects of high temperature on fishes, but shocks caused by cold water, particularly on tropical fishes, have not been studied. This project should provide information on the magnitude of impact to regional fish populations and entrained larvae.

Research related to manganese crust mining. The Minerals Management Service (MMS), Department of Interior, is considering development of lease tracts within the Hawaiian Archipelago for mining of manganese crusts since these crusts are richer in cobalt than are manganese nodules and so of greater economic value. As a general rule, the crusts are thicker towards the northwest stretches of the Hawaiian Archipelago, so it is likely that initial mining development within the U.S. Exclusive Economic Zone (EEZ) will be the seamounts near and northwest of Midway. Preliminary dredging studies have been made on these seamounts to assess the quality and quantity of minerals, but no biological studies on potential impacts due to mining, particularly studies related to fisheries, have been made. Concerns due to mining are habitat destruction, sediment plumes caused by processing, heavy metals, and effects of sediment on bottom life.

Field reconnaissance and habitat description will be necessary to better understand the important biological resources. In the depths affected by actual mining activities, deepwater shrimp and precious corals may represent important commercial resources; fishes such as pelagic armorhead and alfonsin play a similar role in the seamount region. Dives in submersibles, deep-sea photography, and remote video systems could be used for the assessment of these habitats to better understand the behavior and distribution of the resources by habitat type. To complement these field studies, laboratory research would be initiated to determine the effects of sediment on the feeding of larval and juvenile tropical fishes.

Habitat enhancement and mitigation research. Habitat enhancement is generally considered to play a role in revegetation of coasts and mitigation for wetlands lost to development, but is not usually considered necessary in the relatively pristine waters of the Hawaiian Archipelago. For fish habitats, however, there are extensive areas of unproductive bottom which could be enhanced to increase fish production. A better understanding of produc-

tivity enhancement and the attraction of fishes to artificial structures would provide valuable information for mitigation purposes. As habitat is lost to development such as OTEC, mining, and harbor development, mitigating habitat loss through deployment of artificial structures is one of the few options in the limited coastal ecosystem of the Hawaiian Islands. The planned study on movement and migration of bottom fishes will also have application here in allowing a better understanding of recruitment of fishes to new habitats. Future studies may include the economics of mitigation, how artificial reefs change recreational-commercial fishing behavior, and baseline analysis of benefits and losses due to loss of habitat in localities such as Barbers Point.

Understanding habitat requirements of endangered species is also critical to understanding the impact of man's activities. Green turtles and hawksbill turtles live in nearshore habitat most of their lives, leaving for only relatively short periods to migrate to breeding areas. These turtles are known to have a restricted "home range" in this nearshore habitat. Development of the coast by man and other factors have reduced nearshore feeding and residence areas. Research is needed to define the characteristics which make certain habitats preferred and how best to maintain these habitats. This could lead to management action on multiple use of the nearshore marine environment which would conserve endangered resources and provide baseline data for habitat conservation, mitigation, and restoration.

Long-term ecological research. The purpose of long-term ecological research is to provide baseline time series data for detection of habitat and environmental change. Initially, the Honolulu Laboratory plans to support the activities of researchers at the Southwest Fisheries Center Tiburon Laboratory in their nearly 20-yr research in Kona, Hawaii waters. At the same time, program objectives and data collection activities will be more clearly defined in planning sessions.

Future research--ciguatera. There is currently great concern in Hawaii that man's activities, e.g., dredging, in the coastal and nearshore environment lead to outbreaks of ciguatera poisoning. Such case histories have been documented, but there also have been outbreaks in pristine areas where there have been no activities by man. Most ciguatera research in Hawaii has centered on detection methodology, the food chain pathways for the toxin, and the affected fishes, but relatively little research has been done on determining the causes of local outbreaks. For future habitat research the Honolulu Laboratory proposes a modest study to critically examine the relationship between ciguatera outbreaks and disturbances in the coastal environment.

Food and energy consumption of the Hawaiian Green Turtle population

A great deal is known about the types of food that Hawaiian Green Turtles eat under natural conditions. In order to measure the quantity of food that they eat it is necessary to know the volume of the stomach, whether the stomach is filled at each feeding session and the number of feeding sessions a day. This information is extremely difficult, if not impossible, to obtain. Therefore, in order to determine how much food the turtles consume in a given time period, an alternative approach is needed. The only feasible alternative approach is to measure the energy expenditure of the turtles and then, from the energy content of different types of food, to calculate the amount of food that they would have to consume in order to meet their energy requirements. Methods are available for the measurement of both the energy expenditure of free-swimming turtles and the energy content of different types of food. In practice therefore, the bioenergetics of sea turtles provide the only means of determining their food consumption.

Methods

There are two methods of measuring the energy expenditure of sea turtles. One method is indirect and relatively inexpensive. It involves the compilation of time-activity budgets for turtles under natural conditions. The amount of time that the turtles spend sleeping, swimming, feeding, etc., is multiplied by a factor representing the energy expenditure during that particular activity. The factors are determined on captive turtles, usually by measuring the oxygen consumption of swimming or resting turtles.

The alternative method is direct and considerably more expensive. It involves the injection, into the turtle of doubly-labelled water ($^{2}H^{18}O$). The turtle is then released and it has to be recaptured within the following week or ten days, when another blood sample is taken.

The energy content of the types of food eaten by sea turtles is known for some food items. It may be measured directly by bomb calorimetry.

Seasonal variations

The energy expenditure measured over a short period of time may be extended to an entire year if seasonal variations in energy expenditure are known. The major seasonal variations are the migration to the nesting grounds, and, in the case of the females, the production of eggs. The energy contained in the eggs can be measured directly and the cost of migration can be estimated.

Population requirements

The annual food consumption and energetics of individual turtles can be translated into the requirements of the entire population if the population structure is known:

Significance

From a management point of view it is important to know the amount of food consumed by the sea turtle population in relation to the food resources available in the turtles' habitat.

George,
These are some superficial & worthless thoughts on food, energy + water.

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Green Sea Turtle Habitat Study

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The principal sites where studies have been conducted include Kawela Bay on Oahu, an area scheduled soon for substantial resort development; Palaau on Molokai, where introduced mangroves have significantly altered the coastline; Kahului Bay on Maui, where warm water is discharged from a power plant; Keomoku on Lanai, a relatively pristine area where heavy commercial turtle fishing took place during past years; and Polihua on Lanai, where abundant nesting occurred up to 50 years ago. These study sites were selected on the basis of their present or past importance to turtles, based on interviews with local residents and historical documentation in the literature. Scuba and tangle nets have been used extensively to sample turtles for size frequency, abundance, food sources, sex ratios, and status of health. The turtles were captured and released a short time later after being tagged with alloy flipper tags.

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THE HABITAT CONSERVATION PROGRAM OF THE NATIONAL MARINE FISHERIES SERVICE FOR FISCAL YEARS 1984 and 1985

Prepared by the
Office of Protected Species and Habitat Conservation,
Habitat Conservation Division,
National Marine Fisheries Service,
Washington DC, 20235

January 1986

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator

National Marine Fisheries Service
William G. Gordon, Assistant Administrator

The 1982-83 El Nino, the strongest of this century, has had an especially strong impact on the nearshore marine habitats of California. This is shown by studies of changes in ecological relationships since 1973 by researchers at the Center's Tiburon Laboratory.

With surface water temperatures about 3° above normal, the forests of giant kelp that had dominated these habitats during the preceding 10 years were devastated. Equally profound effects were noted among the fishes which in this region are a mix of species that are both tropical and temperate in origin. In general, those with tropical affinities remained prominent in nearshore habitats, whereas species with temperate affinities left for deeper water.

Another equally profound but less obvious effect of the 1982-83 El Nino was a sharp decline among organisms that subsist on phytoplankton, e.g., sponges, brytozoans, and tunicates. Because some of these are important prey of fish, it has been suggested that the departure of so many fish was prompted by food shortages. However, the depleted sponges, bryozoans, and tunicates were major prey, not of the species that left, but rather of certain of the fish species that remained. Clearly, it was not food shortages that drove so many fishes from these habitats.

Conditions associated with El Nino events are extremes of conditions that are a part of the normal annual cycle. Species endemic to this region, therefore, should be expected to have some adaptive capacities to cope with these conditions. The responses noted to the recent El Nino may be exaggerated forms of adaptive responses to the less extreme versions of these conditions that prevail during normal years. If so, study of these exaggerated--and more readily observed--responses, should identify certain more subtle--and previously unrecognized--responses to the usual habitat changes.

Honolulu Laboratory Implements New Fisheries Habitat Program

A new research program at the laboratory considers fishery habitat issues that are relevant to the Hawaiian Archipelago. An interagency task force is planning the direction of the Fishery Habitat Research program for the next five to six years. The participants listed the current and emerging issues in fisheries habitat preservation and habitat research in the central and western Pacific that could be addressed by the Honolulu Laboratory. Information is needed to resolve major habitat-related issues which were identified as 1) determining the effects of Ocean Thermal Energy Conversion (OTEC) projects, 2) determining effects of ocean mining, 3) establishing a habitat

inventory, 4) implementing long-term baseline habitat research, and 5) evaluating mitigation as a method of offsetting habitat losses associated with human activity. Other issues included addressing such problems as the impact of dredge and fill operations, identifying and protecting nursery areas of economically important species, identifying habitat needs of threatened and endangered marine species, identifying habitat-related causes of seafood poisons such as ciguatera, and determining the impact of major coastal construction projects.

Center Studies Potential Impacts of Ocean Thermal Energy Conversion (OTEC) on Fisheries Habitat

Hawaii is the site for proposed development of an OTEC plant. Because a variety of elements of the nearshore marine environment affect recruitment, survival, and reproductive rates of fishery organisms, the effects of OTEC on fishery habitats may be of greater importance than direct effects on the species themselves. As presently planned, the Kahe OTEC plant would irreversibly alter nearly 72,000m^2 of the marine substratum inside the 100m depth contour. Operationally, the major habitat alteration caused by the proposed Kahe OTEC facility would be the removal of over 100m cubic meters per second of shelf water from the nearshore environment and the displacement of nearly the same amount of cold, deep water to the mixed discharge depth of roughly 100m at the shelf edge. Due to the small size of the impact relative to the area of the biota source, entrainment and impingement losses are not expected to significantly affect fishery populations. However, without further study of egg and larval distributions and nearshore water circulation, accurate predictions of the impact of downstream population resulting from OTEC operation are not possible.

Accidental spills of either working fluid (ammonia) or biocide (chlorine) pose the most serious potential threat to nearshore fishery habitats. Modeling studies suggest that a major spill of either ammonia or chloride would produce toxic plumes of sufficient extent and persistence to endanger coral reef communities. However, because there are no data on chlorine or ammonia toxicity to Hawaiian nearshore biota and only sparse data on the kinetics of chlorine in oligotrophic subtropical waters, reliable assessments of the impacts of a major spill cannot be made at this time.

Deepwater Artificial Reefs Assessed for Enhancing Fisheries Habitat

Artificial reefs have been successfully used for habitat enhancement and for mitigation purposes in shallow waters but not generally in deeper water. The Center's Artificial Reef and

Enhancement Program deployed nine artificial reef modules at 50 to 130m on Penguin Bank off the island of Molokai. The objective of the research is to determine if populations of commercially valuable snappers and groupers will develop around the reef modules and to quantify the impact that artificial reefs can have on the production and yield of the deepwater species such as snappers and groupers. If artificial reefs placed on this area can create appropriate habitat for snappers and groupers then the use of artificial reefs on Penguin Bank alone can increase the total snapper and grouper habitat by 25 percent.

Green Sea Turtle Habitat Studied

Researchers at the Honolulu Laboratory acquired data on the dependencies and interrelationships of the herbivorous green sea turtle from habitats at selected sites in the main Hawaiian Islands. Nearly all reproduction in Hawaii by this migrant breeder occurs in the uninhabited northwestern Hawaiian Islands. Emphasis has been placed on characterizing what constitutes good resident habitat for foraging, shelter for resting, and thermoregulation. The similarities and differences of various habitats have been identified, along with the turtles' tolerance and adaptability to different types of habitat impacts which result from human activity. This research will help managers evaluate effects of actual or proposed habitat alteration.

Hawaiian green turtles of all sizes greater than 35 cm carapace length feed on select benthic algae that grow in shallow water, often in the intertidal zone. The turtles graze principally at night. They rest under ledges with soft sand or mud bottoms in deep water, frequently at the 18 m or more drop-off that exists a short distance from shore around all the main Hawaiian Islands. Habitats preferred by turtles are not evenly distributed, but are found at places where food and acceptable shelter are close by. Recent fishing pressure on this slowly maturing species also appears to have affected its distribution and numbers.

August 12, 1985

George

Thanks for your note. I shall need some guidelines for the Recovery Team proposal. Do you want something specific like the energy expenditure of a group of turtles at Kaneohe Bay or do you need something more general such as the population energetics for the entire Hawaiian Archipelago?.

Quite apart from energetics, it seems to me that habitat selection may be important. Do they select waters of a particular temperature?

Are they limited from grazing some pastures by the depth to which they can dive? Are they limited as for reproduction is concerned by the lack of suitable beaches for laying their eggs ("suitable" referring to the ability of oxygen to diffuse through the sand)?

Alden

Ramsey