J. Keidler
103 Huckleberry Court
Sequim, Wa. 98382

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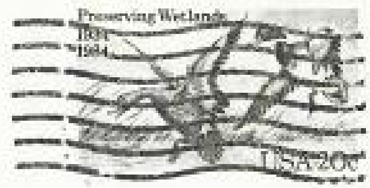

Mr. Alan K. H. Kam
National Marine Fisheries Service
P.O. Box 3830
Honolulu, Hi. 96812

103 Huckleberry Court
Sequim, Wa. 98382
July 31, 1984

Dear Mr. Kam:

During the years 1964-1974 I was the Wildlife Administrator for the Pacific Islands for the Fish and Wildlife Service. Among my responsibilities was the Hawaiian Islands National Wildlife Refuge. Dick Shimura, Ernie Kosaka and Ron Walker know me. I made in excess of 25 trips to the Pearl and Hermes unit during those years.

In the July, 1984 issue of the 'Elepaio I read your article about basking by the green sea turtle on the wreck there. Also your statement that it was the first record of such basking in the wild. Also that it had been overlooked by other researchers and refuge personnel.

I don't know about what refuge personnel did in the last eleven years, but I was one who didn't overlook it. Nor is your observation the first record. I'll explain.

We landed on the wreck a number of times going between Southeast and North Islands and established a dive station there in June, 1967 to sample for Acanthaster and Pinctada galtsoffi. We would also canoe it for monk seals and green (black) turtles. We would also check it by helicopter (Navy) for the same purpose.

Why refuge personnel can't or don't find my records I don't know. My field notes, trip reports, publications were left in the refuge files. Also, the atoll research bulletin just covers the years 1963-1967. However, if you will look on page 234 of it, I'm included in the acknowledgements for the copious records I furnished. I also understand that refuge personnel don't get up there much.

However, I kept some copies of field notes and trip reports as souvenirs (originals left in refuge files). I don't have anything prior to 1967.

July, 1970 5 seals (4 adults, 1 subadult)
March 4, 1972 Nothing
March 15, 1973 3 turtles (adults) 11-18 march 73 TR Kridler-Olsen, P&H ?
June, 1972 2 seals (adults)
Sept 6, 1972 3 seals (adults)
March 31, 1973 1 turtle (adult) No record of report
Aug. 24, 1973 1 seal (adult)
Nov. 19, 1973 and March 5, 1974 Nothing

After the last date, I turned these duties over to another person.

So you see, both turtles and seals use it for basking.

We tagged 800 seals and over 500 turtles. Following refuge managers never followed up on the wealth of information possible. A pity.

Sincerely
Eugene Kridler

An Unusual Example of Basking by a Green Turtle in the Northwestern Hawaiian Islands

by Alan K.H. Kam

The Green Turtle, *Chelonia mydas*, is known to haul out regularly to bask on coral sand beaches and lava rock ledges in the Northwestern Hawaiian Islands (Balazs 1976, 1977, 1980; Whittow and Balazs 1979, 1982; Sheekey 1982). This is unusual since, worldwide, basking behavior by sea turtles is a rare occurrence. Furthermore, of the seven marine turtle species, only the green turtle has been reported basking. In the Northwestern Hawaiian Islands (NWHI) most of the basking sites are isolated, uninhabited islands within the confines of the Hawaiian Islands National Wildlife Refuge.

In Hawaii basking has also been observed in captive-reared juvenile Green Turtles held in a tank (Balazs and Ross 1974). Green Turtles of all sizes at Sea Life Park on Oahu, Hawaii, regularly bask on a sloping concrete ramp in their outside display pool. Basking also takes place in captivity on a wooden ramp constructed in a tank at the University of Hawaii's Kewalo Marine Laboratory (Whittow and Balazs 1982).

On 30 October 1982, the author and a fellow field observer, C. E. Bowlby, saw an unusual example of basking at Pearl and Hermes Reef in the NWHI. A large Green Turtle was observed on the sloping steel plates of an old exposed shipwreck (Figure 1). We sighted the turtle at 0915 while motoring by small boat en route from Southeast Island to North Island. The shipwreck is situated within the barrier reef at the northeastern edge of Pearl and Hermes Reef. It is located 11.1 km from Southeast Island and 4.7 km from Little North Island, the nearest land mass (see maps in Amerson et al. 1974). The turtle was basking on the northern face of the hull on the largest section of the wreckage, about 1.5 m above the water. The winds were from the northeast at 25-35 km per hour, the air temperature was approximately 21°C, and the cloud cover was 80%. The low tide prevented us from motoring close to the wreckage. Consequently, the nearest point of observation was about 100 m.

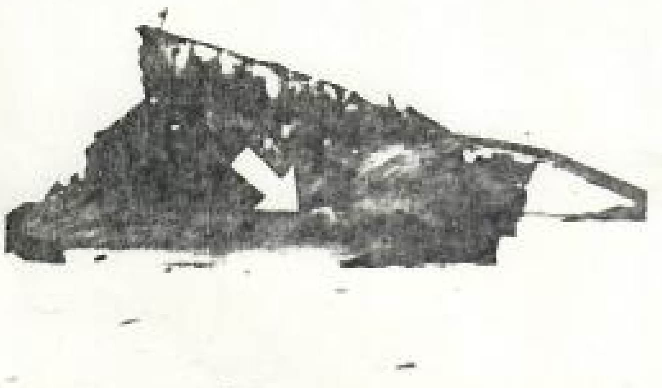

Figure 1. Green Turtle basking on shipwreck, Pearl and Hermes Reef, NWHI, 30 October 1982.

Photo by Alan K. H. Kam

It is interesting to note that the sloping steel wreckage on the reef adjacent to Whale-Skate Island at French Frigate Shoals in the NWHI has never been recorded as a basking site (G.H. Balazs, pers. comm., October 1982). Apparently, turtles find the nearby sand beach to be more acceptable for this purpose. At Pearl and Hermes Reef, the wreck is located several kilometers from any available beach. It is a safe assumption that the temperature of dry steel surface on the wreck would be higher than that of sand (Whittow and Balazs 1982). Because the turtle was observed basking early in the morning, at a time when there was extensive cloud cover, and that it had selected a northerly aspect of the wreck, it can be supposed that basking on this wreck may be more frequent at night or under cool conditions (G. C. Whittow, pers. comm., January 1983).

This is the first record of a turtle basking on the wreck at Pearl and Hermes Reef or any man-made structure in the wild. The wreck's periodic use by turtles may have been overlooked by other visiting researchers and refuge personnel. The wreck is at a remote area of Pearl and Hermes Reef that is not easy to view unless special effort is made to motor close. Future workers in the area should, therefore, try to determine to what extent the wreck is used for basking.

Acknowledgements

I wish to thank George H. Balazs for his editorial assistance and thoughtful encouragement to complete this work.
This observation was made during the research on the Hawaiian monk seal and green turtle by the Marine Mammals and Endangered Species Program, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. Much thanks go to G. C. Whittow, University of Hawaii Department of Physiology, for his helpful insight on adaptive physiology. I also wish to thank the U.S. Fish and Wildlife Service for their cooperation in permitting these observations within the Hawaiian Islands National Wildlife Refuge.

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Marine Mammals and Endangered Species Program
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
P.O. Box 3830, Honolulu, HI 96812

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P. O. BOX 50167
HONOLULU, HAWAII 96850

IN REPLY REFER TO:

8/23/84

George,

Heres the Pearl + Hermes reports you requested. I hope you find them useful. All of Kridler and Sincocks original trip reports are now being held by Peter Stine in our Ecological Services office. If you need any other information please let us know.

Sincerely,

Bruce R. Eilerts

8/20/84

FROM
PALMER SEKORA

Dear George -

What can I say? Gene Kridler is Gene Kridler and he will never change. He refuses to acknowledge ~~that~~ he took and kept at home most, if not all, the bird, turtle & seal data he collected. Marty Taylor & Matt Dillon are witnesses to that. He did the same thing when he was at the Malheur Refuge. He just recently sent them the away data, but only after he had his medical problem. For NMFS (Seattle) to get the monk seal data took a direct order to Kridler from either the Regional Director or Director. What can you say? He was and still is a true blue asshole!!!

I can't really tell from Kridler's letter whether his observations relate to the wreck or the island as a whole. I suspect he missed the point and his data is not specific to the wreck. Thank God there are not many Kridlers in the world.

All is fine here (a little boring after all these years). Family is fine and still enjoying Western Oregon. Best regards,
Palmer

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
300 South Ferry Street
Terminal Island, CA 90731

October 10, 1991 SWO33:ETN

Mr. George H. Balazs
Honolulu Laboratory
Southwest Fisheries Science Center
2570 Dole Street
Honolulu, HI 96822-2396

Dear ~~Mr. Balazs~~: Geo

I am writing to inform you of the current status of sea turtle recovery planning in the Pacific Basin. As a member of the Hawaiian Sea Turtle Recovery Team, you played an important role in helping to develop the research priorities for Hawaiian sea turtle populations, and selected portions of that research are now underway.

As you may have heard, however, a new Pacific-wide sea turtle recovery plan is being developed by the National Marine Fisheries Service. This decision was based upon the need to address priority issues for many of the wide ranging species throughout U. S. waters in the Pacific. Separate teams have been established for the Eastern and Western Pacific areas, and the schedule calls for a Pacific Sea Turtle Recovery Plan to be completed in mid-1993. The Hawaiian Sea Turtle Recovery Plan has been given "interim approval" while the larger effort is underway and will be incorporated into the final Pacific plan. Because the Hawaiian Sea Turtle Recovery Plan has been completed, and issues such as recovery criteria, habitat conservation, and the effects and etiology of fibropapillomas were considered, it should provide a strong basis around which the other plans can be developed. The interim approval means that the research and management priorities you had a hand in formulating can proceed immediately, subject of course, to available funds.

I would like to take this opportunity to thank you for the role you played in developing the Hawaiian Sea Turtle Recovery Plan.

Sincerely,

Chas

E.C. Fullerton
Regional Director

Received WPPO

NOV 17 1986

National Marine Fisheries Service

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P. O. BOX 50167
HONOLULU, HAWAII 96850

NOV 14 1986

Mr. E.C. Fullerton, Regional Director
National Marine Fisheries Service
Southwest Region
300 South Ferry Street
Terminal Island, CA 90731

Dear Mr. Fullerton:

As provided by Section 7 (a) of the Endangered Species Act of 1973, as Amended, we request initiation of formal consultation between the U.S. Fish and Wildlife Service (Service) and the National Marine Fisheries Service (NMFS) regarding a proposal to operate Tern Island on a seasonal basis beginning in FY '87. Enclosed is a copy of the Service proposal which provides detailed information on plans for implementing this action, and discusses potential impacts of this action on the endangered Hawaiian monk seal (Monachus schauinslandi) and the threatened Green sea turtle (Chelonia mydas).

Funding constraints coupled with the recent addition of new units to the Hawaiian and Pacific Islands National Wildlife Refuge Complex have necessitated a re-examination of Refuge Complex programs and priorities. It appears that considerable savings can be incurred through reducing our activities at Tern Island, French Frigate Shoals from a continuously staffed, year round operation to a seasonally staffed, field camp operation. This would be similar to our management presence on other islands in the Refuge and should have little adverse impact on wildlife and habitat. Accordingly, we are proposing to make this transition effective March 31, 1987. The attached proposal details our plans and discusses potential impacts of the action.

For further information please contact Dr. Richard Wass, Refuge Manager, on my staff, at FTS 551-1201.

Sincerely,

Allan Marmelstein
Pacific Islands Administrator

Enclosure

cc: Doyle Gates, Western Pacific Program Office

A REDUCED MODE OF OPERATION AT TERN ISLAND

1. The Present Situation

A. Operations

In 1979, the Fish and Wildlife Service (FWS) established permanent occupancy at Tern Island, French Frigate Shoals when the U.S. Coast Guard dismantled their LORAN transmitter and withdrew from the island. At least two FWS employees, assisted by 1-5 volunteers and part-time workers, have continuously occupied the facility since that date.

A permanent FWS presence within the Hawaiian Islands National Wildlife Refuge is useful for enforcing the Refuge's limited entry policy within French Frigate Shoals and throughout the Northwestern Hawaiian Islands. Permanent occupancy of a station at Tern Island also facilitates the year round collection of biological data for monitoring populations of seabirds and endangered species. Additional benefits include: 1) logistical support for wildlife population monitoring and habitat assessment efforts throughout the Refuge extending from Nihoa Island to Pearl and Hermes Reef; 2) facilitation of research and population monitoring by other agencies and groups including the National Marine Fisheries Service, the State of Hawaii, the University of Hawaii, and the National Weather Service; 3) serving as a point for providing emergency medical evacuation/aid to FWS personnel, other researchers and vessels in the vicinity; and 4) logistical support for commercial fishing operations in the NWHI. Operations and objectives for the station are detailed in the recently completed Hawaiian Islands National Wildlife Refuge Master Plan/Environmental Impact Statement.

B. Cost

Operation of the Tern Island station is expensive. The facilities were received from the Coast Guard seven years ago in near perfect condition, but a lack of adequate funding for preventative maintenance and replacement in the intervening years has resulted in considerable deterioration of systems, equipment and structures. Required maintenance costs escalate every year and will continue to do so. Maintenance tasks require an increasing amount of staff time as well. Routine O&M costs are estimated at $208,900 for FY 87. An additional outlay of about $58,000 (for a total of $266,900) would be required in FY 87 for large purchases of equipment and services.

By 1988 or soon after, the barracks would likely require a new roof at a cost of about $40,000. A very large outlay of funds (approximately $3 million) would be required around 1991 for rehabilitation of the seawall and runway.

2. The Proposed Alternative

A decrease in available funding coupled with mounting operational and maintainance costs is forcing an alternate mode of operation at Tern Island. The continuously staffed, year round occupation of the facility will be reduced to a seasonally staffed, field camp operation in which most of the facilities left by the Coast Guard will be abandoned. Though funds and manpower will be reduced, much greater proportions will be directed toward resource management and away from maintainance of facilities and equipment. Careful planning will ensure that the transition is conducted in a manner that minimizes adverse impacts on wildlife and habitat and maximizes the efficient use of manpower and funds. The following is an outline of that process and a discussion of the potential impacts.

A. Description

The physical process of withdrawing from the facility is planned for completion by March 31, 1986. Most of the items of value including generators, appliances, power and hand tools, outboard motors, pumps, typewriters, etc. and bulky personal items will be packed in crates and shipped back to Honolulu aboard a vessel chartered for that purpose. Personnel and lightweight valuables such as cameras and radios would return to Honolulu via chartered aircraft. Most of the equipment would eventually be sent to the newly created Hakalau Forest NWR and to Midway Atoll NWR when established. Some of the gear could also be used at Johnston Atoll NWR and Kilauea Point NWR. Flammable items such as wooden furniture and supplies would be assembled and burned as would wooden structures such as the boat shed and the garage extension. Equipment and items that are not worth returning to Honolulu would be "trashed" and buried against the seawall to prevent this material from attracting salvors and "treasure hunters".

The tractor, two outboard-powered skiffs, the boat hoist and other equipment useful to personnel operating a long-term field camp would remain on Tern Island for at least the first field season (April - September, 1986). No immediate attempt would be made to demolish the main buildings. They are constructed of steel-reinforced concrete and are designed to withstand tsunamis and hurricane-generated waves and tides. Heavy equipment, dynamite and lots of manpower would be required to dismantle the buildings. Perhaps the assistance of the SEABEES (U.S. Navy) can be enlisted or maybe the Defense Environmental Restoration Account can be tapped for funds at some future date.

In lieu of the current continuous operation of the Tern Island facility, annual, long-term field camps would be established at Tern or one of the other islands at French Frigate Shoals. Biologists from the FWS and other agencies including the National Marine Fisheries Service will be present for 3-7 months each year to continue research and population monitoring efforts on endangered species and seabirds. They will be present during the breeding season which is the most critical time from the standpoint of research and enforcement of limited entry.

B. Positive Ramifications

1) Cost savings is the obvious and major benefit derived from this action. The estimated savings for FY 87 is $69,000. Savings for subsequent years are estimated to be at least $183,000 annually.

2) While the amount is unknown at present, a substantial portion of the annual savings would be available to implement some of the high priority management strategies as recommended by the preferred alternative of the

Master Plan. Funds and manpower to address these strategies would probably not be available under the current mode of operation. Examples of such strategies include: regulate and monitor nearshore vessel traffic; conduct historical surveys; conduct biannual aerial photo surveys; map and ground truth terrestrial and marine ecosystems; conduct comparative monitoring studies on Midway and Kure; develop curriculum materials for school system; and develop educational/interpretive materials for the general public and Midway and Kure personnel. Though French Frigate Shoals will suffer in this respect, funds may be available for increased monitoring of wildlife, habitat and alien species on other Refuge islands. Implementation of these strategies will offset the negative impacts on wildlife resources as listed below.

C. Negative Ramifications

1) Hauled-out seals and basking turtles on the beaches of Tern Island and seabirds nesting in the interior may be disturbed during the phase-out period by the burning of structures and miscellaneous flammables, with the demolition and dumping of equipment and materials and by the increased small boat traffic associated with the loading of equipment on offshore vessels. This disturbance, however, will be minimized by the presence of knowlegable biologists directing and conducting the operation.

2) The lack of a permanent FWS presence at the midpoint of the Hawaiian Islands NWR will increase the likelihood of unauthorized entry at French Frigate Shoals and, to a lesser degree, throughout the island chain. Well over half of the Hawaiian monk seal pup production occurs at French Frigate Shoals and approximately 90% of the Hawaiian green sea turtle population nests there. Both turtles and seals, particularly mother-pup pairs, are susceptible to human disturbance so any increase in human presence on the beaches or near-shore areas will have adverse impacts. Intentional harrassment or illegal take could have grave consequences. Unauthorized entry would also increase the probability of an oil spill or alien species introduction. A program to regulate and monitor nearshore vessel traffic as recommended in the Master Plan would lessen this threat.

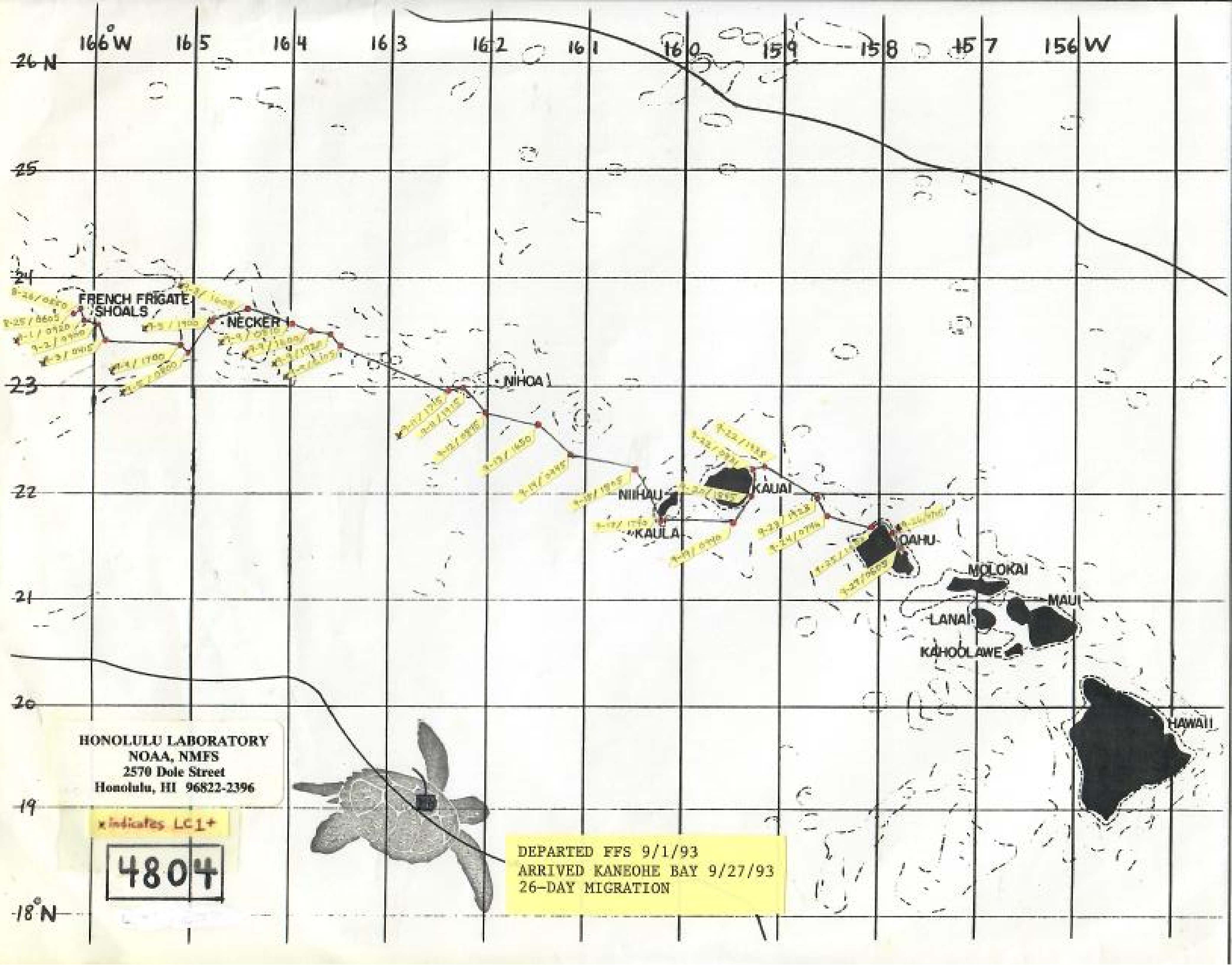
3) The lack of personnel at French Frigate Shoals during the winter months would eliminate wildlife research and population monitoring efforts for that portion of the year. Such efforts, however, would still be conducted during the most critical time of the year by field camp personnel.

4) Every year a few seals and turtles become trapped behind the seawall or other structure at Tern Island or wander up onto the runway and become disoriented. These animals may die or be seriously injured if there is no one on the island to discover their plight. Effort will be made to reduce the chances for entrapment by demolishing structures and certain sections of the seawall before March 31 but the potential cannot be eliminated.

D. Conclusion

The alternative proposed herein merely hastens the inevitable. Unless 2-4 million dollars are spent for renovation within the next few years, the seawall surrounding Tern Island will have deteriorated to the point where it is breached by storm surf. Erosion of the runway will follow soon after, resulting in the cessation of monthly supply flights. A field camp mode of operation is the only alternative at that point.

The reduction from a continuously staffed, year round operation to a seasonally staffed, field camp operation is unlikely to have serious negative impacts on the endangered species and migratory birds of the Hawaiian Islands National Wildlife Refuge. A significant portion of the funds freed by the transition will be re-directed toward the implementation of other high-priority management strategies. Regulation and monitoring of vessel traffic, aerial photo surveys, development of curriculum and interpretive materials, and increased monitoring of habitat and exotic species will all be to the benefit of wildlife populations and habitat. Funding and manpower to implement these strategies will likely be unavailable if the station continues to operate in its present mode.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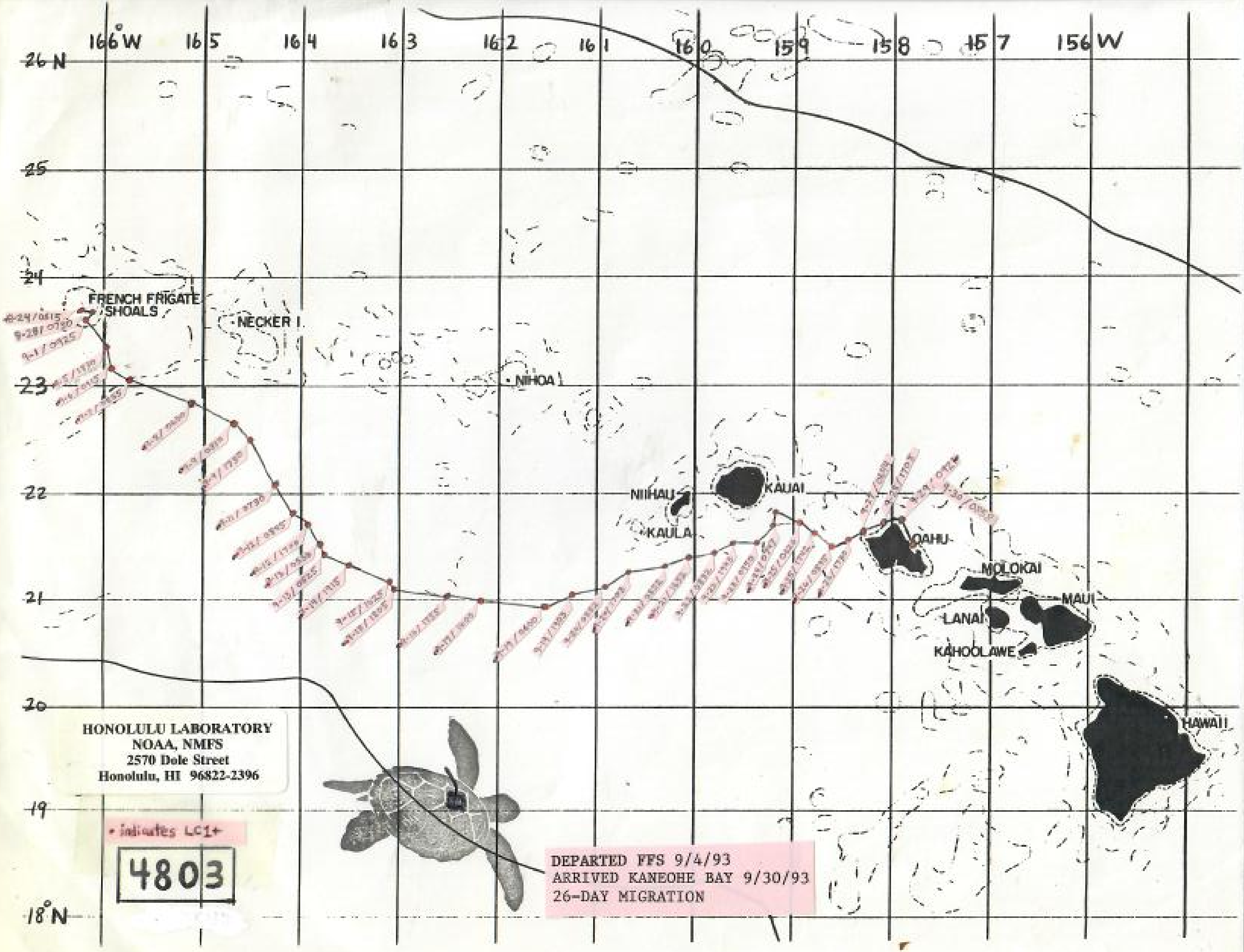
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26-DAY MIGRATION

MARK O. HATFIELD
MARINE SCIENCE CENTER

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Internet: HMSCdiro@ccmail.orst.edu

August 12, 1992

Mr. George Balazs
NMFS/SWFSC
2570 Dole Street
Honolulu, HI 96822

Dear George,

By now you must be back from what I hope was a very successful trip to French Frigate Shoals. I do hope you were able to attach the transmitters easily, and to the turtles you had been hoping to get. I really enjoyed the trip to Hawaii and especially the chance to work with you. Even now, in my minds eye, I see you pouncing on those turtles at Kaneohe Bay. Amazing!! Thank you for a great experience. I was also delighted to meet Russ and Sean, you are lucky to have such fine people working for you. I must also complement you on Christian, what a really nice kid.

Were you able to test your tags, or did Telonics want you to buy their uplink receiver? I am still curious as to what data your tags are collecting, or are the 32 bits ARGOS requires just zeroed out? If you tag again you might consider going ahead and collecting some dive information since these 32 bits are required anyway; the data would be "free" from your point of view.

It's amazing that the second tag we put on came out ok. Taking them off shouldn't be any trouble at all. They will fall off naturally in time, but you could use a small bone saw around the silicone to get the tag off and then sand down the remaining resin. Richard is the expert on getting these things off. So you might ask him if Steve gets worried.

I'm glad you took the chance on those silicone goos. I have been planning to try and publish my attachment methods poster in the Journal of Wildlife Management, if you don't mind, I'd like to include what we did at Sea Life Park. I would be honored if you would consent to join Ed, Richard and me on the publication as an author.

I'm looking forward to hearing how it went at FFS!

Best regards,

Sallie

Satellites Track Turtles In Hawaiian Waters

By Andrew Wood

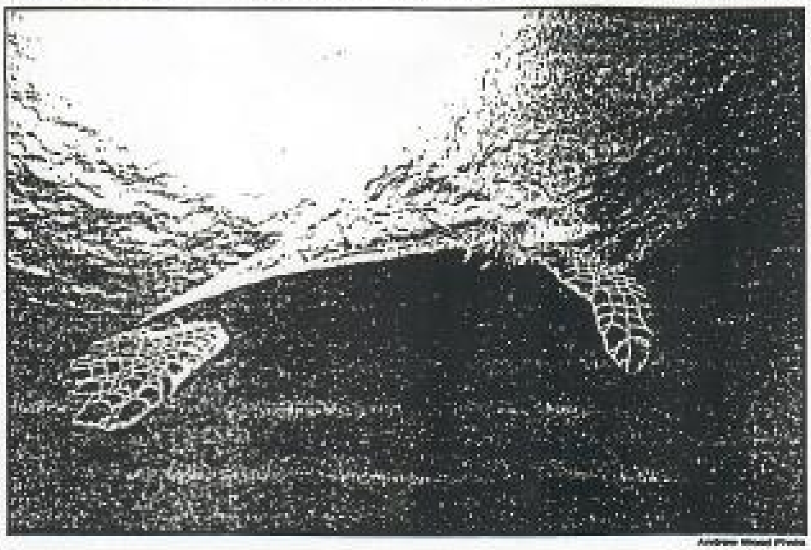
New space-aged technology has provided insight to turtle migrations in the Pacific. In the fall of last year on French Frigate Shoals, three green sea turtles *(Chelonia mydas)* had small satellite transmitters attached to their shells and information was relayed to the Argos satellite system.

The satellites tracked the endangered turtles' progress from their nesting area in the remote Northwestern Hawaiian Islands to their foraging grounds. One turtle swam 610 miles in 21 days, another swam 680 miles in 26 days.

Both were swimming against wind and current. These two turtles found their way back to Kaneohe Bay on Oahu. The third turtle swam to Johnston Atoll about 500 miles south of French Frigate Shoals.George Balazs, the turtle expert for National Marine Fisheries Service (NMFS), directed the research. The U.S. Fish and Wildlife Service which is in charge of the French Frigate Shoals National Wildlife Refuge assisted.

NMFS is the federal agency charged with enforcing the Endangered Species Act which protects sea turtles in United States waters.

Metal flipper tags have been attached to thousands of green sea turtles in Hawaii since 1973 and have shown that they traveled as much as 800 miles. However, Balazs and other scientists were uncertain about such things as routes followed, travel speed, trip duration, plus method of navigation and whether turtles returned to specific foraging pastures. Biologists were pleased with the opportunity to use this new technology to shed some light on the behavior of this ocean reptile.



Andrew Wood Photo

Using transmitters and satellite technology, scientists are learning more about the migration habits of the Pacific Ocean's sea turtles.

The Argos satellites, sponsored by the U.S. and France, are used to track a wide variety of wildlife. Drifting buoys are also tracked to provide information on ocean currents and other ocean features.

Two satellites in polar orbits circle the earth about every 100 minutes and relay information to France.

The data is then processed and forwarded to the Argos facility in Maryland.

The French Frigate Shoals are a series of small islets and atolls about 550 miles northwest of Honolulu. They are part of the Hawaiian Islands National Wildlife Refuge, and are an important nesting area for sea turtles.

These atolls are also home to the rare monk seal and millions of seabirds.

The Hawaiian Islands National Wildlife Refuge was designated in 1909 by President Theodore Roosevelt, and includes most of the small islets, atolls and reefs between Nihoa Island and Pearl and Hermes Reef in the Northwestern portion of the Hawaiian archipelago. These islets — also called the Leeward Hawaiian Islands — span the more than 1,000 miles between Kauai and Midway.

Environmental Groups Fight Proposal For Artificial Hawaii Lagoon

Environmental groups may have won the first round in a fight to stop a project that would have required the blasting and dredging of fringing coral reef on the Big Island of Hawaii. The question remains; did they deliver a knockout punch to the development?

On the drawing board: a manmade, inland, 30-acre lagoon that was originally proposed in 1987 as a 200-slip marina. The Japanese-allied Mauna Lani Resort, developer of the revised "Cove" project, claims the artificial lagoon will have limited boat access. Offshore excavation and blasting of a channel, 600 by 200 feet and 15 to 18 feet deep through a public beach and submerged reef is what prompted the Sierra Club West Hawaii Group, The Surfrider Foundation and others to testify against the Mauna Lani Cove Project. Opponents claim the development would do irreparable damage to the fringing reef and its inhabitants, including the endangered green sea turtle. Ed Lapenas, liaison for the intervening groups, says "through the course of a 5 day conicated case hearing, (we) challenged Mauna Lani's ability to conduct this kind of environmental experiment".

To provide circulation, two salt water wells pumping as much as 13.5 million gallons of water a day from the ocean into the lagoon are proposed. Lapenas says no project of this type and magnitude has ever been undertaken worldwide. Also, he adds that the developers have no "real world" experience to base their claims that the development, and the necessary blasting and dredging to complete the project would do no damage to the coastal ecosystem.

Two experts from the Scripps Institute of Oceanography agree. Drs. Scott Jenkins and Douglas Inman testified that the project would interfere with the natural circulation processes of the coastal area and would cause irreparable damage to the offshore reef by focusing sediment transport and any chemical contaminants that would emanate from the cove during this water exchange process. Interveners in the case claim its environmental impact statement (EIS) prepared by the Mauna Lani Hotel was incomplete. They say the entire plan is a large experiment on Hawaii's coastal reefs. They also claim much of the EIS was based on 2 days of data collection. Mike Matsukawa, who presided over the hearing for the Cove Project permits, recommends "the (Hawaii County) Planning Commission deny the applicant's request..." But in his 47-page report to the Planning Commission, Matsukawa suggests that the commission collect more data and reapply for permits.Local sources claim they have witnessed the uprooting of large coral heads in front of the hotel by heavy equipment, and the importation of fine sand from Oahu that they believe is choking the coral reef. Sources say Hawaii County Council Chairman Spencer "Kalani" Schutte testified in Honolulu in favor of a state resolution to allow the leasing of five acres of ceded underwater land and reef to the Mauna Lani so needed blasting of the channel could be accomplished. Such endeavors are unprecedented in Hawaii where all beaches to the high watermark are public. Furthermore, no public beach or reef has ever been sold or leased. Divers and others are concerned about the development's impact on the fledgling coral reef.

UNDERWATER USA NOV. 93

21 January 1988

MEMORANDUM FOR: George Balazs

FROM: Jerry Wetherall

SUBJECT: Hawaiian sea turtle recovery definitions, viable populations, etc.

I've given some thought to the issues raised by Fullerton regarding the recovery criteria. My views are as follows:

(1) The recovery criterion given in the Recovery Plan, i.e., restore and maintain the nesting population (on each currently used nesting beach) to the carrying capacity of the nesting habitat, is to me quite reasonable. One problem, however, is that we did not define what we meant by "carrying capacity". My notion of this is the number of nesting females that results in the maximum average hatchling production. This target population level is measurable, based on our knowledge of egg deposition rates, nesting habitat requirements, egg and hatchling survival as a function of nesting density, etc. One nice thing about this criterion is that it hinges on the life history phase about which we know the most. If Charlie objects to the term "carrying capacity", perhaps we can use an alternative. A better term may be "optimum nesting population". The turtle nesting situation has parallels with salmon nesting, where the term "optimum escapement" is used to define target spawning populations and densities, and where there is a limit to the number of fry which can be produced in a given spawning area. In the case of salmon, the optimum parent nesting population is usually defined as the number of spawners which maximizes the expected number of progeny recruiting to a fishery operating just prior to the spawning of the yearclass. In the case of turtles, it could be defined simply as the number of nesters producing the maximum average number of hatchlings (with turtles there would be problems in optimizing with respect to number of recruits to other developmental stages, because of our ignorance of population parameters, the long time lags, and so forth).

(2) The alternative suggested by Charlie, "viable population", opens up a whole new bag of considerations. In the literature I've seen on "viable populations", the definition of this term is very loose. Basically, it means the population level at which, according to our best information, the probability of extinction is no greater than some specified level. So it's arbitrary, and the question is, who determines the level of risk? Further, the behavior of models used to predict such extinction probabilities depend critically on the underlying assumptions regarding vital parameters, and especially on the nature of the individual variation in mortality and natality rates. Most of the models I have seen are very abstract, and inadequate for setting meaningful recovery targets in practice. At any rate, given most folks' risk tolerance, it would probably be concluded that the present population is viable (at least the population depending on East Island nesting), and we'd be out of business. I'd rather find out how far we are from our original target, i.e., maximum hatchling production. At the same time, I'd like to see any original documents which discuss the

rationale for placing the various species of sea turtles under protection of the ESA, and the criteria used. Was there an explicit determination that the various population levels were so low that the probability of extinction was at an unacceptable level? What level? If we knew specifically on what basis the turtles were listed in the first place, we would be in a better position to determine when they should be delisted.

(3) We did not consider the issue of exploitation, because we thought the other social objectives of restoring a population for esthetic, educational and non-consumptive recreational benefits were paramount. If Charlie insists that the Recovery Plan allow for the possibility of harvests at some point down the road (if not now), then there is a lot more to talk about. All sorts of harvest schemes could be imagined. For example, one possibility would be to forbid any taking of turtles except in those years when the optimal nesting population (as defined above) was exceeded. In such years, providing the overflow nesting population could be forecast within the nesting season, a quantity of eggs could be selectively removed from the beach, in such a way as to mitigate the effects of the excessive nesting, artificially incubated, hatched and placed into some rearing facility where they would be cultivated for later harvest, distributed to licensed pond operators, etc. So, in this way it might be possible to define a "surplus production" from the wild population in certain years, which could feed an artificial rearing and harvesting operation. The economics of such an operation are another matter, and in no way am I suggesting such a scheme. Another kind of harvesting program would be one which exploited juvenile or subadult turtles. Among the many problems with this type of plan would be that we know too little about the size of these segments of the population. To consider any plans of this sort would require a much better knowledge of turtle population dynamics than we now have. Although I have begun to put together a very rough turtle population simulation model which would allow some exploration of such ideas, it would be foolish to suggest any kind of harvesting scheme without much more data.

(4) In sum, I favor our original recovery target, with slightly different terminology. I think the "viable population" concept is too loose for application to our situation, given our meager knowledge of population dynamics and the problem of setting the risk level. My personal view is that the intangible social benefits (esthetic, educational, etc.) of maintaining a large (i.e., "carrying capacity") population exceed any benefits that would accrue from harvesting. In any case, the notion of harvesting is premature given our lack of knowledge.

George
FYI Jerry

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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March 17, 1988 F/SEC5:LHO:idw

Dr. William J. Richards, Editor
Bulletin of Marine Science
RSMAS
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Dear Bill:

I have reviewed the paper entitled "A report on the status of sea turtle headstarting," by Ross Witham, and was disappointed in the lack of sufficient coverage and detail of a very important subject. It is primarily a review of the history of various head-start projects and results from releases of headstarted turtles, and a cursory account of captive rearing techniques. I guess I was expecting an in depth treatment--at least that's what the title, abstract and introduction implied. Headstarting is more than just a technical issue, and the author stated that his objective was to provide as much current information as possible and to present opinions for and against headstart programs. Unfortunately, he neglected to do so; the pros and cons of headstarting were not thoroughly discussed, and the important aspects of egg handling and incubation techniques were completely omitted.

Technically speaking, headstarting only involves raising turtles in captivity for the first several months of their life. Nevertheless, all headstart projects must obtain their turtles from eggs incubated under controlled or semi-controlled conditions. This initial and critical phase of all headstart projects is vital to the overall success of the project in terms of survivorship of the captive-reared turtles prior to their ultimate release in the wild. It is incumbent upon headstart project personnel to take particular care to avoid the extra mortality and sex-temperature bias frequently associated with egg collecting and incubation activities. In the final analysis, all statistics on the survivorship of these headstarted turtles should include data on the number of hatchlings produced from all the eggs collected and incubated as well as the number of hatchlings that survived captivity and were released. Survivorship from "cradle to the sea" would be a more accurate assessment of the success of the project in circumventing natural and/or uncontrolled mortality.

Recent discussions on headstarting at WATS I and II set forth some basic principles and guidelines to follow concerning the application of various conservation measures. Under the Management Options section of WATS I (Proceedings of the Western Atlantic Turtle Symposium, San Jose, Costa Rica, July 17-22, 1983. Vol. 1:

220-222) panel members ranked headstarting as the last option out of ten action items recommended to recover six different species of sea turtles. The WATS I "Manual of Sea Turtle Research and Conservation Techniques," (2nd Edition, November 1983, pages 100-101) states that protection of natural populations and their habitats takes priority over headstart programs. It goes on to list the criteria used to evaluate the adoption of this experimental technique as a management tool. Two papers presented by panel members of the Management Options session of WATS II (October 12-16, 1987, Mayaguez, P.R.) emphasized protecting older subadult turtles rather than eggs or juveniles if we are to recover or stabilize the populations effectively. The fact that these issues are not addressed in this paper is an oversight; the merits of headstarting must be discussed. The high costs involved, both in money and labor, and the vulnerability of turtles at this particular life stage to pathogens before their immune systems develop fully, dietary disorders, and other sources of trauma are legion. A thorough understanding of these problems by managers of turtle projects is mandatory and these items need to be included in any status review paper.

The good news is survivorship of headstarted turtles can be increased with good husbandry, as the author states. The bad news is we are not sure it will help recover turtle populations--it could contribute to overall mortality because of the problems inherent in high density culture methods, and the possibility we might be targeting the wrong life stage for much of our attention and resources.

In conclusion, if the author does not wish to expand upon the scope of the paper, I suggest the title be changed to something more regional--"Headstarting Florida Green Sea Turtles: A State of Florida Conservation Effort." Also rewrite abstract-introduction to more precisely describe the contents.

Sincerely,

Larry H. Ogren
Fishery Biologist (Research)

REVISED FINAL AS PER ECF MEMO OF 11-13-85

Operational Procedures for the Hawaiian Sea Turtle Recovery Team

Charge

The Recovery Team will develop a plan for the green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) sea turtles normally found in Hawaiian waters, which should lead ultimately to delisting of the species.

Emphasis of the plan is to develop alternative research and management measures, based on biological and ecological parameters that will promote the recovery of sea turtles. Among other things, the plan should identify: a mechanism for monitoring the status of sea turtle populations, activities to restore nesting habitat, sources of mortality and recommended mitigating measures, and develop programs to improve recruitment. It should not deal with socio-economic and political issues. These issues will be considered by the NMFS and the FWS when selecting and implementing the preferred options from the alternative measures presented in the final recovery plan.

The Recovery Team is encouraged to carry out whatever communications are necessary to develop biologically and ecologically alternative measures for the plan. All draft plans should be submitted to the Southwest Regional Director of NMFS before being subjected to outside review. The Regional Director will be responsible for distributing and soliciting comments on written drafts of the plan.

Recovery Plan

Description

A Recovery Plan is a guide that delineates and schedules those actions required for securing or restoring an endangered or threatened species as a viable self-sustaining member of its ecosystem. A typical plan should include: (1) an introduction, which contains relevant information about habitat requirements, population limiting factors, past and current distribution, and conservation efforts; (2) identification of the objectives of the plan, including limiting factors affecting the species and the measures or actions required to alleviate or lessen these factors. These objectives can be revised and refined as new information is obtained during the development of the plan; (3) an implementation sub-plan which identifies agency assignments, priorities and where possible, estimated funding required for the actions described in Section 2, since most Federal budgeting is done in three year cycles; and (4) an appendix, which should include appropriate background material.

Implementation

The final product of a Recovery Plan is a "job list" with suggested assignments to cooperating parties and agencies for action. These jobs can be one-time actions, such as delineating tracts of land that should be purchased, closing an area to public access, or continuing operations such as management of a refuge or law enforcement. Recovery Plans can form the basis for or provide support for NMFS and FWS endangered species program funding, including research, habitat protection, enforcement and habitat acquisition. Funding estimates and acquisition of funds for activities of other agencies lie with the implementing agencies.

Operations

NMFS and FWS Oversight:

The NMFS and FWS exercise their direction over Teams through the following procedures, which provide the necessary oversight as required by the Act:

(1) By the appointment, removal, and replacement of Team members;

(2) By the approval of Recovery Plans and their subsequent amendments;

(3) By instructions to the Team Leader and members regarding Plans.

(4) By instructions to NMFS and FWS representatives.

Communication

Teams meet as frequently as necesssary for matters such as preparing plans, subsequent revisions and assistance in coordinating implementation. At least one scheduled annual meeting is essential for this purpose. It is recognized that much of a Team's business takes place within the context of the Recovery Plans, but it is often supported by written communication and dialogue among members. It should be remembered that the best Team decisions are made through personal interaction, and that meetings, on a regular basis, are a means to accomplish this. Although an annual meeting and annual report is the minimum desired to keep all cooperating parties informed, each Team should prepare minutes of each meeting and distribute them to all cooperating parties and affected States and agencies. Reports on accomplishments, such as inventory work, often are presented at Team meetings and become a part of the minutes. A copy of such minutes should also be sent to the Regional Office. This office needs current population and distribution information for planning purposes and to answer inquiries from writers, conservation groups, agencies and others. It must be emphasized that a free flow of information and recommendations to and from the Recovery Team is highly desirable. Any individual should feel free to communicate personal thoughts or ideas concerning the recovery of a species directly to a Recovery Team Leader or any Team member. Communications between Recovery Team, and any interested parties should be open. NMFS and FWS members of Recovery Team will represent NMFS and FWS, respectively, and may receive direction and instructions regarding NMFS and FWS positions relative to the species concerned from the Regional Directors or their designated representatives. However, NMFS and FWS Team members will receive direction concerning their other Team responsibilities from the Team Leader and should contribute their best professional skills.

Funding

Salary, per diem, and travel costs associated with Recovery Team activities are normally borne by members' employing agencies. Routine business expenses of the Team as a whole may be borne by the Team, through an account provided by the Regional Directors or may be provided by the Region directly. Travel expenses of consultants and non-Federal or non-State members on Team business, clerical and drafting services, supplies, printing costs, and other special services are examples of such expenses. Under certain circumstances, and at the discretion of the Regional Director, travel expenses of Federal or State Team members may be paid by the Region. Observers, will, however, provide their own expenses.

Financing of routine Team business can be handled between the Team Leader and Regional Director who will notify the Team Leader, in writing, stating the amount available to support the Team. The task of overseeing the operation of a Recovery Team is borne by the Regional Director.

Processing Recovery Plans

A Team's first planning objective is the preparation of a Recovery Plan draft that is transmitted to the Regional Director. The drafts are based on what is biologically and ecologically practical and feasible for the species and should not consider socio-economic or political restraints. Before a draft is transmitted to the Regional Director, The Team is encouraged to obtain information from other known experts in the field on biological or ecological factors affecting the species. The Technical Review Draft will then be transmitted to the Regional Director prior to any distribution for review. With regard to realty considerations, a Team may indicate, if it has sufficient knowledge, tracts which should be considered for acquisition. However, they will not contact landowners or enter into appraisal or negotiating activities since these activities are the responsibility of the Federal or State agencies involved and could adversely affect later attempts to acquire the land. With regard to economic considerations, a

Team should indicate, if it has sufficient knowledge, cost estimates of biological recovery actions recommended in the plan. However, they will not address possible economic effects of recovery actions on the local economy or contact local officials or businessmen whose activities might be economically affected by implementation of the plan. In summation, the Team should address alternative biological considerations and leave political, socio-economic, and media relation concerns to the Federal and State participating agencies charged with the responsibility for coordination in such areas. Non-biological concerns will be addressed by appropriate agencies after the Team has officially transmitted its complete draft plan to the Regional Director. Once a draft is officially submitted to the Regional Director by the Team and the Regional Director accepts it as satisfactory for further review, the draft will be transmitted, with comments to all cooperating organizations and the Assistant Administrator for review and comment as an agency review draft. Comments are requested within 45 days from all organizations other than the Assistant Administrator. These organizations should specifically be requested to review and approve actions suggested as they relate to the agency's respective responsibilities in the plan.

Following receipt of cooperators' comments, the Regional Director may elect to return the draft plan to the Team for modification as needed. However, any conflicts in the draft concerning political or socio-economic considerations will be resolved by the Regional Director. After the 45-day comment period is terminated and the Assistant Administrator's comments have been received, the Regional Director will have 60 days to submit the completed plan, with cooperators' comments, to the Assistant Administrator for approval.

Draft plan covers must be clearly marked "TECHNICAL REVIEW DRAFT, SUBJECT TO CHANGE," or "AGENCY REVIEW DRAFT, SUBJECT TO CHANGE," as appropriate.

The approved plan shall be returned to the Regional Director for printing. The Regional Director will disseminate copies as needed to cooperators at the Regional and local levels and forward 25 copies of the approved plan to the Assistant Administrator who will disseminate copies of the approved plan to cooperating organizations at the Washington level.

Biological Review Assistance

The Recovery Team, in addition to its roles with Recovery Plans, may upon request, provide assistance to the Regional Directors on biological matters pertaining to its assigned species. Assistance activities will be kept separate from the Recovery Plan process. Two examples of important assistance roles are providing recommendations to the Regional Director, upon request, of areas that should be considered for determination of "Critical Habitat" and review of permits "to take" listed species under Section 10 of the Act. The terms "Critical Habitat" or "determine Critical Habitat" will not be used in Recovery Plans since they may cause confusion with the determination identified in Section 4 of the Endangered Species Act and described in the Federal Register. No habitat should be referred to as "Critical Habitat" until so determined and published in the Federal Register by NMFS. Misuse of the term in an approved plan could be construed to mean NMFS approval of "Critical Habitat" as described in the plan prior to its formal designation.

A Recovery Team should identify essential areas necessary for maintenance or restoration of their assigned species, but not refer to it as "Critical Habitat."

Coral Reefs (1994) 13: 137–144

Coral Reefs

Reports

The rate of predation by fishes on hatchlings of the green turtle (*Chelonia mydas*)

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Accepted 20 September 1993

Abstract. This study addresses the need for empirical data on the survival of sea turtle hatchlings after entry into the sea by (1) developing a method for measuring marine predation; (2) estimating predation rates while crossing the reef; and (3) investigating the effect of environmental variables on predation rates. Predation rates were quantified by following individual hatchlings, tethered by a 10 m monofilament nylon line, as they swam from the water's edge towards the reef crest. Predation rates under particular combinations of environmental variables (tide, time of day, and moon phase) were measured in separate trials. Predation rates varied among trials from 0 to 85% with a mean of 31% (SE = 2.5%). The simplest logistic regression model that explained variation in predation contained tide and moon phase as predictor variables. The results suggest that nocturnal emergence from the nest is a behavioral adaptation to minimize exposure to the heat of the day rather than a predator-escape mechanism. For the green turtle populations breeding in eastern Australia, most first year mortality is caused by predation while crossing the reef within the first hour of entering the sea.

Introduction

Green sea turtles (*Chelonia mydas*, Linnaeus 1758) spend most of their lives at sea. The females leave the water briefly to dig deep nests in coastal and island sand dunes in which they lay a relatively large clutch of about 100 eggs (Carr 1967; Bustard 1972; Ehrhart 1982). In each nesting season 500–800 eggs are laid in several clutches. Individual turtles do not breed annually but return to the nesting beach at 4–6 year intervals (Limpus et al. 1984). Age to sexual maturity has been estimated to be between 30 and 50 years and may differ significantly between populations using different foraging areas (Limpus and Walter 1980; Balazs 1982; Bjorndal and Bolten 1988). The reproductive life span of marine turtles is not known, but has been estimated for a population of loggerhead turtles (*Caretta caretta*) in the southern United States as 32 years (Frazer 1983).

The only parental care offered to the eggs is the female's choice of the nesting site and the construction and burial of the nest (Carr 1973; Bustard and Greenham 1969; Bustard 1972; Hendrickson 1980). The eggs hatch after incubating for 7–11 weeks and the hatchlings take several days to dig through the sand before they emerge, usually during the night (Carr 1973; Mrosovsky 1968; Bustard 1967; 1972; Miller and Limpus 1981; Miller 1985). On emergence, they rapidly make their way to the sea, where they are lost to human observers until, several years later, they are sighted again in their shallow water feeding habitats as small juveniles (Carr 1973; Limpus et al. 1984).

Many aspects of sea turtle life history are a direct consequence of anatomical and physiological limitations imposed by terrestrial ancestors (Hendrickson 1980). The unusually large number of eggs produced distinguishes marine turtles from most other reptiles (Hendrickson 1980). High mortality during the early life stages (i.e., eggs and hatchlings) is usually considered one of the major factors leading to such high fecundity. The fertility of eggs may exceed 95%, but emergence success of the hatchlings may be somewhat lower even in undisturbed nests (Miller 1985; Whitmore and Dutton 1985; Wyneken et al. 1988; Harry and Limpus 1989). Although the effect of predators recently introduced by man into sea turtle nesting habitats can be substantial, most workers have suggested that few of the natural predators of eggs and hatchlings on the beach normally inflict heavy losses (Limpus 1982; Stancyk 1982).

Thus, natural mortality of eggs and hatchlings prior to entry into the sea does not seem high enough to explain the observed high fecundity. However the survivorship of hatchlings once they enter the water is unquantified. Estimates of mortality after hatchlings enter the sea are mostly anecdotal or based on theoretical considerations (Hendrickson 1958; Hirth 1971; Bustard 1972; Witham 1974; Frith 1975; Balazs 1980; Richardson and Richardson 1982; Crouse et al. 1987). Witherington and Salmon (1992) recently attempted to measure predation on loggerhead turtle (*Caretta caretta*) hatchlings but their conclusions are limited by small sample sizes and non-standardized methods.

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This study addresses the need for empirical data on survival after entry into the sea by (1) developing a method for measuring aquatic predation; (2) estimating predation rates of hatchling turtles in the first hour or so of their aquatic life; and (3) investigating whether environmental variables have a significant effect on predation rates.

Material and methods

Study site

Heron Island reef, at the southern end of Australia's Great Barrier Reef, is an elongate lagoonal platform reef approximately 11 km long and 5 km wide at its eastern end (Fig. 1). A vegetated sand cay, Heron Island, is situated on the western end of the reef. Tidal range varies between 2 m (springs) to 1 m (neaps). On spring tides a large proportion of the reef crest and reef flat is exposed at low water, isolating a large lagoon which occupies much of the eastern reef. Water depth in this lagoon ranges between 0.5 and 7 m at low tide. The approximate areas of the three major habitats are: reef crest and reef slope ≈ 5.5 km^2, reef flat ≈ 14.3 km^2 and lagoon ≈ 8.4 km^2 (Limpus and Reed 1985). Because of the greater spatial heterogeneity in the lagoon, measurements of predation were limited to the more uniform reef flat and reef slope habitats.

Heron Island provides a nesting habitat for green turtles which dig their nests in the vegetated sand dunes. The emerged young cross 10–30 m of dune and beach area before entering the sea. As with other green turtle rookeries, the total number of females using Heron Island's beaches for egg laying may vary by several orders of magnitude from season to season (Limpus and Nicholls 1988). During the three years of this study, however, the numbers of nesting turtles at the Heron Island rookery were similar to a total of approximately 500–1000 females for the season, and 80–120 turtles nesting nightly at the peak of the nesting season. (Limpus 1989). As there were no cyclones or other major environmental perturbations during this period, it was assumed that the numbers of hatchlings were similar between nesting seasons. Thus, three years' data were analyzed as a single set.

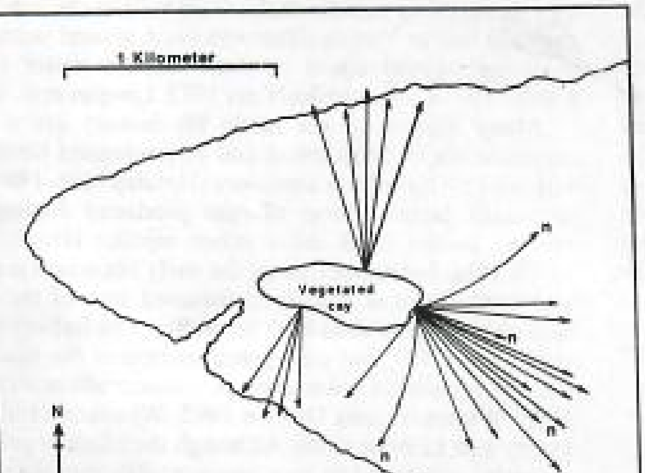

Fig. 1. Map of Heron Island reef showing boundaries of major habitats. The island is shown in solid colour, the reef flat surrounding the lagoon is stippled. The western end of the reef and Heron Island is enlarged. Arrows indicate the directions taken by free-swimming hatchlings after release from the beach. "n" denotes those hatchlings released at night

Collection of hatchlings

Hatchlings were collected shortly after emergence as they crossed the beach on their way to the sea. All animals were stored in Styrofoam boxes which were kept in a cool, shaded area. Most animals were used in experiments within 12 h of capture and no animals were held in captivity for a period exceeding 24 h. After placement in the boxes the hatchlings would soon assume quiescence, but would regain activity in response to handling. Occasionally hatchlings failed to regain their post-emergence vigor and such animals were not used in the experiments.

Observations of predator-prey interactions

Free-swimming hatchlings ($n = 57$) were followed by snorkel divers during mid- to late afternoons at the maximum distance allowed by conditions of visibility (generally about 5 m). Turtles were followed until they were eaten, lost from view or reached deep water over the reef crest. Predator-prey interactions were observed and the outcome recorded. Movements of 24 hatchlings were tracked by compass.

Measures of predation

Most predation trials were carried out on the northern reef flat and the adjacent reef slope because the prevailing south-easterly wind often made other sites unsuitable. Predation rates were quantified by following individual hatchlings for a period of ten minutes as they swam from the water's edge towards the reef crest and the deep water beyond. Hatchlings were tethered by a fine, monofilament, nylon line (Platypus 27 N 0.25 mm 6 lb and Super Schneider 0.20 mm 4 lb) which was secured through the distal edge of a post central scute. This prevented the hatchling disengaging itself, but allowed the tug of a predator to release the hatchling. The hatchlings' swimming ability was unimpaired by this tether except for some reduction in speed (see later). In most cases, the observer holding the free end of the line could feel the predation event.

Because hatchlings tended to swim directly against any tension, the lines were kept slack in order to minimize effects on the direction of swimming. To facilitate night observations a 1.5 ml plastic vial filled with 1 ml of luminous Cylume fluid was attached approximately 4 m behind the hatchlings, allowing the observers to follow the chosen path of the hatchling. These vials were never attacked by fish. The vials filled with exhausted Cylume were left attached in the daytime trials for consistency. Observers either walked or swam 8–10 m behind the experimental hatchlings. During extremely low spring tides, when the reef flat was completely exposed, predation trials were run on the rising or falling tide when water depth was just sufficient to allow the hatchlings to swim without having to crawl over much exposed coral. During high tide at night, most observers used surf ski paddle boards to follow the turtles as protection against larger sharks. Hatchlings that were not taken by fish by the end of the ten minute observation period were released from the line by the observer and allowed to swim away.

A variation of the general technique was used to investigate predation over the reef slope. Hatchlings were attached to a 20 m monofilament line without Cylume (20 m was chosen to approximate the width of the reef slope). Hatchlings were released with the observer standing on the reef crest at low tide or were released from a dinghy anchored at the crest. The turtles were allowed to swim 20 m in any direction.

These predation experiments were used to investigate the effects of three environmental variables on the rate of predation of hatchling green turtles. The variables investigated were tide, as an index of water depth (high and low tides were calculated from tide tables issued by the Queensland Marine Board), time of day (day and night), and lunar period. Days between the four moon phases (new moon = phase 1, first quarter = phase 2, full moon = phase 3, last quarter = phase 4) were categorized on the basis of the moon phase closest to the day on which an experiment took place. No experiments took place at dawn and only a few at dusk. Predation experiments over the reef slope covered only a 6 day period (12–18 February 1990) and therefore moon phase was not included as a variable in that part of the study. However, because the windward and leeward reef slopes show a marked difference in the species abundance and composition of fishes (Goldman and Talbot 1976), location was included as one of the predictor variables.

Predation rates under particular combinations of these environmental variables were measured by following 20 individual hatchlings for ten minutes each. The resulting group of 20 observations is referred to as a trial. A series of nested logistic regression models was used to examine the effects of these predictor variables on predation rates. Because predation rates were expressed as the proportion of hatchlings preyed upon in each trial, resulting in a non-continuous variate, logistic regression was considered the appropriate method for analysis (Anon 1990; G. De'ath, personal communication). When comparing successively simpler models, the usual analysis of deviance using X^2 was replaced by the F-ratio test, based on the mean deviance because the data were overdispersed. The general form of this tests is as follows:

$$F = \frac{\dfrac{^{RSS}\text{simple model} - {}^{RSS}\text{more complex model}}{^{df}\text{simple model} - {}^{df}\text{more complex model}}}{^{RSS}\text{more complex model}/{}^{df}\text{more complex model}}$$

(where RSS = residual sum of squares and df = degrees of freedom).

If the successive models are not significantly different, the more complex model does not explain the data significantly better than the simpler model and the simpler model is preferred. If the models are significantly different, this indicates that the factor that was removed from the more complex model, had a significant effect on the dependent variable (i.e., predation rate).

Validation of techniques

Effects of the monofilament line. To establish the optimum tether length, predation rates were measured using 5 m, 10 m, and 15 m lines. The 60 hatchlings used in this experiment were all from the same clutch. All three tether lengths were tested simultaneously with 20 hatchlings used for each length.

The length of the tether had a significant effect on predation rates. Increasing the distance between the hatchling and the observer from 5 m to 10 m resulted in increased predation rates. Predators showed interest in the hatchlings on the 5 m lines, but only one attack was made. Results obtained for the 10 m and 15 m lines were identical with 6 of the 20 hatchlings in each group preyed upon. Because the 15 m line would quite often get tangled on handling and because of the extra drag it presented to the hatchlings towing it, the length of line used in all the predation experiments over the reef flat was standardized at 10 m.

The swimming speed of tethered hatchlings was compared with free-swimming hatchlings to provide a basis for calculating overall predation rates during the hatchlings' swim across the reef flat. The width of reef flat to be crossed was estimated using an aerial photograph of Heron Island reef. The time required by free-swimming hatchlings to traverse a given distance was calculated.

Free-swimming hatchlings moved significantly faster than their tethered counterparts (28 vs. 16 m/min; t-test $P < 0.01$). Salmon and Wyneken (1987) obtained a similar swimming speed for free swimming loggerhead turtle hatchlings.

Observer bias. Numerous observers assisted in the field project, usually on a replacement basis. Thus, the investigation of observer bias was limited to two periods where individual observers overlapped long enough to be compared. The proportion of hatchlings preyed upon within each trial was calculated for each observer. The average proportion for each observer was then compared by the Friedman two-way ANOVA (Siegel 1956) using 'trials' as a blocking factor. The analysis was conducted separately for each period between the two different sets of observers. No significant difference was detected between individual observers ($df = 3$, $P = 0.5945$ and $df = 2$, $P = 0.2668$ for the two periods).

Results

A total of 84 predation trials were performed in reef flat habitats around Heron Island in three separate breeding seasons (23 March–5 April 1987; 4 January–3 April 1988; and 2–18 February 1990). Of the 1740 tethered hatchlings followed, nine were attacked by seagulls at the water's edge. Fresh animals were substituted for these individuals.

Observations on the behavior of hatchlings and their aquatic predators

Fish predation on the free-swimming hatchlings was high (93.6%). Of the 57 free swimming hatchlings that were followed by snorkel divers, ten were lost from sight, 44 were eaten by fish and three survived to reach the reef slope (Table 1). Most attacks were sudden rushes by demersal predators. Often hatchlings were attacked unsuccessfully by one or more predators before one finally succeeded. Of the 44 successful predation events 28 were preceded by attempted predation by fish too small or too weak to be successful. No hatchlings ever took evasive action to avoid predation.

Compass tracking of the free-swimming hatchlings ($n = 25$) indicated that they swim directly away from the island's beaches, towards the reef crest (Fig. 1). Because the circumference of the reef crest is much greater than that of the island (Fig. 1) the density of hatchlings decreases as they swim away from the beach. This effect is especially pronounced on the eastern reef flat and lagoon.

As summarized by Table 1, the most commonly observed predators were fish of the family Serranidae, followed by Lutjanidae and Labridae. Small sharks, lethrinids and eels were occasionally observed to prey on hatchlings. Long toms (Belonidae) often attempted to prey on hatchlings but were never successful. In the predation experiments with tethered hatchlings over the reef flat, *Choerodon cyanodus* (Labridae) was the most commonly observed predator. No data were obtained on the identity of nocturnal predators although some of the predators observed during the daytime are known to feed at night also (Hobson 1965; Smith et al. 1971).

Table 1. The fate of 57 free-swimming *C. mydas* hatchlings which were followed by snorkel divers during the daytime (mid- to late afternoons) over the eastern reef flat

Date/time	Outcome Eaten	Survived	Lost from sight	Predators
9 Jan 1987 1650 h	5		1	3 *Epinephelus* (var. spp.) 1 Black tip reef shark 1 *Lutjanus carponotatus*
12 Jan 1987 1700 h	2			1 *Epinephelus* sp. 1 Black tip reef shark
10 Jan 1987 1700 h	31		4	24 *Epinephelus* (var. spp.) 1 *Cromileptes altivelis* 1 Scarid 1 *L. carponotatus* 2 Serranid 1 Muraenid eel 1 *Choerodon cyanodus*
3 Feb 1990[a] 1600 h	5		3	1 *C. cyanodus* 1 *L. mahsena* 1 *C. cyanodus* 1 *L. carponotatus* 1 *Epinephelus* sp.
4 Feb 1990[a] 1600 h	1	3	2	1 *L. carponotatus*
Total (Σ = 57)	44	3	10	

[a] In 1990, hatchlings were followed off the northern reef flat which is considerably narrower than the reef flat off the eastern end of the island (used in the 1987 observations). Some of these hatchlings survived to reach the reef crest and open water

Environmental variables influencing predation: reef flat

Predation rates varied among trials from 0 to 85% with a mean of 31% (SE = 2.5%).

The simplest model that explained variation in predation contained tide and moon phase as predictor variables. Moon phase was entered into the model as the quarter about the new moon. Tides were entered into the model as high and low with no distinction made between spring and neap periods (Figs. 2 and 3). The *F*-ratio test was significant when either tide ($P < 0.0001$) or moon phase ($P = 0.0015$) was removed from the regression model indicating that both factors are important as determinants of predation rates (Table 2).

The observed and calculated probabilities of survival under the various tidal and lunar conditions are summarized in Table 3. The model fits the data well. Survival rate was the lowest under conditions of moon phase 2, 3

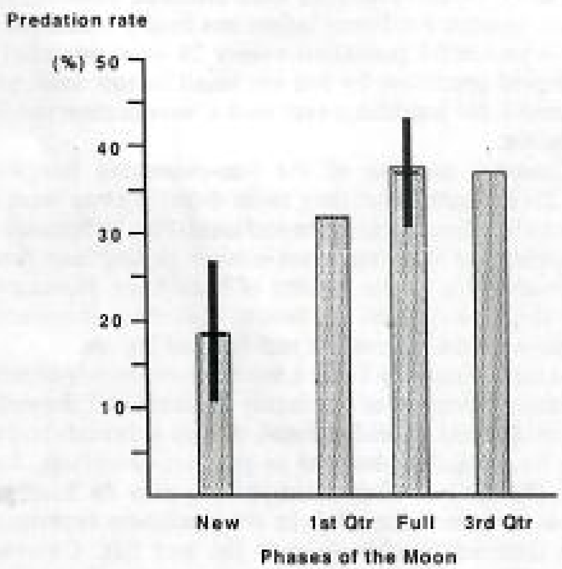

Fig. 2. Predation rates of hatchling green turtles after 10 minutes swimming over the reef flat under the four different moon phases. The mean and 95% confidence intervals of predation rates obtained in trials during the new moon and during other moon phases (combined) are indicated

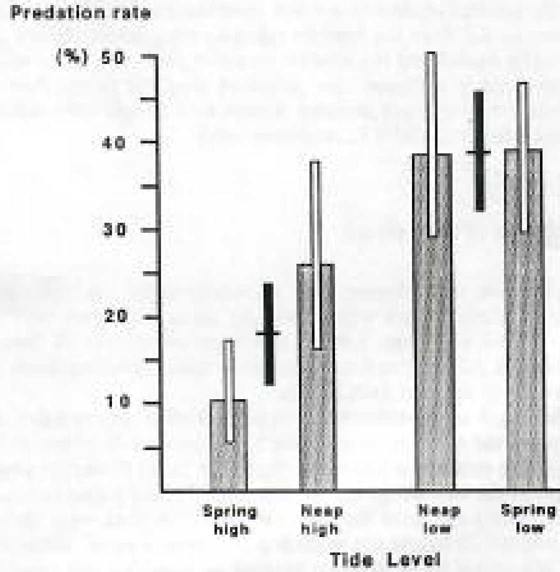

Fig. 3. Predation rates of hatchling green turtles after 10 minutes swimming over the reef flat during various tides showing the 95% confidence intervals for each tide level (clear bars). The mean and 95% confidence intervals of predation rates obtained in trials during the combined neap and spring low and high tides are also shown (dark bars)

Table 2. Summary of logistic regression analysis of predation trials over the reef flat showing deviance and degrees of freedom

Predictor variables included in model	Deviance	*df*	*F* (*df*)	*P*
Analysis 1: predation trials in reef flat habitat; entire data set				
Model 1 Time of day Tide Moon phase Time of day + tide Moon phase + tide Time of day + moon phase	257.1	71	N.A.	N.A.
Model 5 Tide Moon phase	295.4	81	0.4326 (2,79)	0.6559
Model 6 Tide	334.7	82	10.7763 (1,81) (i.e., moon phase has a significant effect)	0.0015
Model 7 Moon phase	401.4	82	28.6781 (1,81) (i.e., tide has a significant effect)	<0.0001
Analysis 2: night-time only predation trials in reef flat habitat				
Model 1 Tide Presence of moon	181.9	36	N.A.	N.A.
Model 2 Presence of moon	221.2	37	7.7702 (1,36) (i.e., effect of tide is significant)	0.0084
Model 3 Tide only	190.1	37	1.6213 (1,36) (i.e., presence of moonlight is not significant)	0.2111
Analysis 3: day time only predation trials in reef flat habitat				
Model 1 Tide Moon phase	123.1	4	N.A.	N.A.
Model 2 Moon phase	207.9	43	28.9025 (1,42) (i.e., effect of tide is significant)	<0.0001
Model 3 Tide	133.4	43	3.4083 (1,42) (i.e., effect of moon phase is not significant at 0.05 level)	0.0719

The columns *F*, (*df*) and *P* list results and probabilities of the *F*-ratio tests based on comparisons of successively simpler models. (Note that not all the successive steps involved in the backward elimination steps are shown). Analysis 1: 'Model 1' is the initial model followed by the simplest model (5) that adequately describes the data. Analysis 2: Results obtained when trials were run during the night are re-analyzed with tide and presence/absence of the moon in the night sky being the predictor variables. Analysis 3: Results obtained when trials run during daytime only are re-analyzed with tide and moon phase being the predictor variables

Table 3. Survival rates (S) (observed and estimated) of hatchling turtles after 10 minutes swimming over a reef flat under various environmental conditions

		High tide	Low tide
New moon	Observed	$\frac{171}{180} = 0.95$	$\frac{187}{260} = 0.72$
	Estimated	**0.91** (0.85–0.95)	**0.75** (0.62–0.84)
Full moon, 1st and 3rd quarters	Observed	$\frac{336}{420} = 0.80$	$\frac{446}{820} = 0.57$
	Estimated	**0.82** (0.73–0.87)	**0.56** (0.44–0.58)

(95% confidence intervals for the estimated values are shown in parenthesis)

and 4/low tide and the highest during new moon/high tide.

The data were analyzed further to test whether predation is affected by the availability of light, rather than other lunar effects. Using data for the night time trials only with moon (up or down) and tides (high, low) as predictor variables, it was determined whether the presence/absence of the moon in the night sky had a significant effect on predation. In addition, the effect of lunar periodicity on predation during the day, when illumination level did not change with changes in the phase of the moon, was also investigated. The availability of moonlight was not significant in determining predation rates ($P = 0.2111$). Also moon phase could not be entirely disregarded as a factor of significance for the daytime trials ($P = 0.0719$) adding further support to the conclusion that the phase of the

the moon significantly effects predation. Results of these analyses are shown in Table 2.

Environmental variables influencing predation: reef slope

Logistic regression analysis of 13 predation trials over the reef slopes identified no predictor variables (see methods) that accounted for the observed variability in predation rates. The observed survival rate was comparatively high and ranged between 0 and 25% with a mean of 7% (SE = 2.4%). However, a considerable proportion of the hatchlings were preyed upon (approximately 40% of those surviving at the end of their 20 m swim) while they were being retrieved in order to disengage them from their 20 m lines. Mortality that occurred during retrieval was not considered in the regression analysis. This type of predation was not observed over the reef flat.

Estimate of total predation over the reef flat

Assuming that predation rates are constant across the reef flat and that predation rates of tethered hatchlings are the same as those of free-swimming hatchlings, the proportion of turtle hatchlings that survive the swim across the reef flat to reach deep water was estimated. The number of hatchlings surviving for a given period can be estimated from the standard exponential survivorship function (Ricker 1975):

$$N_t = N_0 * e^{-Z*t} \quad \text{or} \quad N_t = N_0 * S^t$$

where N_0 is the number at the start of a run and N_t is the number alive at time "t". The symbol "Z" refers to the instantaneous rate of mortality and "S" the rate or proportion of survival in a unit of time (Ricker 1975). The instantaneous mortality rate is calculated from the experimental data by the function:

$$Z = -\text{Log}_e S = -\text{Log}_e \frac{N_1}{N_0}$$

where N_1 is the number surviving at the end of 1 unit of time, in this case 10 minutes.

The probability of survival derived from the logistic regression analyses was used to estimate the value of "S" for the various environmental factors of interest. (See Table 3 for the values of "S" which apply under various combinations of environmental conditions)

If one considers the approximately 1 km wide section of the northern reef flat, for example, which takes 30 min for the average free-swimming hatchling to cross, only 18% of them would be expected to survive and reach deep water during low tide at the first quarter of the moon. By contrast 55% are expected to survive if they enter the water during the same lunar period but at high tide. These two survival rates are significantly different, their 95% confidence ranges being 16–20% and 39–65% respectively.

Discussion

While digging out from the nest, and to a lesser degree while crossing the beach, group facilitation is quite an important feature of the hatchlings' behavior (Carr and Hirth 1961; Bustard 1967; Carr 1973). Once hatchlings enter the water, however, all associations between individuals cease (Frick 1976; Carr 1982). No semblance of schooling was ever observed in this study, nor has this behavior been noted in the literature. The seaward orientation of the hatchlings entering the water at Heron Island is consistent with the observations of previous workers (Frick 1976; Salmon and Wyneken 1987).

Because the observations on the free swimming hatchlings were timed to coincide with water depth convenient for the observers and not with high or low water explicitly, and because the period of observation was not standardized, the results obtained through the observations of free swimming hatchlings are not considered as actual measures of predation. However, in the experiments involving the tethered hatchlings, the categorical predictor variables (day/night, moon phase and tide) were determined without error and the experimental conditions (habitat, tether length and period of observation) were standardized. Thus, with certain assumptions, these experiments may be considered to approximate the true rates of predation of hatchlings over the reef flat per unit of time.

The tether, when kept slack, imposed no impediment, other than some reduction in speed, to the swimming ability of the hatchlings. However, even the relative speed of the free-swimming hatchlings did not seem to offer protection against the much greater swimming speed and maneuverability of predators, as evidenced by the observations of interactions between the free-swimming hatchlings and their fish predators; 44 of the 47 hatchlings succesfully followed over various periods (most often less than 20 minutes) were eaten by fish (i.e., 93.6%). Furthermore, few of the tethered hatchlings were taken by fish as they swam seaward over the reef slopes, although many of these hatchlings were taken by predators when their swimming became poorly coordinated threshing while being retrieved by the observer, indicating that tethering per se is not likely to increase the probability of predation.

The lower predation rates on sea turtle hatchlings during high as opposed to low tides are consistent with known patterns of fish behavior. The majority of shallow water reef fish show a strong avoidance of swimming far above the protection of the substrate as they themselves might then be exposed to predation (Shulman 1985). This is especially so with individual predators such as the serranids, and may also apply, albeit to a lesser extent, to schooling predators such as the lutjanids. With increasing water depth, a hatchling would likely be further from the bottom and thus less accessible and, in addition, less detectable, to the bottom dwelling predators.

Variation in predation associated with the phases of the moon is somewhat more difficult to account for in terms of known patterns of fish feeding behavior. Amongst other sensory inputs, visual cues are considered to be an important aid to fish in locating and seizing prey (McFarland 1991). During new moon the nights are dark, therefore fish predators might be either less active or less successful than on nights during other moon phases. This explanation, however, does not account for the fact that on many nights other than during the new moon there are several hours when the moon is not up. The availability of moon light did not affect predation rates during night trials (Table 2). Further, it would appear that the moon phase cannot be dismissed as a factor affecting predation during daylight hours (Table 2). It is therefore likely that lunar periodicity, rather than degree of illumination alone, is a significant factor influencing predator behavior. In support of this hypothesis there are numerous accounts of associations between moon phase and behavior of fish and other reef animals (Johannes 1981).

Two advantages of nocturnal emergence of hatchlings from the nest have been proposed: (1) it eliminates exposure to diurnal predators and (2) it removes exposure to the potentially lethal daytime heat of the beach. Two quantitative studies of terrestrial predation on turtle hatchlings have been published to date. Mortality of loggerhead, *Caretta caretta*, hatchlings due to predation was less than 2% at dawn at Mon Repos, a mainland beach in southern Queensland (Limpus 1973). At Crab Island, off the northern coast of Australia, between 3 and 38% of emerged flatback, *Natator depressa*, hatchlings were preyed upon while crossing the beach (Limpus et al. 1983). In addition there are a few anecdotal accounts of heavy bird predation on hatchlings that emerge during the day (e.g., Mrosovsky 1971; Fowler 1979; Stancyk 1982). In the absence of comparative studies of nocturnal versus diurnal predation it is not possible to conclude whether nocturnal emergence offers hatchlings significant protection from predation as they cross the beach. The greatest predation of hatchlings probably takes place after they have entered the water (Hendrickson 1958; Bustard 1967, 1972; Limpus 1978; and this study). Reef fish show pronounced diel rhythms of activity with different composition of species feeding during the day and the night (Collette and Talbot 1972; Smith et al. 1972). This diel periodicity is also reflected in the presence and the feeding activity of the various carnivorous species in different reefal habitats. Yet surprisingly, in this study of aquatic predation, the day/night factor did not emerge as a significant predictor variable. Crossing the reef flat at night as opposed to during daytime conferred no detectable protection from aquatic predators. Considering further that most terrestrial predation occurs while the eggs/hatchlings are still concealed under the sand, soon after oviposition and again after hatching (Carr 1973; Fowler 1979), it is most likely that nocturnal emergence from the nest is a behavioral response to minimize exposure to the heat of the day rather than a predator-escape mechanism.

No attempt was made to investigate the larger scale spatial and temporal variation of aquatic predation of hatchlings, although it is almost certain that significant variations exist. Limpus (1978) and Mortimer (1982) noted that the intensity of predation in the water may be influenced by the type of offshore habitat that hatchlings must cross. Published descriptions of turtle rookeries seldom give details of the type of aquatic habitat immediately adjacent to the nesting beach, but throughout their global distribution, nesting beaches are not necessarily bordered by coral reefs, e.g., Tortuguero (Meylan 1982) and Ascension Island (Mortimer 1982). Predation rates are likely to be different for different seaward zones. Predation on logger-head turtle hatchlings was relatively low on the east coast of Florida (Witherington and Salmon 1992).

Most green turtle nesting in eastern Australia occurs on coral cays which are surrounded by reefal habitats comparable to Heron Island reef (Limpus 1978). It is therefore reasonable to extrapolate from the results of this study and conclude that for the green turtle populations nesting along the Great Barrier reef cays, most first year mortality occurs as a result of predation within the first hour of entering the sea.

Acknowledgements. This study was conducted under permits from the Great Barrier Reef Marine Park Authority, the Queensland National Parks and Wildlife Service (Q.NPWS) Queensland Fisheries, and the James Cook University of North Queensland Animal Research Ethics Committe. Logistic support was provided by the Q.NPWS and Special Research Grants from the James Cook University of North Queensland. I thank the following individuals for their contributions: Drs. R. Alford, G. De'ath, P. Doherty, B. Goldman, C. J. Limpus, H. Sweatman and Prof. H. Marsh. Further, I am grateful to the many volunteers who assisted in following the hatchlings.

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Table 1. Estimated number of green turtles nesting at East Island, French Frigate Shoals, 1973-2004.

Year	Survey nights	Estimated nesters	90% bootstrap CI lower	90% bootstrap CI upper
1973	43	67	65	68
1974	59	105	103	106
1975	30	120	115	125
1976	13	39	31	47
1977	9	82	67	97
1978	11	101	89	113
1979	13	77	67	86
1980	20	52	46	57
1981	23	149	140	158
1982	19	130	121	137
1983	17	35	30	40
1984	20	199	185	212
1985	18	162	152	172
1986	29	69	62	74
1987	26	143	135	150
1988	101	180	179	180
1989	143	294	293	294
1990	133	150	150	150
1991	119	107	107	107
1992	129	384	383	384
1993	31	191	185	196
1994	26	132	127	137
1995	31	252	246	257
1996	31	367	358	374
1997	33	504	494	512
1998	32	64	61	66
1999	31	209	203	214
2000	33	353	346	360
2001	31	314	304	320
2002	34	467	459	475
2003	41	219	215	223
2004	38	548	542	554

Estimated number of green turtles nesting at East Island, French Frigate Shoals.

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1979	13	77	67	86
1980	20	52	46	57
1981	23	149	140	158
1982	19	130	121	137
1983	17	35	30	40
1984	20	199	185	212
1985	18	162	152	172
1986	29	69	62	74
1987	26	143	135	150
1988	101	180	179	180
1989	143	294	293	294
1990	133	150	150	150
1991	119	107	107	107
1992	129	384	383	384
1993	31	191	185	196
1994	26	132	127	137
1995	31	252	246	257
1996	31	367	358	374
1997	33	504	494	512
1998	32	64	61	66
1999	31	209	203	214
2000	33	353	346	360
2001	31	314	304	320
2002	34	467	459	475

JAW
7 August 2002

[6] From: George Balazs 5/20/93 11:39AM (1220 bytes: 29 ln)
To: George Balazs
Subject: 47-U

-------------------------------- Message Contents --------------------------------

If turtle was sighted before this, it was classified as UNKnown
Adult Female nesting on Tern Is., French Frigate Shoals

1st sighting: 6-23 0310am Tags: LHF - A989 Crawling
LFL - A991
RFL - A990
RHF - stump/no tags

Curved Carapce Length= 104 cm

6-24	2350pm	Crawling
6-26	0747am	DEC
6-29	0536am	DEC
7-13	2022pm	Crawling
	0245am	Crawling
7-15	0445am	Digging Body Pit
7-16	0320am	DEC
7-17	2217pm	DEC
7-18	0010am	Crawling
	0415am	Digging Body Pit
7-19	0358am	DBP

No further resightings.....................

[13] From: Bryan Winton 6/4/93 4:16PM (581 bytes: 9 ln)
To: George Balazs
Subject: Re[3]: 46U

------------------------------------ Message Contents ------------------------------------

Yes, your right. "Correction, however" The male you are thinking about is 60-U NOT 46-U which is a female.

60-U is a Male w/ a missing Right Front Flipper (healed). I apologize for not including that this last time.

*****Will be working on the Tern Island stuff first thing Monday morning. Had plenty of things to stay busy this past week....just the way I like it!!!

[3] From: Mitchell Craig 5/26/93 10:35AM (607 bytes: 7 ln)
To: George Balazs
Subject: turtle on P and H

Message Contents

Howdy George. Please excuse the delay in reporting this to you. While on Southeast I. at Pearl and Hermes in April (4/20) Steve Gregg noticed a living adult male green turtle with a fresh 3/4 amputation of the right foreflipper and a 1/2 amputation of the right hindflipper. This turtle also had 46-U moto-tooled on (I think) the right side. We have photos of the moto-tool and the injuries.

[8] From: Bryan Winton 6/2/93 8:31AM (352 bytes: 10 ln)
To: George Balazs
Subject: Re: 46U

------------------------------- Message Contents -------------------------------

46U Information:

Initially sighted: 6-21-92 Tern Island 0455 East Bch.

Male Turtle tagged (60-U) on 7-20-92 @ 2350
LFL - F375
LHF - F374
RHF - F851

Punaluu
S3 2371 + R3-4 2372
SL 67.3, CL 71.7
Punaluu 4/20/78

RECOVERED TAGS: EAST ISLAND, FFS, 1993

S1 [redacted] 3632 LFL, 3633 RFL / S4 [redacted] 3610 LFL / S6 [redacted] W672 LFL
S7 [redacted] W630 RFL, W631 LFL / [redacted] W822 RFL, W668 LFL /
S10 [redacted] 6068 RFL, 6069 LFL, 6070 L2 / 16 [redacted] 2999 LFL, 3002 RFL /
S25 [redacted] W676 RFL, W677 LFL / [redacted] W378 LFL, W379 RFL [redacted] 10121 RFL /
S19 [redacted] 3655 LFL, W244 RFL / 29 [redacted] 2370 RFL, (237?) LFL / [redacted] 3777 LFL, 5233 RFL
S22 [redacted] 6073 LFL, 6075 RFL / [redacted] 10125 RFL / [redacted] 33 10335 LFL, 10336 RFL /
S35 [redacted] 5782 LFL, 6927 L34, 5096 RFL 36 [redacted] A322 L34, A321 RFL /
S37 [redacted] W185 RFL, 8190 LFL / 44 [redacted] 10080 RFL 45 [redacted] 45 9992 RFL / S64
S47 [redacted] 7202 RFL, 7184 LFL / [redacted] 9675 RFL, 9674 LFL / [redacted] 3152 RFL, W503 L34
S55 [redacted] 8244 L34, 3590 RFL, 10095 R34 / [redacted] 3158 RFL, 3151 LFL /
S60 [redacted] W172 LFL / [redacted] 62 5243 RFL, 5244 L1, ?692 LFL / [redacted] 63 3796 LFL, 5336 R2
S64 [redacted] W383 RFL / [redacted] 66 W632 RFL, W633 LFL / [redacted] 67 W758 RFL, W759 LFL /
S68 [redacted] W500 RFL / UK W634 RFL / [redacted] 73 3732 LFL, 3787 L34, 5216 R34, 5223 RFL /
S74 [redacted] 8238 RFL, ?343 LFL / [redacted] 5441 R34, ??42 L34 / [redacted] 9763 RFL, 9784 LFL
S77 [redacted] W680 LFL, W681 RFL / [redacted] 6123 R2, 2234 RFL, W752 LFL (/) UK 9386 RFL
S80 [redacted] W620 RFL, W629 LFL 74

TOTAL (40)

AS OF 6/11

S76

82 [redacted] 9346 LFL, 9347 RFL S82
83 [redacted] 10223 RFL, 10229 LFL S83
84 [redacted] 5475 LFL, 5471 RFL S84
86 [redacted] W120 LFL S86
88 [redacted] 6183 RFL, 6192 LFL S88
90 [redacted] 10168 L34 S90
91 [redacted] A413 LFL, A412 R23 (HEAVILY TUMORED) S91
95 [redacted] W694 RFL, W695 L12 S95
98 [redacted] 9779 LFL, 9780 RFL S98
S97 [redacted] 7331 LFL, 7332 RFL → 2/9/84 Palaau Molokai SL 78.0
[redacted] W686 RFL, W684 LFL
100
101 [redacted] W640 RFL, W641 LFL S101
102 [redacted] 3422 LFL, 3411 RFL S102
105 [redacted] W619 L34, W617 RFL S105
109 [redacted] W268 RFL S109
110 [redacted] W693 LFL S110
111 [redacted] 9778 RFL S111
112 [redacted] W58 RFL S112
115 [redacted] 9680 RFL, 9681 LFL S115
117 [redacted] 2232 LFL
119 [redacted] A358 LFL, 6099 L3, 6094 RFL
121 [redacted] 6131 LFL, 5999 RFL
125 [redacted] A223 LFL, 5340 RFL
126 [redacted] W737 LFL
126 [redacted] 10543 LFL, 10207 RFL
129

TOTAL (25)

5-20

LHF F709 Curve 84.5
RHF F710 no straight yet.
LFL 237?2 (embedded)
RFL 2370

As of 6/15 - Up to [5-143]

On 6/8 a heavily tumored turtle, 5-91, nested. We'll keep our eyes open for her return. (8/9) EAST - SCORE = 0
S91 A395 RFL
A396 LFL

OPTIONAL FORM 99 (7-90)

FAX TRANSMITTAL # of pages ▸ 1

To George Balazs	From Steve FWS
Dept./Agency	Phone # 541-1201
Fax # 943-1290	Fax #

NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

S142 left FF

Table 1. Weather Data from Tern Island for 1993

1993 TERN ISLAND WEATHER DATA					
Month	Mean Temperature (°F)			Mean Wind (kts)	Total Rain (in)
	Max.	Min.	Daily		
January	78.0	68.0	72.9	14	1.59
February	82.0	68.5	75.0	11	0.27
March	80.0	69.0	76.1	11	0.25
April	84.5	75.0	79.4	12	0.57
May	83.0	78.5	80.6	11	0.53
June	86.0	80.0	83.8	10	1.12
July	89.0	81.0	84.1	12	2.97
August	86.0	81.0	84.0	12	1.78
September	87.0	79.0	84.7	9	2.61
October	83.5	75.1	81.3	12	2.05
November	81.6	73.0	78.1	12	1.42
December	79.5	73.0	76.9	12	1.06
Mean	83.3	75.1	79.7	12	16.22

Table 2. Annual Precipitation Recorded at Tern Island 1981-1993

ANNUAL PRECIPITATION FOR TERN ISLAND, FRENCH FRIGATE SHOALS 1981-1993.	
YEAR	TOTAL PRECIPITATION (in.)
1981	32.1
1982	37.4
1983	19.6
1984	32.7
1985	33.0
1986	33.0
1987	17.0
1988	25.1
1989	36.0
1990	28.0
1991	35.6
1992	30.2
1993	16.2
MEAN ANNUAL	28.9

United States Department of the Interior

FISH AND WILDLIFE SERVICE
PACIFIC/REMOTE ISLANDS NWR COMPLEX
P.O. BOX 50167
HONOLULU, HAWAII 96850
PHONE: (808) 541-1201 FAX: (808) 541-1216

3 pairs
F619 - F700

FAX TRANSMISSION

12 May 1993

TO: George Balazs
National Marine Fisheries Service
2570 Dole Street
Honolulu, HI 96822

FROM: Craig Rowland
Assistant Refuge Manager

FAX: 943-1290

SUBJECT: Turtle Activity Update

NUMBER OF PAGES: 1

REMARKS:

Here is the turtle activity report from French Frigate Shoals for 12 May 1993.

Date	Island	Observation
7 May	Whaleskate	4 pits, 2 possible nests
7 May	Trig	4 pits, 1 possible nest
8 May	Tern	1 possible nest
10 May	East	second nest
11 May	East	41 baskers, 6 floaters
11 May	Gin	7 pits, lots of tracks, 1 copulation, 13 baskers, no nests observed
11 May	Little Gin	3 pits, lots of tracks, 15 baskers, no nests

Thanks meeting with Tim and the new crew yesterday. I think that was a very valuable session for all concerned.

Aloha,

Craig

Which is Little Gin South or North?

South

Check gray Book at home

NAMES/INITIALS OF DATA COLLECTORS
DURING 1988 EAST ISLAND NESTING TURTLES

NAME/INITIAL	BOOK #	PAGE #
1. Sheila Moriarty	1	Inside cover 2
2. Phil Dye	1	Inside cover 2
3. G.N.	1	Sea water temp. 1
4. S.M.	1	Sea water temp. 1
5. H.F.	1	Sea water temp. 1
6. V.G.	1	Sea water temp. 1
7. L.F.	1	Sea water temp. 1
8. P.D.	1	Sea water temp. 2
9. T.C.	1	Sea water temp. 3
10. M.A.B. H.	1	Sea water temp. 4
11. D.B.	1	Sea water temp. 4
12. M.J.	1	Back pages
13. M.J. (Melissa)	2	#114
14. L.F. (Lynn Fukuda) LYNNE	2	#121

R. Bob ~~Cummings~~ R. Cummins

Ken Niethammer

Jennifer Meggesi

T. Michael Moser

R. Bauer

Tim Clark

Marilyn Major

Alyssa Ward

C. Dippel

~~R. Vetter~~

R. Vetter

Susan Pultz

M. Webber

Glynnis Nakai

B. Winton

G. Spencer

Vanessa Gauger

NAMES/INITIALS OF DATA COLLECTORS
DURING 1988 WHALE-SKATE ISLAND NESTING TURTLES

NAME/INITIAL	BOOK #	PAGE #
1. Lynn F.	1	#2
2. V.G.	1	Summary 1
3. G.N.	1	Summary 1
4. S.M.	1	Summary 1
5. H.F.	1	Summary 1
6. P.D.	1	Summary 1
7. D.B.	1	Summary 1
8. T.C.	1	Summary 2
9. M.A.B.	1	Summary 2
10. M.J.	1	Summary 3
11. L.F.	1	Summary 3
12. Lynn F.	2	#46 yellow

NAMES/INITIALS OF DATA COLLECTORS
DURING 1988 TERN ISLAND NESTING TURTLES

NAME/INITIAL	BOOK #	PAGE #
1. H.F.	1	Nos. 1
2. G.N.	1	Nos. 1
3. V.G.	1	Nos. 1
4. S.M.	1	Nos. 1
5. K.N.	1	Nos. 3
6. P.D.	1	Nos. 3
7. L.F.	1	Nos. 3
8. A.G.	1	Nos. 4
9. T.C.	1	Nos. 4
10. D.B.	1	Nos. 4
11. M.B.	1	Nos. 4
12. D.A.	1	Nos. 4

[8] From: George Balazs 5/31/94 4:56PM (2001 bytes: 28 ln)
To: William Gilmartin
cc: George Balazs
Subject: Turtle nest monitoring on Tern
------------------------------ Message Contents ------------------------------

Bill- Here's an overview so you'll be aware of status.

Field work there involves one walk by one person each morning at around 8am. Purpose of the walk is to count tracks, and to count and mark likely egg-nest sites. The objectives are twofold. (1) to continue monitoring nesting trends on Tern, albeit at a low level from what was initiated and accomplished during a 6-year period by Ken Niethammer (1986-91); and (2) to identify specific nest sites so that later in the season rescue efforts can be carried out to free and release those hatchling that invariably get trapped due to environmental (non-genetic) reasons. This activity follows one of the recommendations set forth in the interim turtle recovery plan.

The project on Tern is not now, nor ever has been, a MTRP project. It is a full-fledged FWS project. However, I have regularly had input into the work, so feel a definite part of it. Just recently Marc and I conferred at length about the project to make sure all was on-track, and that I fully understood how the activity was being conducted. As near as I can determine, it involves little if any disturbance of seals. Marc tells me that this important point (non-disturbance) is repeatedly stressed to the person that does the morning walk (and the person who later digs the nests). Is the work worthwhile, goal focused, and with scientific merit? I would have to say, absolutely yes. I say this because the manuscript (the one you now have) lead-authored by Niethammer appears to be first-rate, containing valuable information that will published in a peer-reviewed journal.

If there is information relating to this topic that I'm not aware of, please let me know. But at present, the above is my understanding of the status.

Set up Laysan Island as site for storing radioactive waste

The state of Hawaii can earn a billion dollars and better Oahu environmentally by setting aside Laysan Island for the storage of radioactive waste.

Laysan is legally a part of Hawaii more than 900 statute miles distant from Oahu. The island has a land area of 790 acres, and a channel depth of over 16,000 feet.

One of the first applicants for the storage of radioactive waste on Laysan Island should be the Pearl Harbor Naval Shipyard. The accumulation of waste there and the safeguards in storage have been shown and explained to our legislators. Pearl Harbor is joined in this problem by naval shipyards and by commercial power reactors over the United States.

E. ALVEY WRIGHT
Kailua

PACIFIC/REMOTE	PRI	ACT	FYI	CC	INIT
Complex Manager					
Biologist					
Admin. Suppt. Asst.					
Secretary					
HI NWR Manager					
Bio. Sci. Tech.					
Johnston					
Midway					
Tern					
File					

East Island Turtle Report, 1994
U.S. Fish and Wildlife Service

Alyssa E. Ward
Susan L. Pultz

I. General Monitoring

The 1994 turtle season was a short season consisting of only one month of monitoring. There were 121 nesting green sea turtles (*Chelonia mydas*) identified on East Island during this time as calculated from the ID data.

Turtle Camp began on June 7, 1994 and ended July 7, 1994 consisting of 30 nights of monitoring. Each night consisted of five turtle walks around the island at 21:00, 23:00, 1:00, 3:00, and 5:00 (sunset to sunrise). This meant that no more than two hours lapsed between turtle sightings. Due to the duration between walks, it is possible that some turtles that were up crawling or digging false pits were not seen. However, it is unlikely that those turtles that actually nested were not recorded as being up.

There were 73 possible nests recorded on East Island the short season. Eggs were witnessed for 30 of these nests. Turtles were seen covering egg chambers (patty-caking) for 18 nests and backfilling 25 nests.

II. Data Notes

Moto-tool numbers Z1 through Z117 were used during the 1994 season. The turtle identified as Z77 was also given the ID Z109. All entries for this turtle in the data base should be listed as Z77. ID number Z43 was duplicated. Both turtles were identified by tag number and designated as 43A and 43B in the ID files. There were four turtles this season without a moto-tool identification. These turtles are listed as UK1, UK2, UK3 and UK4 in the both the ID and sightings files. All turtles listed in the ID files have at least one tag. Those turtles in the sightings files listed as UK without an identification number were turtles that were seen up, but, due to their proximity to seals, were not identified.

Identification data is recorded in the DBASEIII file EASTID94.DBF. This includes tag numbers applied and measurements taken for nesting females in the 1994 season on East Island. It also includes tumored turtle information. Sighting information is recorded in the DBASEIII file ESTSIG94.DBF. This file contains the turtle activity for each night of monitoring.

Tags U302-U396 were used on East this season. Tags misapplied and recovered are: U302, U336, U593, U597, U560, U455, U377, U335, U503, U485, U320, U467, U379, U371, U541, U484, U529, U336, U591, U592, U573, U358, U517, U533, U551, U388, U494, U501, U502, U504, U505, U506. Tags lost: U377, U386, U390, U394, U500, U529 and U533.

III. Miscellaneous Notes

A. Immature turtle was seen basking on the East end of East Island on 7/5/94. No tags were read or measurements taken. It is believed that this is the same immature turtle that has been seen basking in previous years on East Island.

B. There were six tumored turtles identified during the 1994 season. These were listed as Z26, Z33, Z93, Z105, Z107 and Z116. Tumor information (i.e. location and size) are found in EASTID94.DBF. Three other turtles had grey lumps approximately 1 cm in diameter.

These turtles are Z18, Z50 and Z56 (Z18 had 11 lumps). The lumps did not appear to be tumors, but their positions are listed in the data base.

C. A mature female turtle was found on the runway on Tern Island on 6/9/94. This turtle was tagged, measured and released. Tag information is as follows:

F619 RHF, F620 LHF, F621 RFL, F622 LFL
Curved carapace length: 102.5 cm

D. A significant number of male baskers were seen late into the season. During the first week of July, a minimum of 5 males were seen basking on East island. Isolated males (those removed from other baskers and seals) found basking were tagged and measured. They are recorded as M1-M7 in the file EASTID94.DBF.

E. Clutch size was collected for ten turtles. One of these turtles was heavily tumored. Data collected was as follows:

Z9:	6/13/94	105 eggs	
Z33:	6/13/94	124 eggs	(heavily tumored)
Z75:	6/19/94	110 eggs	
Z81:	6/20/94	45 eggs plus 1 spacer	
Z86:	6/21/94	82 eggs plus 2 spacers (Pit too small. Broke at least one egg while covering nest. A few other eggs not covered.)	
Z90:	6/21/94	125 eggs	
Z37:	6/29/94	112 eggs	
Z43B:	6/30/94	104 eggs	
Z113:	7/5/94	111 eggs	(nest marked)
Z91:	7/6/94	87 eggs	

United States Department of the Interior

FISH AND WILDLIFE SERVICE

300 ALA MOANA BOULEVARD
P.O. BOX 50167
HONOLULU, HAWAII 96850

IN REPLY REFER TO:

RWR

JUN 26 1980

Mr. George H. Balazs
Assistant Marine Biologist
Hawaii Institute of Marine Biology
PO Box 1346
Kaneohe, HI 96744

Dear George:

In response to your inquiry regarding Fish and Wildlife Service support of turtle research, you should be aware that the Service recognizes the value of your research to our long term resource management objectives. We have cooperated through logistical field support at French Frigate Shoals and have also expressed support of this work in ongoing discussions regarding future triparty research.

In the immediate future, I anticipate that we will be able to provide some assistance through access to Service chartered aircraft on scheduled Tern Island flights, assuming all necessary equipment and other cargo can be accommodated. I don't believe there would be any problems with access to Johnston Island NWR for additional research, but this work would need to be coordinated with the Commanding Officer.

I suggest that you, Richard Shomura and I get together upon your return from Tern Island to discuss cooperative involvement of National Marine Fisheries Service and Fish & Wildlife Service in future turtle research.

Sincerely yours,

Pacific Islands Administrator

cc: Richard Shomura

[1] From: Timothy Ragen 6/13/94 2:56PM (2409 bytes: 37 ln)
To: George Balazs
Subject: Re[3]: Tel. message on my recorder
------------------------------ Message Contents ------------------------------

Tim- Earlier this morning there was a "message" on my recorder that consisted of a short conversation between you and Brenda. Was any of that really meant for me, or was it just a dialing mistake.

> Glad you mentioned this, because I think a fair amount of burning still goes on in some places. If you think it is not clear to everyone at FFS, let me know, and I'll send a message to them to bring it all back.

Tim- Line and debris pick up on the islands? What's absolulely clear to me that SHOULDN'T be done with the stuff (like was done a couple of years ago) is to burn it on the island. East, WS, Trig, Gins are all turtle nesting habitat- critical
habitats. Each entire island (but especially East and WS) hosts nesting, not just the "beach" perimeter. It grieved me awhile back to see that fws and or mmrp were piling up stuff in the center of the East and burning it. The charred remains then mixed with the soil. Or even burning in 55 gal drums, since the ash debris and smoke could reasonably be expected to affect turtles and the soil of their nesting habitat. I spoke with Bill back then and he 100% agreed with me. IF it must be burned, the burning should be done well outside the nesting and hatching season, (Jan.-March) and in such a way as to not contaminate the earth used for nesting (ie, burn at low tide in the intertidal zone. Or, bring it unburned back to Tern and deep in the center of the island. Or haul it out via the Cromwell. geo.

Brenda had called me to find out about dumping marine debris from FFS, and I wasn't sure where to dump it. Since you have had experience with the dump, I tried to check with you to see if you might be able to give me some advice. My telephone has some sort of short in it, and I was having trouble getting the connection to work. I tried to cut off the connection with your phone, but apparently, it didn't work. We've resolved the problem. Sorry about the distraction.

12/94 TERN

Seals were inspected for injuries, entanglements and entrapment daily on Tern Island.

b. Hawaiian Green Sea Turtle

Platter sized turtles were removed from behind the north seawall on three separate occasions during December. The first (measuring approx. 50 cm) was found just west of Shell Beach. The second (approx. 40 cm) was found about 120 meters west of the NE corner of the island. The third (approx. 40 cm; missing left rear flipper) was located along the seawall opposite the generator building. All three turtles were found in pools of seawater and appeared to be in good condition. It is believed that all three animals were washed through holes in the seawall on wave surges.

Male and female adult turtles were seen basking on Tern Island on several occasions during the second half of December.

3. Waterfowl

Four unidentified ducks were observed in the north channel on 1 December.

4. Marsh and Water Birds

NTR

5. Shorebirds, Gulls, Terns, and Allied Species

a. Laysan Albatross

There were 1,987 eggs counted during an island wide egg count for Tern on 23 December. There appeared to be many more non-breeders arriving on the island during the end of the month.

The annual outer island albatross egg count took place on 21 and 27 December. Details can be found under section 5.B.1. (Outer Islands Monitoring Studies).

b. Black-footed Albatross

There were 1,034 eggs counted during an island wide egg count for Tern on 23 December. There appeared to be many more non-breeders arriving on the island during the end of the month.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Science Center Honolulu Laboratory
2570 Dole St. • Honolulu, Hawaii 96822-2396
(808)943-1221 • Fax: (808)943-1290

November 21, 1994   F/SWC2:ghb

Mr. Marc Webber
Refuge Manager
Hawaiian and Pacific Islands
National Wildlife Refuge
P.O. Box 50167
Honolulu, Hawaii 96850

Dear Marc:

While it's still early, I want to take this opportunity to let you know my plans for proposed sea turtle research at French Frigate Shoals during the summer of 1995. The following provides a short outline of activities and estimated scheduling.

1) Population monitoring of nesting green turtles at East Island for the 23rd consecutive year. As conducted during the 1993 and 1994 seasons, a 30-40 day monitoring period is envisioned, starting during late May or early June. I hope that cooperative sponsorship of this critical work between our agencies will once again be possible. As in past years, I plan to fund transportation (air charters) and other necessities outside of personnel costs. As we discussed, I believe that Kellie Takimoto will be an excellent person to share the nightly monitoring at East Island.

2) Deploy satellite transmitters on two adult male and two adult female green turtles at East Island and/or Tern Island. This work will be a continuation of satellite tracking accomplished with adult females during 1992 and 1993 (publications enclosed). Ideal scheduling would involve 3-4 days of work during mid-to-late May (for males), and another 3-4 days during mid-to-late August (for females). I would personally travel to French Frigate Shoals to conduct this work.

3) Deploy and retrieve up to 12 computerized temperature recorders in nesting substrate at East Island and Tern Island. This work, to be facilitated by Kellie Takimoto, will provide valuable insight on temperature-dependent sex determination and sex ratios of green turtles hatched at French Frigate Shoals. Each unit is self-powered and weighs only about 100 grams. The units would be buried at different depths to approximate the depths of egg nests. They would be deployed during February and dug up the following December. Three measurements are automatically recorded and stored in memory each day. All data for the 11-month period are obtained via computer link after retrieval.

4) Obtain small 6 mm skin biopsies from nesting females at East Island for DNA analysis. This work will refine and expand the earlier DNA population research for French Frigate Shoals' green turtles reported by Bowen et al. (publication enclosed). Kelli Takimoto has been trained to carry out this relatively benign, simple, and extremely quick technique using a hand-held biopsy punch commonly employed in human medicine. Sampling at East Island would take place at the same time that a turtle is tagged and measured.

I would be pleased to discuss the above topics with you in greater detail, at your convenience, as we approach the new year.

Sincerely,

George H. Balazs
Leader, Marine Turtle Research Program

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Science Center Honolulu Laboratory
2570 Dole St. • Honolulu, Hawaii 96822-2396
(808)943-1221 • Fax: (808)943-1290

December 13, 1995 F/SWC2:JRH:JLK
MAW-2L.RML

Marc A. Webber
Refuge Manager, Remote Islands
Hawaiian Islands National Wildlife Refuge
U.S. Fish & Wildlife Service
P.O. Box 50167
Honolulu, Hawaii 96850

Dear Mr. Webber:

Enclosed is an application for a Special Use Permit to conduct research on Hawaiian monk seals and green sea turtles within the Hawaiian Islands National Wildlife Refuge. Please note that although I am the applicant and will be the permittee, the field research will be under the direction of the respective program leaders for the Marine Mammal Research Program (Gilmartin or his successor) and the Marine Turtle Research Program (Balazs), who will be responsible for keeping you informed as the field season progresses. In that regard, please consult them if you have questions or require clarification. Finally, because our FY 96 budget is not yet resolved, the research plans stated in the application are tentative. The program leaders will keep you informed.

Thank you for your attention to the application and for your continued support of our research within the Refuge.

Sincerely,

Michael Laurs

R. Michael Laurs
Director, Honolulu Laboratory

Enclosure

cc: W. Gilmartin (w/enclosure)
G. Balazs (w/enclosure)

1. Title: Hawaiian monk seal and green turtle research

2. Project Number: 12501-

3. Objectives:

Nihoa Island:

1. Resight tagged individuals
2. Collect scats and spews for prey species identification

Necker Island:

1. Resight tagged individuals
2. Collect scats and spews for prey species identification

French Frigate Shoals:

1. Population monitoring[1]
2. Collect undersized female weaned pups for rehabilitation
3. Collect scats and spews for prey species identification
4. Remove transmitters from seals instrumented in late 1995
5. Attach instruments to seals
6. Attach satellite transmitters to adult turtles
7. Monitor turtle nesting at East Island
8. Obtain skin biopsies from nesting turtles for DNA studies
9. Deploy and retrieve temperature recorders in turtle nesting substrate

Laysan Island:

1. Population monitoring
2. Monitor mobbing activity
3. Maintain adult male identities for mobbing research

---

[1] Population monitoring activities include: determining number and dates of births, tagging weaned pups (Temple Tags and PIT tags), collecting tissue plugs for DNA analysis from weaned pups, conducting beach counts, identifying all marked individuals, flipper tagging all untagged immature seals, replacing lost flipper tags, releasing entangled seals from debris, documenting injuries, performing necropsies on dead seals, and cataloging amd destroying marine debris capable of entangling seals.

4. Collect scats and spews for prey species identification

Pearl and Hermes Reef; Lisianski Island

1. Population monitoring
2. Bleach mark population
3. Collect scats and spews for prey identification

4. Justification: This research schedule was developed following a program activity review with the Hawaiian Monk Seal Recovery Team (HMSRT) during 6-7 December 1994, and will be discussed with the HMSRT during a meeting in late January, 1996. Emphasis on the 1996 field work will be placed on research related to the recent decline in the French Frigate Shoals (FFS) monk seal population, population monitoring at major breeding sites, monitoring the mobbing problem at Laysan Island, and continuing foraging studies at all breeding sites where field research is conducted. Additional research includes resighting tagged seals at Necker and Nihoa Islands.

5. Procedures:

A. Campsites will be in the following locations:
Laysan Island: Northwest side of the island, adjacent to the Refuge sign and the permanent USFWS camp.
Lisianski Island: West side of the island, adjacent to the Refuge sign.
Pearl and Hermes Reef: Southeast Island, on sand flat just west of the lagoon; North Island, on top of beach crest at north side of island, in line with offshore rock islet. Furthermore, a temporary camp not to exceed three days in duration may be established on Seal-Kittery Island, in an unvegetated area on the south end of the island.

No campsites will be established on Nihoa or Necker Islands. All field activity will be conducted from a supporting vessel.

B. Population monitoring procedures will be identical to those conducted by NMFS in the past.

C. Scats and spews will be collected on an opportunistic basis as they are found on the beach.

D. Up to 18 underdeveloped weaned female pups at French Frigate Shoals will be collected for rehabilitation. These seals may be temporarily maintained at Tern Island for several weeks prior to transport to Honolulu. During this time most pups will be initially tube-fed a Multi-milk® or a Multi-milk/herring mixture. After several days on this mixture, pups will be force-fed whole herring. The criterion for determining which seals to collect will be an axillary girth of 95 cm measured within two weeks of weaning. Smaller seals (girth < 90 cm) will be given priority, however.

A temporary holding pen for seal pups will be erected on "Shell Beach", Tern Island. The pen will be constructed of wire mesh suspended from pipes and metal posts sunk into the sand, and will extend from approximately 2 m above the high water mark to approximately 1 m below the low water mark. Dimensions of the pen will be approximately 7 m x 12 m.

E. Up to four adult green turtles will be instrumented with satellite transmitters. This activity will occur at French Frigate Shoals during July-September.

F. Skin biopsies will be collected from up to 500 nesting female turtles at East Island. The 6mm diameter circles of tissue will be collected with a hand held biopsy punch commonly used in human medicine. The procedure will be conducted at the same time that a turtle is tagged and measured. It is realized that sampling a total of 500 individuals is likely not feasible, but a large sample size is necessary to establish a DNA data base for the breeding population of turtles at FFS.

G. Temperature recorders will be deployed in the substrate of East Island to provide data on temperature-dependent sex determination and sex ratios of green turtle hatchlings. Units will be buried at different depths approximating depths of nests. They will be deployed in February and dug up in December.

6. Personnel: The following summarizes personnel who may visit the refuge to conduct the proposed research: Kyler Abernathy[2], George Balazs, Brenda Becker, Mitch Craig[3], Robert Dollar, Denise Ellis[3], Frank Parrish, William Gilmartin, Mark Hansen[3] John Henderson, Lance Jeffery[3] Thea Johanos-Kam, Shawn Murakawa[3], Tim Ragen, Suzanne Russell, Amy Sloan[3], Jim Swensen[3], and Chad Yoshinaga[3]. Other personnel assisting the research program will be added to the permit when their identities become known. Specific islands for personnel are listed with the schedule.

7. Cooperators: Cooperators include: The National Ocean Service, which will provide transport via the R/V *Townsend Cromwell;* the Joint Institute for Marine and Atmospheric Research (JIMAR) and the University of Minnesota, which will employ some of the researchers conducting the work; and the NOAA Teachers at Sea Program, who will provide volunteer personnel.

7. Responsibility: All activities will be under the supervision of R. Michael Laurs, Director, Honolulu Laboratory. Immediate direction of research/activities will be provided by the leader, Marine Mammal Research Program (seal research), and by George Balazs, Leader, Marine Turtle Research Program (turtle research). Field camp leaders will include Mitch Craig (FFS), Brenda Becker (Laysan), and 1 TBN each at Lisianski Island and Pearl and Hermes Reef. We will inform USFWS once assignments are completed.

Regular radio schedule will be maintained between the field teams and USFWS staff at Tern Island. Regular contact will be maintained with NMFS, Honolulu via INMARSAT at all islands.

8. Cost: No cost will accrue to the USFWS.

9. Schedule:

Necker Island

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[2]University of Minnesota

[3]Joint Institute for Marine and Atmospheric Research

Dates: Necker will be visited as time permits during cruises on the R/V *Townsend Cromwell* returning from breaking field camps in the more Northwestern islands.
Staff: TBN

French Frigate Shoals

Dates: 17 - 28 January (TC 96-01); April 18 (TC 96-05)- mid September (air charter); October-November (TC cruise and dates to be determined).
Logistics support: TC 96-03; TC 96-05; TC 96-08; air charters
Camp Leader: M. Craig
Staff: 3-4 TBN

Laysan Island

Dates: 11 April (TC 96-05) - 19 July (TC 96-08);
Logistics support: No support cruises scheduled
Camp Leader: B. Becker
Staff: 1 TBN

Lisianski Island

Dates: 13 April (TC 96-05) - 17 July (TC 96-08)
Logistics support: No support cruises scheduled
Camp Leader: 1 TBN
Staff: 2 TBN

Pearl and Hermes Reef:

Dates: TBN
Camp Leader: 1 TBN
Staff: 3 TBN
Note: Some staff and equipment used at Pearl and Hermes Reef may transfer directly from a field camp at Kure Atoll. Equipment to be transferred between sites would include a 17' whaler and attendant engines, engine parts, safety equipment, and gasoline. Some data collection equipment (cameras, computer, binoculars), and personal effects of staff may also be transferred. No tents, non-canned food, or other materials likely to harbor specimens or seeds of

pest species (e.g. *Verbecena*) would be transferred. Furthermore, all items to be moved will be thoroughly cleaned, fumigated, and inspected.

10. <u>Other permits</u>: All activities have been approved by the NMFS office of Protected Resources under marine mammal permits issued to the NMFS Southwest Fisheries Science Center and the University of Minnesota.

Abstract.–Research and commercial trapping data show variation in recruitment to the fishery for spiny lobster *Panulirus marginatus* at Maro Reef, relative to Necker Island which is 670 km to the southeast. Recruitment to the fishery at Maro Reef is shown to be highly correlated with the difference in sea level 4 years earlier between French Frigate Shoals and Midway Islands. Geosat altimeter data indicate that the relative sea level between French Frigate Shoals and Midway is an indicator of the strength of the Subtropical Counter Current. Mechanisms linking the Subtropical Counter Current with larval advection and survival are discussed. The sea level index provides a forecast of recruitment 4 years later to the fishery at Maro Reef.

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Variability in spiny lobster *Panulirus marginatus* recruitment and sea level in the Northwestern Hawaiian Islands*

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Significant correlations between commercial landings or recruitment estimates and one or more environmental indices are commonly reported in the fisheries literature, but few have served as accurate predictors of future population levels (Drinkwater and Myers 1987). However, such correlations can lead to the formulation or support of hypotheses regarding the factors responsible for population changes. For example, an inverse correlation between the survival of Pacific mackerel *Scomber japonicus* to age 1 and the strength of the California Current, and the lack of correlation between survival and plankton biomass, have been offered as evidence that advection, rather than starvation, controlled survival of the planktonic stages of this species (Sinclair et al. 1985).

Correlative studies on lobsters suggest that population size results from changes in survival and advection at the larval stage, but in at least one instance, density-dependent mechanisms after postsettlement may dampen this variation (Pollock 1986). Fluctuations in sea-surface temperature appear to result in changes in larval survival and catches 6 years later for the clawed lobster *Homarus americanus* in Maine (Fogarty 1988). Variation in the strength of the Leeuwin Current, which may be linked to El Niño Southern Oscillation (ENSO) events, is suggested as a cause of variation in the number of larvae returned to the coast and subsequent recruitment to the fishery for the western rock lobster *Panulirus argus* (Pearce and Phillips 1988). Changes in recruitment levels of the California spiny lobster *P. interruptus* to the northern portion of its habitat may be episodic, influenced by large-scale, interannual El Niño events (Pringle 1986). Variation in postlarval recruitment in the South African rock lobster *Jasus lalandii* is thought to arise from changes in the paths and velocities of extensive offshore currents, which eventually return larvae to the coast. However, density-dependent phenomena influ-

* Contribution 2820 of the School of Ocean and Earth Science and Technology, University of Hawaii; JIMAR Contribution 91-0243.

encing juvenile and adult stages may substantially dampen this variation and produce fairly stable recruitment to the fishery (Pollock 1986).

In the Northwestern Hawaiian Islands (NWHI), a substantial drop in catches and catch-per-unit-effort (CPUE) of spiny lobster *P. marginatus* Quoy and Gaimard 1825 was recently documented (Polovina 1991). This study examines whether these declines in catches and CPUE are due to overfishing or to oceanographic factors which impact spiny lobster population dynamics.

NWHI lobster fishery

The NWHI region is an isolated range of islands, islets, banks, and reefs that extend 2775 km northwest from Nihoa Island to Kure Atoll (Fig. 1). In 1977 after research cruises documented a substantial lobster population in the NWHI, a commercial trap fishery was initiated. The fishery targeted two species: the endemic spiny lobster *P. marginatus* and the slipper lobster *Scyllarides squammosus* Mike-Edwards 1837. A fishery management plan implemented in 1983 mandated that vessels submit logbooks recording daily catch and number of traps set (effort); the plan also established a minimum harvest size for spiny lobster and prohibited the harvest of egg-bearing females. Subsequent amendments to this plan added a minimum legal size for slipper lobster and required that traps have escape vents. In 1990, low catches and CPUE prompted a 6-month closure of the fishery (May–November 1991).

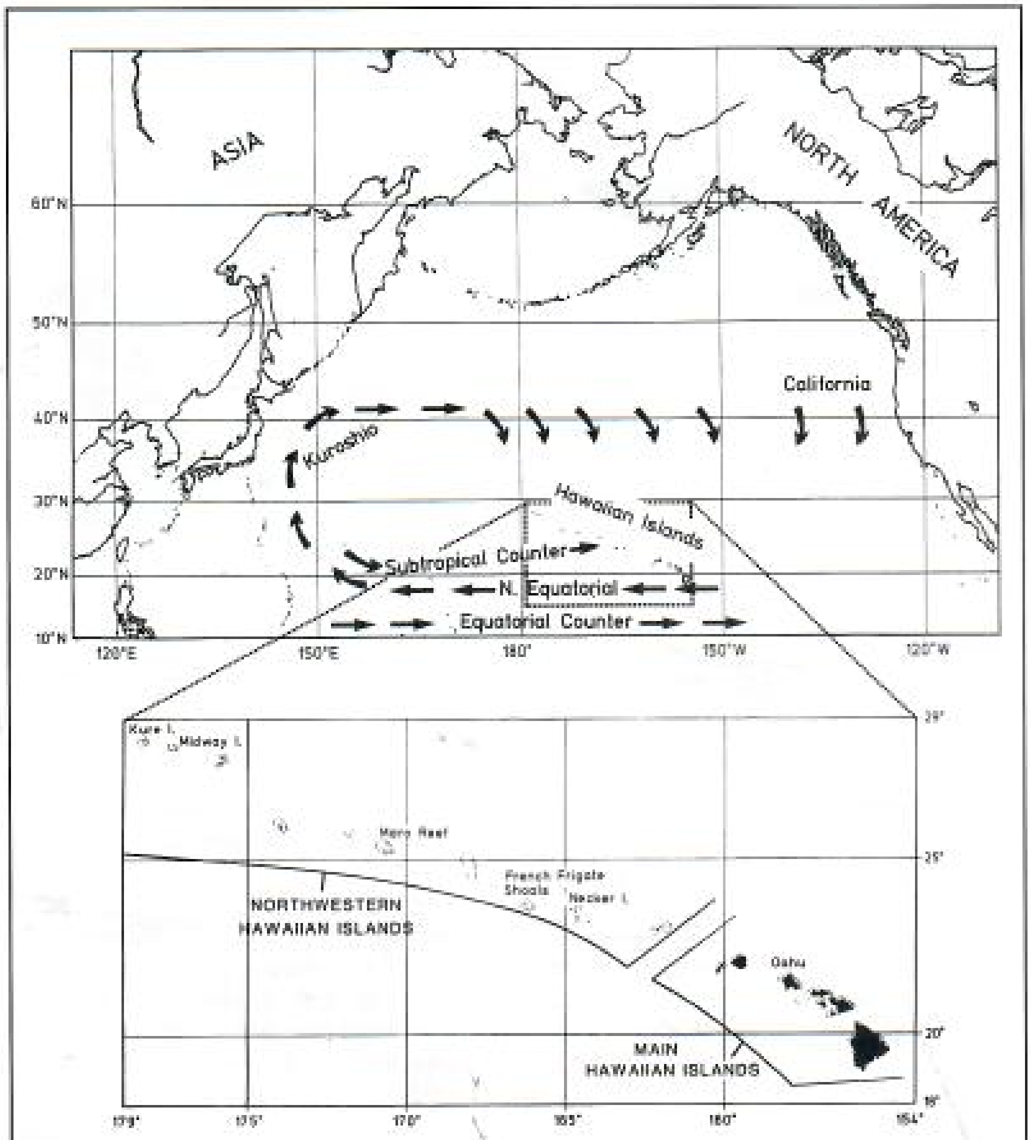

Figure 1
Pacific Ocean and major currents with an inset of the Hawaiian Archipelago, including the Northwestern Hawaiian Is.

Since 1983, the lobster fleet has been composed of 9–14 vessels (20–30 m long), each averaging 3 trips per year. The vessels set about 800 traps per day and remain at sea almost 2 months per trip. Landings in recent years have averaged almost 1 million lobsters, valued at about US$6 million ex-vessel. Because of heavy fishing since 1986, the population has been fished down to the point that 3-year-old recruits comprised most of the fishery catches (Polovina 1991). Since 1988, about 80% of landings have been spiny lobster (Table 1). Two banks—Necker I. at the southeast end of the NWHI, and Maro Reef which is 670 km northwest of Necker I.—account for over 60% of the fishery's catches. There is no recreational lobster fishery in the NWHI.

Table 1

Annual landings of spiny (*Panulirus marginatus*) and slipper (*Scyllarides squammosus*) lobsters, trapping effort, and percentage of spiny lobster in the landings, 1983–90.[1]

Year	Lobster landings (10^3) Spiny	Slipper	Total	Trap hauls (10^3)	CPUE	% spiny lobster
1983[2]	158	18	176	64	2.75	90
1984	677	207	884	371	2.38	78
1985	1022	900	1922	1041	1.83	53
1986	843	851	1694	1293	1.31	50
1987	393	352	745	806	0.92	53
1988	888	174	1062	840	1.26	84
1989	944	222	1166	1069	1.09	81
1990	591	187	778	1182	0.66	76

[1] Data were provided to the NMFS Honolulu Lab., as required by the Crustacean Fishery Management Plan of the W. Pac. Reg. Fish. Manage. Counc., Honolulu.
[2] April–December 1983.

Spiny lobster spawn over a broad spring, summer, and fall period. After hatching, the eggs are planktonic; the planktonic period for the larvae is estimated at 12 months based on spawning season and larval tow data (NMFS Honolulu Lab., unpubl. data). Further, the larval tow data suggest that mid- to late-stage spiny lobster larvae are close to the surface at night and move down to ~100 m during the day (Polovina, pers. observ.). Based on growth curves estimated from both tagging (MacDonald 1984) and length-based methods (Polovina and Moffitt 1989), spiny lobster reach the minimum legal size (which is slightly larger than the size at onset of sexual maturity) approximately 3 years after they settle onto benthic habitat. After settlement, the lobster probably do not move between banks since interbank depths exceed 1000 m.

Regional oceanography

The Hawaiian Archipelago lies within the subtropical gyre formed by the Kuroshio Current to the west and the north, the California Current to the east, and the North Equatorial Current to the south (Fig. 1). The speed of the gyre in the vicinity of the archipelago is slow (<5 cm/s; Roden 1991). An eastward-flowing current within the subtropical gyre, named the Subtropical Counter Current (SCC), was predicted by Yoshida and Kidokoro (1967) and subsequently confirmed by Robinson (1969) and Uda and Hasunuma (1969) (Fig. 1). More recent work has shown that, in at least the western portion, the interior of the subtropical gyre is composed of a quasi-stationary banded structure of easterly- and westerly-flowing currents (White and Hasunuma 1982). The SCC consists of two bands of eastward flow at 23° and 28°N, with mean annual speeds of 8 and 6 cm/s, respectively (White and Hasunuma 1982).

In addition to these large-scale features, the mesoscale oceanography around the Hawaiian Archipelago is a complex system of fronts and eddies resulting from both interactions between alternating east and west currents and interactions between current and the topography of the archipelago.

Data and analysis

Research data

Standardized trapping surveys, using the same traps set at the same sites, were conducted at Necker I. and Maro Reef during June and July of 1986–88 and 1990. The size-frequency data were converted to age-frequency data with a von Bertalanffy growth curve (MacDonald 1984). The age-frequency distribution was standardized for the number of traps deployed to estimate the relative age-frequency distribution of the population.

Fishery data

Although detailed catch and effort data were not available until after the logbook regulations were established in 1988, catch and effort were generally light and were concentrated around Necker I. from the inception of the fishery until 1984 (Fig. 2). The combined CPUE for slipper and spiny lobsters in 1983–90 generally declined from 2.8 to ~0.7 lobster per trap-

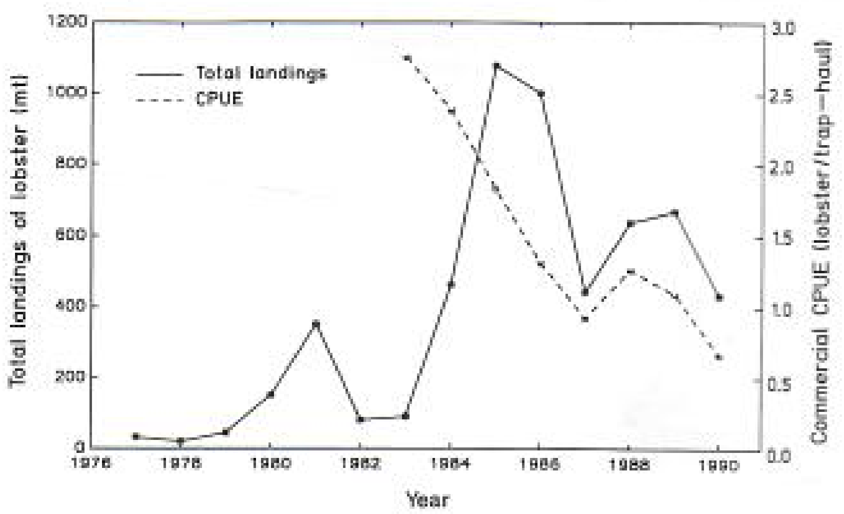

Figure 2
Total slipper (*Scyllarides squammosus*) and spiny (*Panulirus marginatus*) lobster landings and CPUE from the Northwestern Hawaiian Is., 1977–90.

haul (Fig. 2), based on catch and effort data reported in the logbooks. Catch data in the logbooks are checked against landings by enforcement agents, so misreporting is not a problem. Common assessment approaches, such as length-based cohort analysis, are not applicable to this fishery, given the relatively short time-series of catch and effort data, the difficulty in routinely ageing lobsters, and the lack of information on the size-frequency from the landings and the nature of a stock-recruitment relationship. While a dynamic surplus production model has been applied to the data, an implicit assumption about the form of the stock recruitment relationship is required (Polovina 1991).

A more general approach is to begin with a model which expresses N_t as the number of exploitable lobsters at time t as a function of N_{t-1}, Z as the total instantaneous mortality from time t−1 to t, and r as the number which recruit and survive from t−1 to t as

$$N_t = r + N_{t-1}\, e^{-z}.$$

Using the relationship that the product of catchability (q) and $N_{(t)}$ is $CPUE_{(t)}$, this model becomes

$$CPUE_t = q*r + CPUE_{t-1}\, e^{-M-qf},$$

where M and f are annual instantaneous natural mortality and fishing effort, respectively, during the period t−1 to t. This CPUE model, a simple version of a size-structured model developed by Schnute et al. (1989), was used to estimate population parameters and to evaluate the extent that fishing effort explains the observed variation in CPUE. This model assumes constant catchability and recruitment; hence, the differences between predicted and observed CPUE are interpreted as variation in recruitment, catchability, or both.

The commercial data do not indicate whether effort was directed at slipper or spiny lobster. However, the catches can be grouped into two periods based on the proportion of spiny to slipper lobsters. In period 1 (1983–84 and 1988–90), ~80% of the landings were spiny lobster; in period 2 (1985–87), ~56% of the landings were spiny lobster (Table 1). The change in proportion of spiny lobster catches is likely due to changes in targeting and abundance. The CPUE model is modified so that a catchability coefficient can be estimated for each period. Our modified CPUE model regresses the CPUE of spiny lobster above the minimum size in month t ($CPUE_t$) on the CPUE of the same month in the previous year:

$$CPUE_t = R*Q_t\, e^{-\frac{(M+Q_t f_t)}{2}} + (CPUE_{t-12})\,(e^{-M-Q_t f_t})\left(\frac{Q_t}{Q_{t-12}}\right)$$

with

$$Q_t = q_1 I_{1,t} + q_2 I_{2,t}$$

where q_1 is the catchability of spiny lobster during period 1, q_2 is the catchability during period 2, M is the annual instantaneous natural mortality, R is the annual recruitment, f is the cumulative fishing effort during the period (t−12, t−1), and $I_{i,t}$ (i=1,2) is the indicator or set function which takes the value 1 if t is within period i or otherwise takes the value 0. Estimates of R, q_1, q_2, and M were obtained by minimizing the sum of squares of the difference between the square root of the observed and predicted CPUE with a simplex algorithm.

Sea level data

To examine the relationship between lobster recruitment variation at Maro Reef and physical factors such as variation in the SCC, we focused on the analysis of sea level data from the NWHI. Our choice of sea level was primarily a practical one. In comparison to current or upper-layer temperature records, the sea level records are of long duration, and the data are measured continuously and are available in nearly real-time. An additional advantage is that sea-surface height data from the Geosat satellite altimeter are available to provide a spatial description that complements the temporal description available from the sea level stations.

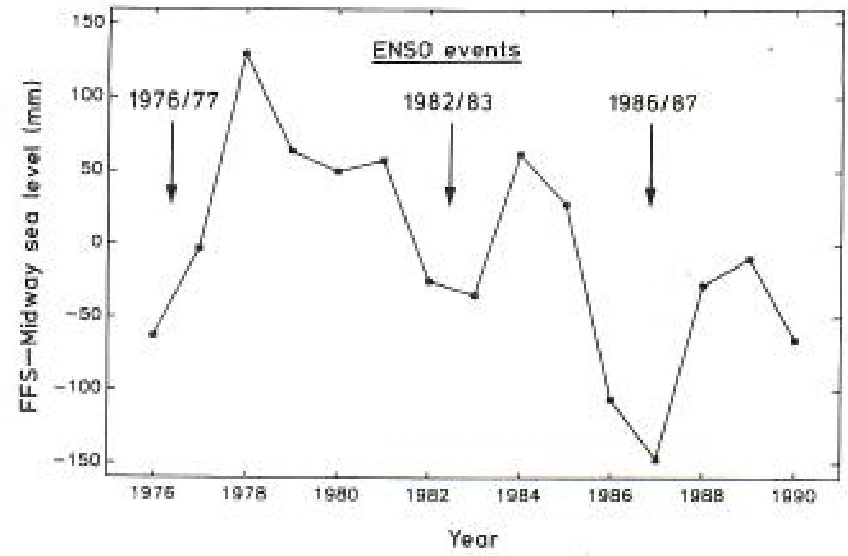

Figure 3
Annual French Frigate Shoals (FFS)–Midway sea level differences from tide gauges, 1976–90 (ENSO = El Niño Southern Oscillation).

Data on the difference in sea level between the gauges at French Frigate Shoals (FFS) and at Midway Is. have been available since 1976 (Figs. 1,3). This sea level difference (denoted as FFS–Midway sea level) serves as an index of the geostrophic current anomalies across the NWHI in the region of Maro Reef. For example, an increase in the sea level height at FFS relative to Midway Is., measured from tide gauges, indicates the strengthening of a current that is across the gradient between the two locations and is flowing from the southwest to the northeast.

To interpret these flow anomalies as a manifestation of the variations in SCC strength, the spatial structure of the sea-surface height variation was examined by mapping the variability observed by the Geosat altimeter during November 1986–November 1988. These 2 years were selected because more accurate orbit estimates were available during this time-period and would result in more accurate sea-surface height fields. The Geosat geophysical data records were obtained from NOAA (Cheney et al. 1987) and were processed with software developed at the University of Hawaii.

Averages of the Geosat data over November 1986–November 1987 were subtracted from the averages over November 1987–November 1988. Before using the Geosat data, we checked that the resulting sea level differences from the altimeter were consistent with the corresponding sea level differences from tide gauges at FFS and Midway (not shown). Choosing these time-periods also allowed us to contrast conditions during the ENSO period of 1986–87, when the FFS–Midway sea level was low (~520 mm), with conditions during the normal period of 1987–88, when the FFS–Midway sea level was higher (~600 mm).

Puerulus settlement

During the last planktonic stage (i.e., postlarval or puerulus stage), spiny lobster acquire the benthic morphological features of adults and become active swimmers seeking benthic habitat. MacDonald (1986) studied puerulus settlement in the Hawaiian Archipelago with traps known as Witham Collectors at Kure Atoll (north of Midway Is.) in 1979–83 and at FFS in 1981–85. He computed mean catch per collector over 12-month periods (June–May) at Kure Atoll and FFS. These data will be compared with the FFS–Midway sea level data.

Results

The fit of the model to the commercial CPUE data and the resulting residuals indicate the model fits the trend in CPUE, but considerable unexplained variation exists in CPUE within and between years (Fig. 4). For example, given the fishing effort, CPUE was greater than expected in 1988 but declined more than expected in 1990. Since the model assumes both constant recruitment and constant catchability, the residuals may reflect variation in these factors. From the fit of the model, $R = 1.2 \times 10^6$ adult lobsters/yr, $M = 0.71$/yr, $q_1 = 1.2 \times 10^{-6}$, and $q_2 = 0.6 \times 10^{-6}$. Thus 1.2 million lobsters recruit to the fishery annually; with an M of 0.71/yr, only 50% of the 3-year-olds survive 1 year (in the absence of fishing). Further, a CPUE of 1.2 spiny lobster/trap-haul means the exploitable population is 1 million spiny lobster. An independent estimate of M from tagging at FFS is 0.5/yr (MacDonald 1984).

Commercial trapping effort since 1985 has averaged about 1 million trap-hauls (Table 1); using the q_1 estimate as catchability, annual fishing mortality (F) is estimated as 1.2/yr or $1.7 \times M$. With these figures and the estimates of growth and age at onset of sexual maturity, the Beverton-Holt yield equation estimates the spawning-stock biomass per recruit, when effort is 1 million trap-hauls, is 40% of what it would be in the absence of fishing (Polovina 1991). Thus, the ratio of F to M and the relative spawning-stock biomass calculations suggest that the spawning biomass in 1985–86 was not fished down to a level that would cause the poor recruitment to the fishery 4 years later (1989–90).

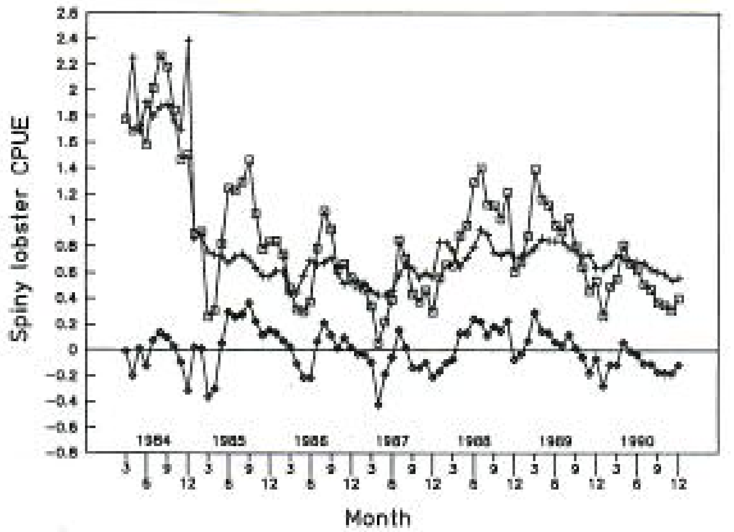

Figure 4
Fit of the CPUE model (+) to monthly CPUE (□) for spiny lobster *Panulirus marginatus* in the Northwestern Hawaiian Is., and residuals from the fit (◆).

Much of the variation in residuals from the CPUE model is due to variation in recruitment at Maro Reef. For example, for the entire NWHI in 1990, trapping effort increased 11% from the previous year while the catch declined 33%, resulting in a 39% decline in CPUE. However, the decline in CPUE was most striking at Maro Reef, where CPUE declined 42% even though effort decreased by 37%. At Necker I., CPUE also declined (40%) but effort increased 35%.

The estimated age-frequency distributions based on research cruises at Maro Reef show a strong 3-year-old class in 1988 and a striking absence of all age-classes in 1990 (Fig. 5). This is consistent with the hypothesis that recruitment of the 3-year-olds to the fishery was weak in 1990 and subsequent fishing reduced all older age-classes. Necker I. had many more 2-year-olds in the samples since some trapping sites include nursery habitat; but between years, the abundance of 2-year-olds was relatively constant, whereas older lobsters declined in 1990, likely because of the increase in fishing effort (Fig. 6).

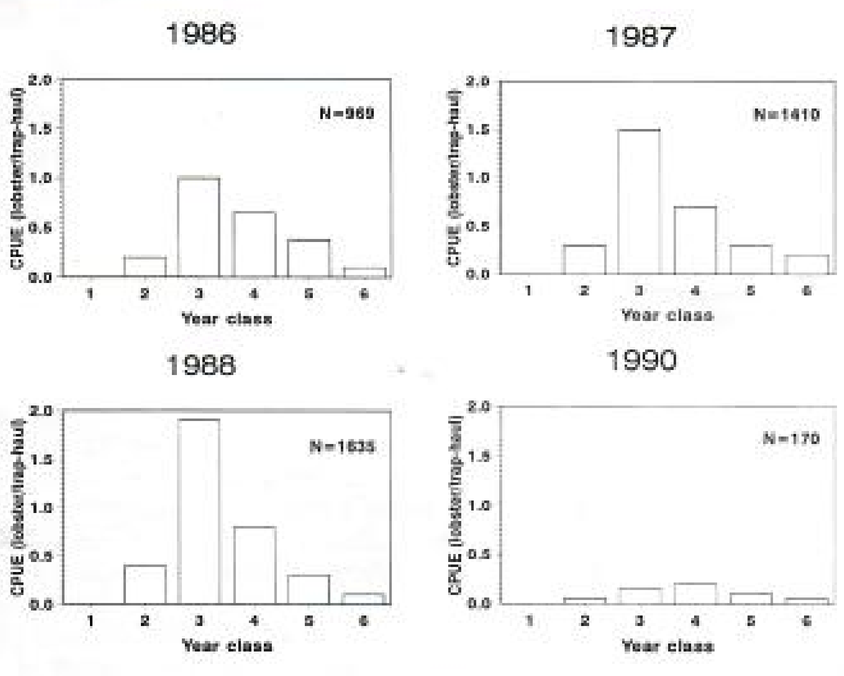

Figure 5
Age-frequency distributions of spiny lobster *Panulirus marginatus*, based on research sampling in 1986–88 and 1990 at Maro Reef (N = no. of spiny lobster in the sample).

The NWHI lobster fleet is very mobile and shifts its trapping locations according to abundance of lobsters. By 1985, both Maro

Reef and Necker I. had gone through a period of fishing down the pre-exploitation population; the relative change in catches between the two banks may reflect changes in their relative recruitment. Since both banks are not always fished each month, we pooled the catches by quarter. A 3-quarter moving average of the ratio of quarterly catches at Maro Reef to the combined quarterly catches at Necker I. and Maro Reef shows considerable variation (Fig. 7). For example, catches from Maro in 1985 and 1988 represented almost 80% of the catches from the two banks, but in 1990 they represented less than 20%. A 3-quarter moving average of the residuals from the CPUE model shows the same trend as the ratio of catches from Maro Reef relative to Necker I. and Maro Reef combined (Fig. 7). This suggests that the variation in recruitment, catchability, or both at Maro Reef is responsible for most of the variation not explained by fishing effort observed for the entire NWHI.

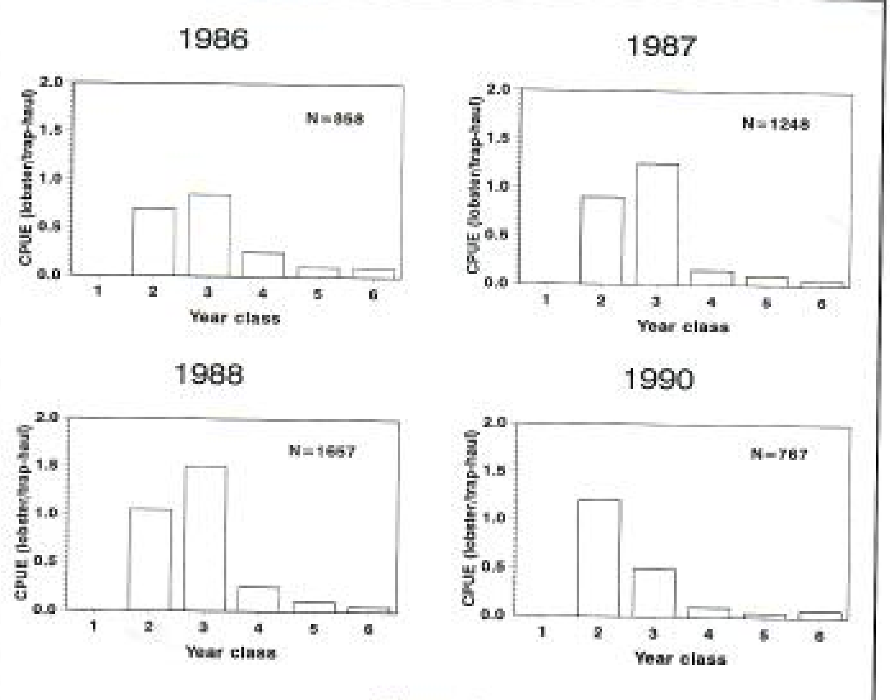

Figure 6
Age-frequency distributions of spiny lobster *Panulirus marginatus*, based on research sampling in 1986–88 and 1990 at Necker I. (N = no. of spiny lobster in the sample).

Variation between sea level and the SCC

Differences in sea level over the Pacific, between a year when the FFS–Midway sea level was high and a year when it was low, appear as a ridge of positive values, extending from southwest to northeast, that parallels a trough of negative values to the northwest (Fig. 8). Midway lies in the trough, Honolulu is on the ridge, and FFS lies on the gradient, which corresponds to the region of the most energetic geostrophic flow anomalies. This ridge and trough indicate that the change in the FFS–Midway sea level from low to high reflects the increase in a ridge extending across the western Pacific. The increase in the ridge and trough pattern represents an increase in the current flow along the gradient of this ridge. The path of this gradient or flow across the Pacific is consistent with the general path of the SCC. Thus FFS–Midway sea level measures a large-scale oceanographic feature which is represented by the height of the sea level ridge stretching across the Pacific. The height and location of this sea level ridge

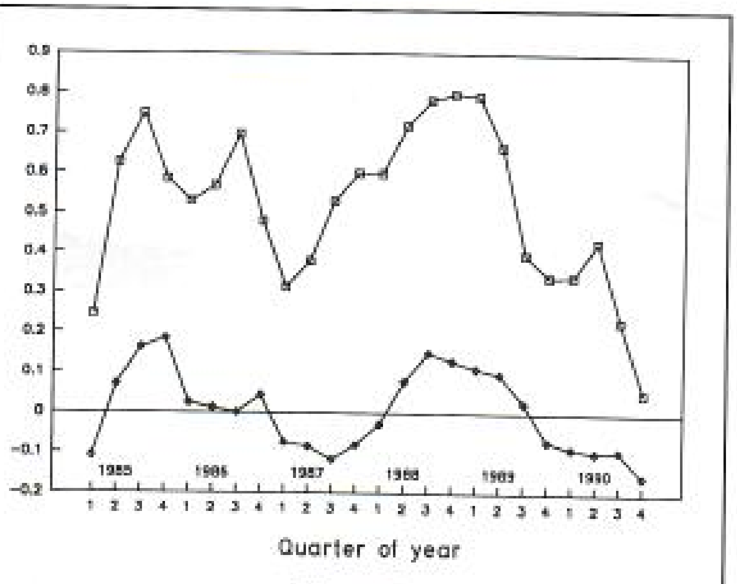

Figure 7
Three-quarter moving average of the ratio of quarterly landings of spiny lobster *Panulirus marginatus* at Maro Reef to quarterly landings at Maro Reef and Necker I. (□), and 3-quarter moving average of the residuals from the fit of the CPUE model to monthly spiny lobster CPUE (◆).

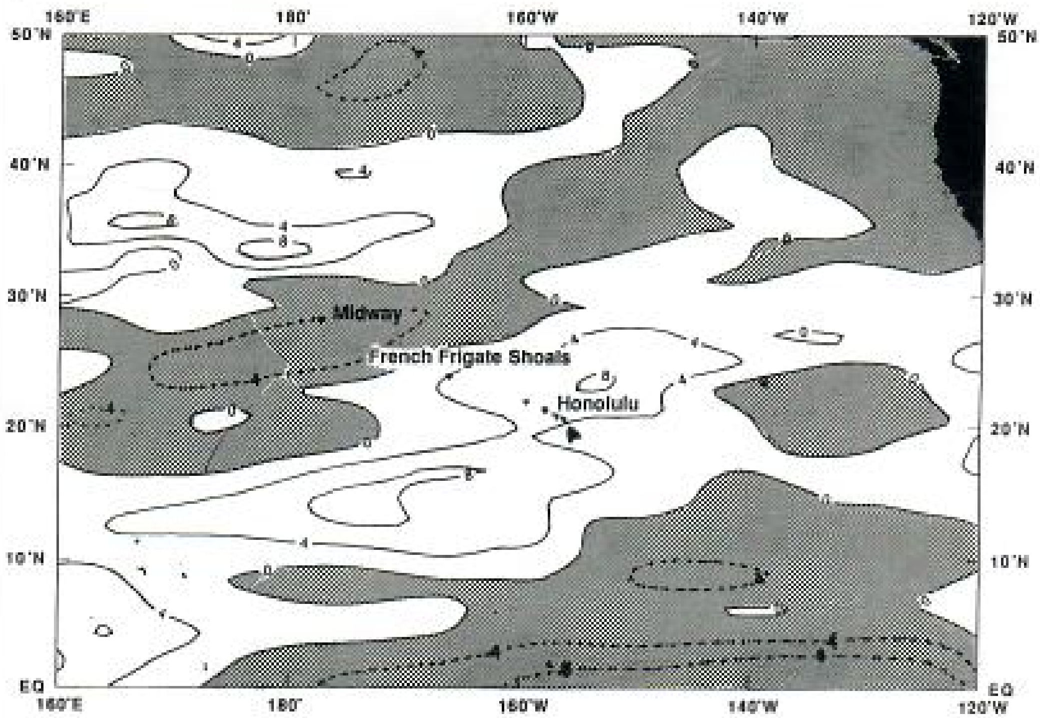

Figure 8
Differences between mean sea level during a non-ENSO (El Niño Southern Oscillation) period (Nov. 1987–Sept. 1988) and an ENSO period (Nov. 1986–Sept. 1987) from Geosat data. Negative values denoted by shaded areas.

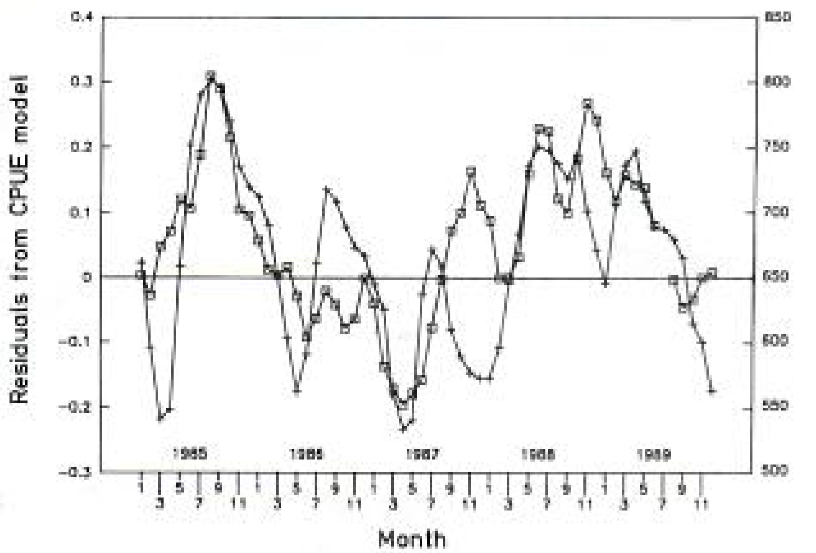

Figure 9
Overlay of 3-month moving average of French Frigate Shoals (FFS)–Midway sea level advanced by 4 years (□) with a 3-month moving average of residuals from the fit of the CPUE model (+).

correspond to the SCC strength and position, respectively.

Relationship between sea level and lobster abundance

Lagged cross-correlations between FFS–Midway sea level and the variables (i.e., the ratio of catches at Maro Reef to the combined catches at Maro Reef and Necker I., and the residuals from the CPUE model) have their strongest correlations (r 0.82 and 0.68, respectively) with sea level lagged by exactly 4 years. When sea level is lagged by 4 years and overlayed with these time-series, there is good agreement (Figs. 9,10). Based on research samples pooled over 1986–88, the mean estimated age of lobsters caught by the fishery is 3.8 years (after settlement).

Based on the comparison of FFS–Midway sea level with the available puerulus settlement data from MacDonald (1986) in the same year, the FFS–Midway sea level correlates positively with mean puerulus catches at Kure Atoll (r 0.78, P 0.11) and shows no significant correlation with mean puerulus catches at FFS (r −0.37, P>0.25) (Fig. 11).

Discussion

The research and commercial catch and effort data presented here show that the recruitment of 3-year-old spiny lobster to the fishery has varied considerably at Maro Reef but has remained stable at Necker I., 670 km to the southeast. Fishing effort is not considered sufficiently heavy to explain a decline in recruitment, especially a decline at one bank and not the other. The relationship between recruitment to the fishery at Maro Reef and the FFS–Midway sea level advanced by 4 years suggests that environmental factors impacting the larval stage are responsible for the recruitment variation. The Geosat data suggest that the FFS–Midway sea level measures the SCC. Hence the SCC strength or location dictates recruitment strength to the fishery 4 years later. Consistent with this hypothesis is the mean age of lobsters in the commercial catches as well as the correlation between puerulus settlement at Kure Atoll and FFS–Midway sea level. The lack of correlation between puerulus settlement at FFS and sea level is consistent with the observation that recruitment at the lower end of the NWHI is not linked to the same pattern of variation as Maro Reef. Annual variation in both SCC strength and position has been observed in the western Pacific (White and Hasunuma 1982). In summary, the temporal pattern of spiny lobster recruitment differs between Necker I. and Maro Reef. At Maro Reef, large-scale oceanographic features appear to control the abundance of late-stage larvae, which in turn results in interannual variation in recruitment to the fishery.

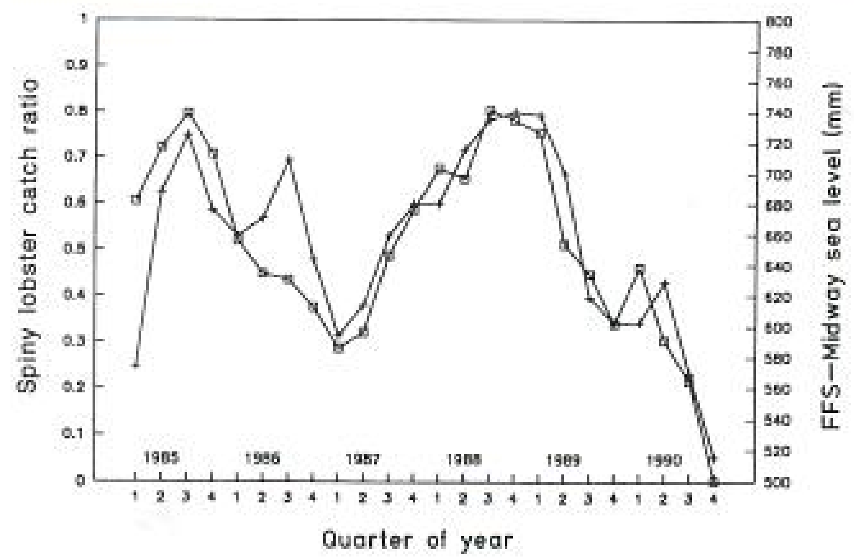

Figure 10
Overlay of 3-quarter moving average of French Frigate Shoals (FFS)–Midway sea level advanced by 4 years (□), with a 3-quarter moving average of the ratio of Maro Reef to Maro Reef plus Necker I., spiny lobster landings (+).

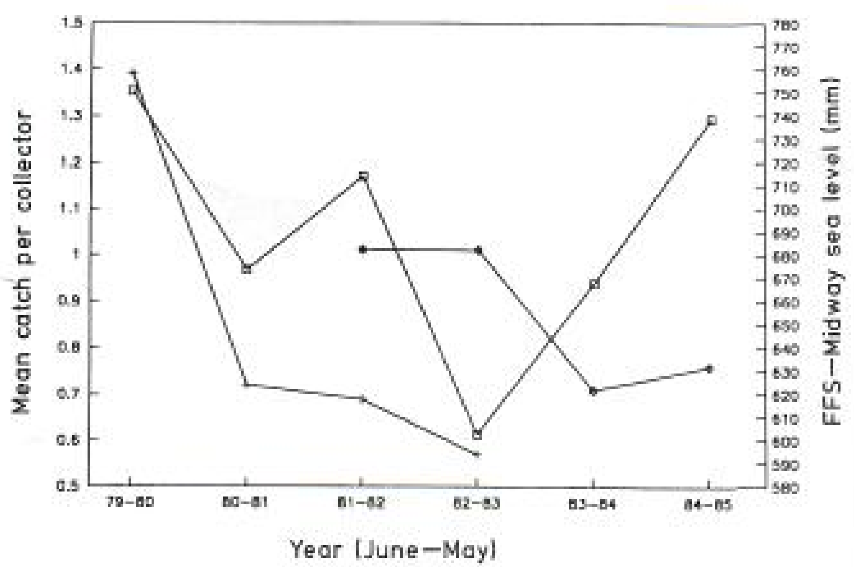

Figure 11
Mean annual puerulus settlement from traps at Kure Atoll (+) and French Frigate Shoals (FFS) (◊) and FFS-Midway sea level (□), all computed on a June-May year.

The underlying mechanism linking the correlation between the SCC and subsequent recruitment at Maro Reef is not known. It is possible that the SCC returns larvae, which have been advected west of the archipelago, back to Maro Reef. The SCC has been hypothesized to transport *Acropora* coral from Johnston Atoll (lat. 16°45′N., long. 169°31′W) to FFS (Grigg 1982). In addition, larvae of a spiny lobster species not recorded as an adult in Hawaii have been transported from the Marshall Is. to the Hawaiian Archipelago (Phillips and McWilliam 1989).

However, it may be that the SCC impacts not advection but larval survival. Laboratory studies have shown that spiny lobster larvae suffer a high level of mortality when water temperatures drop below 20°C (T. Kazama, NMFS Honolulu Lab., pers. commun., Sept. 1991). In the years we estimated that the SCC was weak, water temperatures <20°C in the winter have been observed at Maro Reef but not Necker I. If little larval mixing occurs between Maro Reef and Necker I., larval mortality at Maro Reef resulting from low winter temperatures could account for the observed recruitment variation.

A third hypothesis is that when the SCC has a particular speed and location, it produces fronts which retain larvae near Maro Reef. When the SCC is weak or shifts, these fronts are not formed near Maro Reef. Preliminary evidence from the drifter buoys and larval sampling in our study suggests fronts north of Maro Reef and south of Necker I. may be important for lobster larvae (Polovina, pers. observ.)

One potential management application of the lagged relationship between FFS–Midway sea level and recruitment is that it provides up to a 4-year forecast of recruitment to the fishery at Maro Reef. A 3-quarter moving average of the FFS–Midway sea level shifted forward by 4 years forecasts poor recruitment in 1991, followed by an improvement beginning in late 1992 (Fig. 12). During January–May 1991 before the fishery was closed for 6 months, recruitment at Maro Reef clearly had not recovered, as only 1052 spiny lobster were harvested from Maro Reef while 34,746 spiny lobster were harvested from Necker I. Recall that the relative catches between banks provide an index of relative abundance, since the fleet moves to maximize the CPUE. The FFS–Midway sea level data forecast that catches at Maro Reef will improve beginning in late 1992 (Fig. 12). Data from larval tows are consistent with this forecast. Standardized larval tows, taken in June and November 1989 over a grid of stations from the 200 m isobath out to 56 km around both Necker I. and Maro Reef, caught 3802 and 3342 late-stage phyllosomes, respectively (J. Polovina, unpubl. data). A *t*-test, based on a lognormal distribution, finds no significant difference in the mean abundance of larvae between Maro Reef and Necker I. If we assume that larval abundance was high around Necker I. in 1989, then good larval recruitment apparently has returned to Maro Reef. This is consistent with the observed higher sea-level values in 1989 (shown as 1993 values in Fig. 12, since the sea level has been advanced by 4 years) and suggests that catches will be high at Maro Reef in 1993.

The FFS–Midway sea level time-series from 1976 to 1990 (Fig. 3) shows that ENSO events may result in poor recruitment to the fishery 4 years later, but the series also shows a long-term decline. Reasons for the low FFS–Midway sea level during ENSO events are not known, but may be related to a decrease in surface water supplied to the SCC in the western Pacific. Such a change could be associated with the circulation disruptions observed in the tropical Pacific during ENSO events (Meyers and Donguy 1984). The long-term decline in sea level from 1976 to 1990 suggests there is a low-frequency component in the variation in SCC strength and, hence, lobster recruitment. Thus, it may be some time before recruitment to the fishery is at the early 1980s' level.

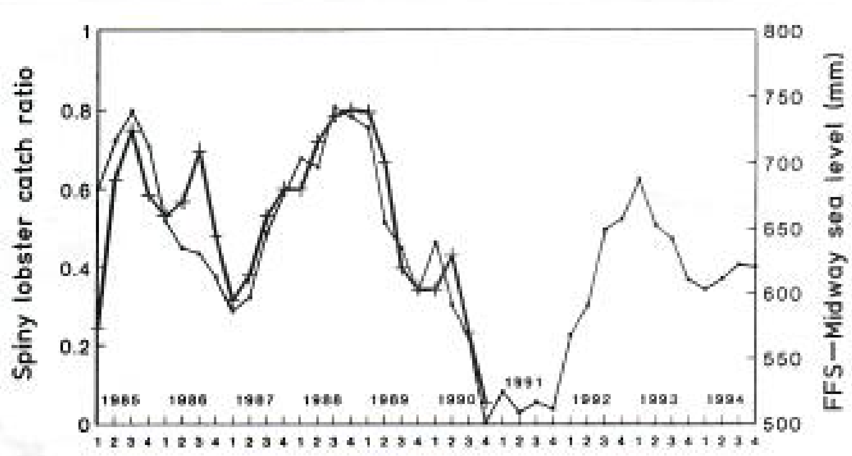

Figure 12
Three-quarter moving average of the ratio of quarterly landings of spiny lobster *Panulirus marginatus* at Maro Reef to quarterly landings at Maro Reef and Necker I. (bold line) overlayed with the 3-quarter moving average of French Frigate Shoals (FFS)–Midway sea level deviation advanced by 4 years (thin line).

Acknowledgments

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The Southern Oscillation Regulates the Annual Numbers of Green Turtles (*Chelonia mydas*) Breeding around Northern Australia

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Abstract

The green turtle (*Chelonia mydas*) is one of six turtle species which breeds around northern Australia and Indonesia. The number of green turtles observed nesting varies substantially from year to year. The interannual fluctuations in the number of nesting turtles are in phase at widely separated rookeries. They are also correlated with an index of the Southern Oscillation, a coherent pattern of atmospheric pressure, temperature and rainfall fluctuations which dominates the interannual variability of the climate of the tropical Pacific. Major fluctuations in the numbers of turtles breeding occur two years after major fluctuations in the Southern Oscillation. The relationship is strong enough to be useful in predicting, two years in advance, the numbers of green turtles breeding in Great Barrier Reef rookeries. This is the first study to report a biological impact of the Southern Oscillation that allows such a long-range prediction of the impact.

Introduction

The green turtle (*Chelonia mydas*) is a pantropical herbivorous sea turtle. It is one of six species of sea turtles breeding in tropical Australia. Typical of sea turtles, *Chelonia mydas* lives in widely dispersed feeding grounds, in this instance seagrass flats and algal rich reefs, but migrates to aggregate most of its breeding at a small number of traditional rookeries. Within the Great Barrier Reef region (GBR) there are two such major rookery areas, one centred on Raine Island in the north and the other in the Capricornia Section in the south. The green turtles nesting at these eastern Australian rookeries are drawn from feeding grounds not only within the GBR but from the region encompassed by Northern Australia, New Caledonia, Vanuatu, Papua New Guinea, Irian Jaya, to as far west as Ambon in Indonesia, i.e. the Coral Sea, Gulf of Carpentaria and the Arafura Sea (Limpus and Parmenter 1986). Green turtles nest almost entirely during the summer within the GBR; maximum nesting density occurs in December and January. During a breeding season, each female lays several clutches of eggs at about 2-weekly intervals (Bustard 1972; Limpus 1980; Limpus *et al.* 1984).

Materials and Methods

Data have been collected on the numbers of green turtles nesting on two islands at opposite ends of the GBR, Heron Island (23°26′S.,151°55′E.) and Raine Island (11°36′S.,144°01′E.), for the breeding seasons between October 1974 and April 1986. Because of different logistics of working on these islands, the size of the annual nesting population was assessed differently at each island. For Heron Island the annual total number of nesting female green turtles visiting the island was measured by a tagging census conducted over several months. For Raine Island, the average number of nesting females visiting the island per night at a standard time of the nesting season (early December) was measured. The natural

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logarithm of these data is graphed in Fig. 1 to illustrate that substantial variations occur in the numbers of turtles nesting, and that the variations on the two widely separated islands occur in phase. There is no evidence that these fluctuations in any way reflect fluctuations in the actual numbers of turtles in the feeding grounds.

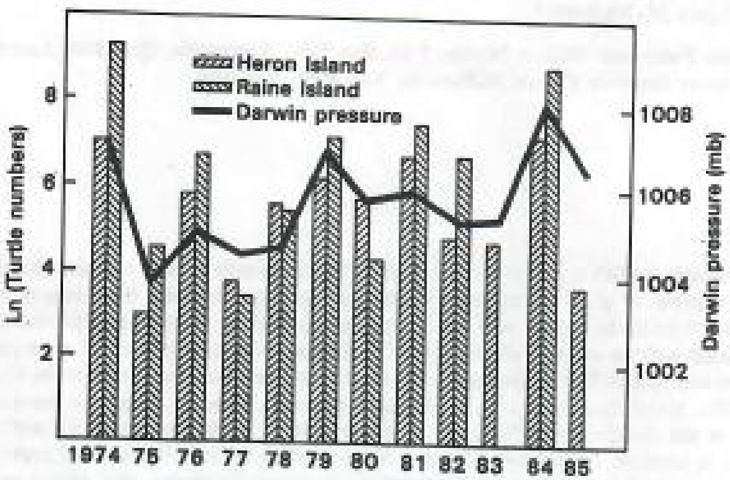

Fig. 1. Histograms of natural logarithms of the numbers of green turtles breeding at Raine Island and Heron Island between 1974–75 and 1985–86. Note that the numbers of nesting turtles were assessed in different ways at the two islands (see text). Darwin atmospheric pressure for Nov.–Jan. two years earlier is also shown. Data were unavailable for Raine Island for 1983–84 and for 1985–86.

Results

The numbers of turtles nesting at Heron Island and Raine Island have been correlated with an index of the Southern Oscillation (SO). The SO is a coherent pattern of pressure, temperature, and rainfall fluctuations which dominates the interannual climate fluctuations of the tropical Pacific and Indian Oceans (Rasmusson and Carpenter 1982). It is related to the El Niño phenomenon which has a marked effect on the marine biology of the east Pacific (Barber and Chavez 1983). The primary manifestation of the SO is an aperiodic seesaw in atmospheric pressure between the southeast Pacific and Indian Oceans. Darwin atmospheric pressure is one of several indices of the SO available and has been related to rainfall, sea surface temperature and tropical cyclone activity in and around northern Australia and Indonesia (McBride and Nicholls 1983; Nicholls 1984*a*, 1984*b*, 1985*a*). The atmospheric and oceanic fluctuations associated with the SO in this area suggested themselves as possible causes of the fluctuations in the numbers of green turtles breeding so these numbers were correlated with 3 month means of Darwin pressure from up to 3 years prior to the mid nesting season (1 January). Strong positive correlations were found with Darwin pressures 22–32 months prior to nesting. The strongest correlation was with the pressure averaged over the November–January period 2 years before the nesting season. The correlation coefficients between the pressure averaged over the November–January period two years before nesting and the turtle numbers were 0·78 (with Heron Island numbers) and 0·74 (with Raine Island numbers). Even with the small sample available (12 years at Heron Island, 10 at Raine Island) these are significant at the 2% level. Darwin pressures averaged over the period November–January two years prior to nesting are graphed in Fig. 1. The close relationship between Darwin pressure and the numbers of turtles nesting two years later, at both Heron and Raine Islands, is clear for the short period of data. The data are graphed as a scatter diagram in Fig. 2 which reveals the relationship more clearly.

The period 1974–75 to 1985–86 is the only one for which quantitative data on the numbers of turtles nesting at these islands are available. Qualitative descriptions of the numbers of turtles nesting at these islands are available from various sources for some earlier years. Those years with known poorer turtle numbers (e.g. 1928, 1949, 1964) were preceded by lower than normal Darwin pressures two years earlier. In addition, qualitative data suggest that males and females appear to be similarly affected. In poor seasons at Heron Island not only did the turtles not nest in abundance, but the females and the corresponding male component of the population did not arrive in abundance on the adjacent reefs for courtship (Limpus *et al.* 1984).

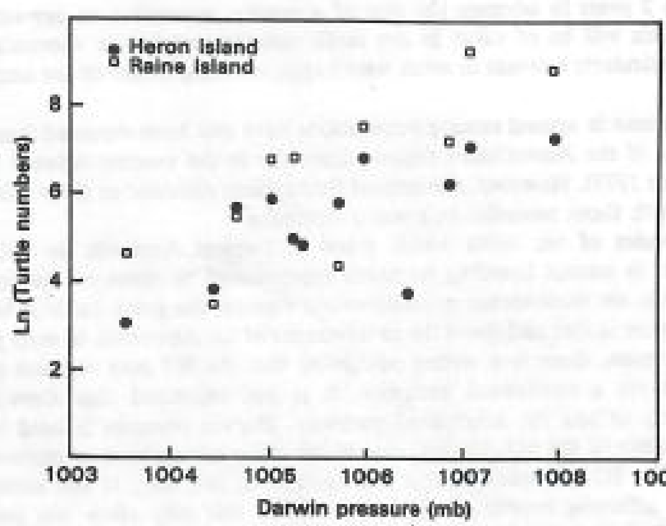

Fig. 2. Scatter diagram of data shown in Fig. 1.

Discussion

As noted earlier, the SO, of which Darwin pressure is an index, has marked effects on the atmosphere and ocean in the Australian region. It is not, therefore, totally surprising that the SO is related to fluctuations in the numbers of turtles breeding. Previous work has demonstrated strong biological impacts of the SO in this area, specifically crop yields (Nicholls 1985*b*, 1986). But why should there by a lag of 2 years? From any one feeding ground, only a portion of the mature females green turtles are breeding in any one year (Limpus and Reed 1985*a*, 1985*b*). In Australia, the same female green turtle has not been recorded breeding in successive years. Indeed the modal remigration interval recorded from Australian rookeries is 5 years (uncorrected for tag loss—Limpus *et al.* 1984). The events preceding a breeding season are as follows (Limpus, unpublished data). Most of the females have left their home feeding grounds a month or two before nesting commences in late October. Before that however, each female will have deposited several kilograms of yolk into the hundreds of follicles she has prepared for the breeding season. This vitellogenic process appears to take about 9 months, developing follicles being visually recognisable in ovaries in the late January before a breeding season. Before vitellogenesis begins the females will have already laid down additional fat deposits, but the duration of the fat deposition period is not known. Thus preparation for a breeding season commences more than 1 year before oviposition. The observed correlation between numbers of breeding turtles and the SO effects with a lag time of 2 years indicates that the SO may be determining the proportion of females able to acquire the fat reserves necessary for entering the vitellogenic phase of preparation. While the time sequence of preparation for a breeding season has not been documented with the males, the observation that fewer males migrate to courtship in the poorer nesting years suggests that they have a similar preparation time for breeding as the females.

There are also indications that the nesting density of green turtles in south western Java, based on egg harvest data 1981–84, fluctuates in parallel with that of the GBR green turtle rookeries (Limpus, unpublished data). This is to be expected given the wide region that the SO influences. This needs confirmation through measurement of the annual nesting density at one of these Indonesian rookeries and calculation of the correlation between numbers of green turtles breeding in any one year and the SO effects 2 years before. Once the same pattern can be confirmed for some widely spaced reference rookeries, it should be possible to predict up to 2 years in advance the size of a nesting population at any other rookery in the region. This will be of value in sea turtle management in the Australia–Indonesia region, being particularly relevant in areas where eggs, courting turtles or the nesting females are harvested.

Large fluctuations in annual nesting populations have also been reported from *C. mydas* rookeries outside of the Australasian region, especially in the western Atlantic basin (Carr *et al.* 1978; Schulz 1975). However, the annual fluctuations recorded at these other areas are not in parallel with those recorded in eastern Australia.

The other species of sea turtle which breed in tropical Australia do not appear to have fluctuations in annual breeding numbers synchronous to those of the green turtles. These other species are carnivorous or omnivorous whereas the green turtle is herbivorous. Given this difference in diet and given the involvement of fat deposition in early preparation for a breeding season, there is a strong possibility that the SO may regulate green turtle nesting numbers via a nutritional pathway. It is not suggested that Darwin pressure necessarily directly affects the nutritional pathway. Darwin pressure is used here simply as a convenient index of the SO. Rather, one of the other atmospheric or oceanic variables associated with the SO probably affects the nutritional pathway. If the atmospheric or oceanic variable affecting breeding could be isolated, this may allow the prediction of breeding fluctuations at rookeries located in other areas not markedly affected by the SO (e.g. western Atlantic Ocean).

Acknowledgments

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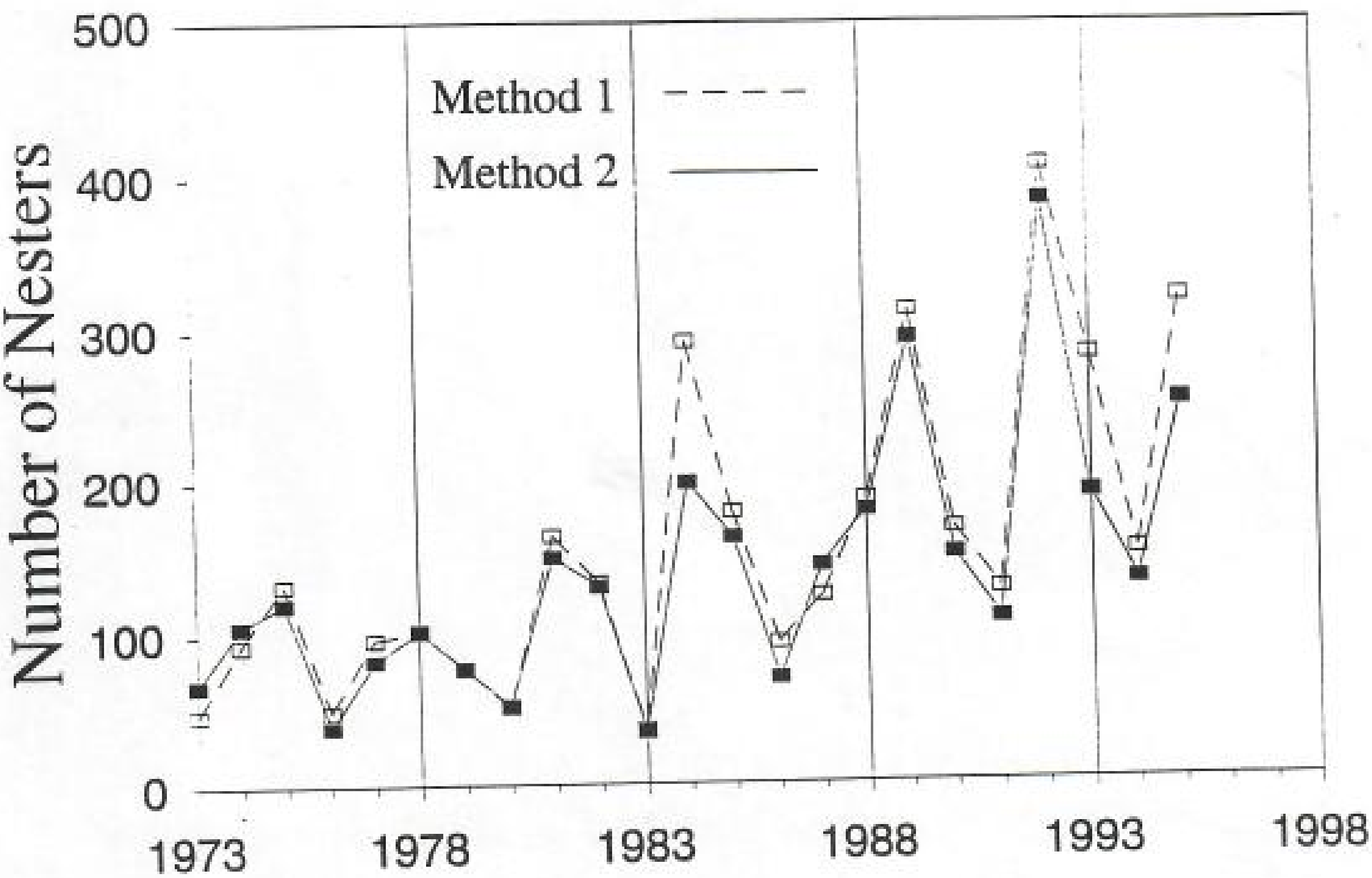
East Island green turtle nesting population estimates (N)
using Method 1 and Method 2
(20 July 1995)

Year	Coverage Rate	Method 1 N	Sighting Probability	Method 2 N
1973	3.94	48	0.98	67
1974	4.51	93	0.99	105
1975	2.50	132	0.93	120
1976	0.92	49	0.62	39
1977	0.73	96	0.53	82
1978	1.01	101	0.65	101
1979	1.19	77	0.71	77
1980	1.89	51	0.86	52
1981	1.81	164	0.85	149
1982	1.83	133	0.85	130
1983	1.58	36	0.81	35
1984	1.48	293	0.79	199
1985	1.57	179	0.81	162
1986	1.83	92	0.85	69
1987	1.92	123	0.87	143
1988	7.19	188	1.00	180
1989	7.85	312	1.00	294
1990	7.82	168	1.00	150
1991	7.73	127	1.00	107
1992	7.63	407	1.00	384
1993	2.78	283	0.95	191
1994	2.45	153	0.92	132
1995	2.89	320	0.95	252

NOTE: Method 2 estimates, based on counts of ID'd (tagged) nesters are more accurate than Method 1 estimates, which are based on total counts of nesters ashore.


Number of Nesters
Method 1
Method 2
500
400
300
200
100
0
1973
1978
1983
1988
1993
1998

Levels of Green Turtle (*Chelonia mydas*)Hatchling Mortality Due to Entrapment in Vegetation and Seabird Burrows on East Island, French Frigate Shoals

Kimberly K. Berger

1995

OBJECTIVES

The main objective of this study was to determine the effect of vegetation and seabird burrows on the level of green turtle hatchling mortality at East Island, FFS. This was determined through several transections of the island. Random quadrates along the transections were studied for percent cover of vegetation, species of vegetation and relative abundance of each, the number of active and inactive seabird burrows, and the number of dead and/or trapped hatchlings found within each.

MATERIALS AND METHODS

MATERIALS:

- 1 50 meter measuring tape
- 2 8 meter long rope (for measuring quadrates)
- compass
- camera

To begin the study, the length of the island was measured from the SE to the NW point by running a meter tape the length of the island down the center. Based on this measurement, the length of the island was divided up into 15 equal sections, each transect being 30 meters apart. Thirteen transections were completed, due to the fact that the first and last sections were on the beach at each end of the island rather than on the berm (see figure 1). The first transect was started at the 30 meter mark. The tape was run the width of the island from the berm on the south side to the berm on the north side. A compass bearing was taken prior to laying the tape down to assure that the transect ran at a 30 degree angle. The next 12 transections occurred at each 30 meter increment along the length of the island (SE to NW) with a compass bearing again taken for each to assure that each transect was placed at a 30 degree angle. Along each transect a 2 m by 2 m quadrate was measured out every 15 m with each 15 m increment being the center of the quadrate. Along the transect the first quadrate was placed at the 0 m mark, the second at the 15 m mark, the third at the 30 m mark. In some cases, where the island was wider, a fourth quadrate was placed at the 45 m mark, and if feasible a fifth at the 60 m mark as well.

In each quadrate, the percent cover of vegetation was determined by examining and estimating the amount of ground covered by all species of plants. Next, within each quadrate the relative abundance of each species of plant and type of substrate was determined by first identifying each plant or substrate and then estimating how much of the percent cover that specific species contributed. Thirdly, seabird burrows were counted within each quadrate, separated into either active or inactive status. Inactive burrows were ones in which no bird was found, or traces of fresh feathers signifying that the burrow was currently occupied. Thus, active burrows were classified by fullfilling one or both of these conditions. These combined determined the total burrow density. Next, all inactive burrows were searched by reaching in and pulling out the contents of the burrow (being careful not to collapse the burrow in the process), recording the number of hatchlings found. All active seabird burrows were looked into only and any hatchlings seen were recorded (as reaching in would disturb the birds). Lastly; the entire quadrate was searched for trapped and/or dead hatchlings in the vegetation and the number found recorded. Any live hatchlings found during the study were to be released on the beach immediately following the conclusion of the transect.

As a final measurement, the area of the island covered with vegetation was estimated. This was done to calculate roughly what portion of the island covered with vegetation was searched. Photographs were then taken to show the abundance of vegetation at the time the study was completed.

DATA

TABLE 1-EAST ISLAND ESTIMATED TOTAL AREA

MEASUREMENT	LENGTH	AVERAGE WIDTH	ESTIMATED AREA
entire island	430 meters	60 meters	25800 square meters
vegetation only	380 meters	40 meters	15200 square meters

TABLE 2-AREA SEARCHED ON EAST ISLAND

AREA MEASURED (EACH QUADRATE)	# OF QUADRATES SEARCHED	TOTAL AREA SEARCHED	% OF TOTAL AREA SEARCHED	TOTAL # OF QUADRATES IN VEGETATION	TOTAL AREA IN VEGETATION SEARCHED	% OF AREA IN VEGETATION SEARCHED
4 square meters	49	196 square meters	0.75	40	160 square meters	1.05

TABLE 3-EAST ISLAND STUDY; IDENTIFIED PLANTS AND SUBSTRATES FOUND WITHIN QUADRATES

ASSIGNED NUMBER	PLANT SPECIES AND SUBSTRATES
1	soil
2	coral sand
3	coral gravel
4	coral rubble
5	*Setaria verticillata*
6	*Portulaca lutea*
7	*Boerhavia repens*
8	*Tribulus cistoides*
9	*Eleusine indica*
10	*Sonchus oleraceus*
11	*Chenopodium oahuense*
12	*Malva parviflora*
13	*Lepturus repens var. repens*
14	*Chenopodium murale*
15	*Cyndon dactylon*
16	*Heliotropium curassavicum*

Table 3 lists the numbers which were given to plant species and substrates to save space on the field data sheet. The numbers correlate with table 4 as the substrate/ plant species #. Relative abundance for these plant species was calculated as the percent that particular plant species contributed to the total percent coverage of the quadrate. Relative abundance for the substrate is the percent of the quadrate that was covered by that particular substrate and is not included in the percent cover of vegetation.

TABLE 4-TRANSECT STUDY DATA

TRANSECT #	QUADRATE #	METER MARK #	% COVER OF VEGETATION	SUBSTRATE/PLANT SPECIES (#)/ RELATIVE ABUNDANCE # %	# OF ACTIVE BURROWS	# OF INACTIVE BURROWS	# OF LIVE HATCHLINGS IN BURROWS	# OF DEAD HATCHLINGS IN BURROWS	# OF LIVE HATCHLINGS IN VEGETATION	# OF DEAD HATCHLINGS IN VEGETATION	TOTAL NUMBER OF HATCHLINGS FOUND
1	1	0 M	0	4-100%	0	0	0	0	0	0	0
1	2	15 M	15	3-85%, 7-5%, 13-10%	0	0	0	0	0	0	0
2	1	0 M	0	2-100%	0	0	0	0	0	0	0
2	2	15 M	90	4-10%, 5-2%, 6-8%, 12-80%	0	0	0	0	0	0	0
2	3	30 M	60	3-40%, 5-25%, 6-10%, 10-20%, 12-5%	0	0	0	0	0	0	0
3	1	0 M	0	2-50%, 4-50%	0	0	0	0	0	0	0
3	2	15 M	75	2-5%, 4-20%, 5-20%, 6-4%, 12-50%, 14-1%	0	0	0	0	0	0	0
3	3	30 M	90	3-10%, 5-5%, 6-75%, 7-5%, 12-2%, 13-1%, 15-1%, 16-1%	0	0	0	0	0	0	0
3	4	45 M	85	4-15%, 5-25%, 7-15%, 8-40%, 12-5%	0	0	0	0	0	0	0
4	1	0 M	0	2-50%, 4-50%	0	0	0	0	0	0	0
4	2	15 M	40	2-30%, 4-30%, 5-7%, 6-1%, 7-1%, 10-1%, 13-30%	0	0	0	0	0	0	0
4	3	30 M	90	2-10%, 5-70%, 6-10%, 7-8%, 15-2%	0	0	0	0	0	0	0
4	4	45 M	99	4-1%, 5-1%, 7-18%, 8-60%, 13-20%	0	0	0	0	0	0	0
5	1	0 M	0	2-50%, 4-50%	0	0	0	0	0	0	0
5	2	15 M	30	2-50%, 4-20%, 5-1%, 6-1%, 7-1%, 12-2%, 13-25%	0	0	0	0	0	0	0
5	3	30 M	85	2-10%, 4-5%, 5-70%, 7-15%	0	0	0	0	0	1	1
5	4	45 M	95	4-5%, 5-50%, 6-25%, 12-15%, 13-5%	0	0	0	0	0	0	0
6	1	0 M	0	4-100%	0	0	0	0	0	0	0
6	2	15 M	2	2-20%, 3-50%, 4-10%, 5-2%, 12-1%, 13-17%	0	0	0	0	0	0	0
6	3	30 M	75	2-20%, 4-5%, 5-65%, 7-6%, 12-2%, 13-2%	0	0	0	0	0	0	0

TABLE 4- TRANSECT STUDY DATA (CONTINUED)

TRANSECT #	QUADRANT #	METER MARK #	% COVER OF VEGETATION	SUBSTRATE/ PLANT SPECIES (#)/ RELATIVE ABUNDANCE	# OF ACTIVE BURROWS	# OF INACTIVE BURROWS	# OF LIVE HATCHLINGS IN BURROWS	# OF DEAD HATCHLINGS IN BURROWS	# OF LIVE HATCHLINGS IN VEGETATION	# OF DEAD HATCHLINGS IN VEGETATION	TOTAL # OF HATCHLINGS FOUND
6	4	45 M	60	2-30%, 4-10%, 5-4%, 6-53%, 10-2%, 13-1%	0	0	0	0	0	0	0
7	1	0 M	0	6-100%	0	0	0	0	0	0	0
7	2	15 M	50	2-15%, 4-35%, 6-10%, 12-40%	0	0	0	0	0	0	0
7	3	30 M	80	3-20%, 5-50%, 10-1%, 12-29%	0	0	0	0	0	0	0
7	4	45 M	75	3-15%, 4-10%, 5-5%, 12-70%	0	0	0	0	0	0	0
8	1	0 M	0	4-100%	0	0	0	0	0	0	0
8	2	15 M	60	3-15%, 4-25%, 6-17%, 7-1%, 10-2%, 12-40%	0	0	0	0	0	0	0
8	3	30 M	50	2-25%, 4-25%, 5-19%, 6-1%, 12-30%	0	0	0	0	0	2	2
8	4	45 M	75	2-20%, 3-5%, 5-4%, 11-5%, 12-20%, 13-20%, 14-1%, 15-5%	1	1	0	1	0	0	1
9	1	0 M	0	2-100%	0	0	0	0	0	0	0
9	2	15 M	24	1-50%, 3-26%, 5-4%, 6-6%, 12-10%, 14-2%, 15-2%	0	0	0	0	0	0	0
9	3	30 M	85	3-15%, 7-1%, 12-77%, 14-5%, 15-2%	0	0	0	0	0	0	0
9	4	45 M	90	2-10%, 6-5%, 11-40%, 12-28%, 14-2%, 15-15%	1	2	0	0	0	0	0
10	1	0 M	2	2-70%, 4-28%, 10-1%, 12-1%	0	0	0	0	0	0	0
10	2	15 M	96	4-4%, 5-50%, 6-6%, 12-25%, 14-5%, 15-5%	0	0	0	0	0	0	0
10	3	30 M	85	2-15%, 9-25%, 12-35%, 14-25%	0	1	0	0	0	0	0
10	4	45 M	85	1-10%, 2-5%, 6-2%, 9-25%, 12-58%	0	0	0	0	0	0	0
10	5	60 M	85	3-10%, 4-5%, 6-40%, 9-5%, 12-10%, 13-30%	0	0	0	0	0	0	0
11	1	0 M	3	2-50%, 3-20%, 4-25%, 6-1%, 12-4%	0	0	0	0	0	0	0
11	2	15 M	80	3-20%, 5-50%, 6-2%, 12-25%, 14-3%	0	0	0	0	0	0	0
11	3	30 M	75	2-10%, 3-15%, 6-1%, 9-10%, 11-40%, 12-24%	0	1	0	0	0	0	0
11	4	45 M	95	2-5%, 9-40%, 11-25%, 12-30%	2	1	0	0	0	1	1
11	5	60 M	90	2-10%, 5-50%, 9-20%, 12-20%	1	1	0	0	0	0	0

TABLE 4- TRANSECT STUDY DATA (CONTINUED)

TRANSECT #	QUADRATE #	METER MARK #	% COVER OF VEGETATION	SUBSTRATE/ PLANT SPECIES#/ RELATIVE ABUNDANCE	# OF ACTIVE BURROWS	# OF INACTIVE BURROWS	# OF LIVE HATCHLINGS IN BURROWS	# OF DEAD HATCHLINGS IN BURROWS	# OF LIVE HATCHLINGS IN VEGETATION	# OF DEAD HATCHLINGS IN VEGETATION	TOTAL # OF HATCHLINGS FOUND
12	1	0 M	5	2-45%, 3-50%, 12-5%	0	0	0	0	0	0	0
12	2	15 M	20	2-40%, 3-40%, 5-15%, 12-5%	0	0	0	0	0	0	0
12	3	30 M	90	3-10%, 5-27%, 6-1%, 9-20%, 12-40%, 16-2%	0	0	0	0	0	1	1
12	4	45 M	11	2-74%, 4-15%, 6-1%, 15-10%	0	0	0	0	0	0	0
13	1	0 M	0	2-10%, 3-45%, 4-45%	0	0	0	0	0	0	0
13	2	15 M	2	2-48%, 3-20%, 4-30%, 10-1%, 12-1%	0	0	0	0	0	0	0
				TOTALS	5	7	0	1	0	5	6

FIGURE 1- EAST ISLAND; TRANSECT DIAGRAM

Figure 1 represents the thirteen transects which were run at 30 degree angles across the width of the island at 30 meter intervals. Note that two other transects are present but not numbered, these were the first and last transects in the fifteen equal divisions of the island which were not included in the study because they were located below the berm.

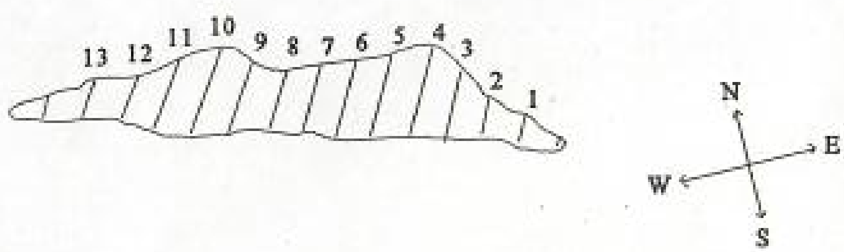


TABLE 5- TERN ISLAND, FFS RECORDED WEATHER DATA

RECORDED RAINFALL							
YEAR	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	SEASON TOTAL
1986	3.7	0.47	0.81	8.05	1.53	1.18	15.74
1987	0.51	1.46	1.2	2.83	0.73	2.24	8.97
1988	4.38	0.71	2.53	1.65	1.84	1.08	12.19
1989	1.02	2.26	6.14	2.02	1.07	3.2	15.71
1990	0.95	1.89	1.08	0.85	1.00	3.75	9.52
1991	0.97	0.94	0.22	1.77	2.65	5.56	12.11
1992	1.19	1.4	3.51	2.63	6.43	0.4	15.56
1993	0.53	1.12	2.97	1.78	2.61	2.05	11.04
1994	1.81	0.48	2.27	1.31	1.39	8.38	15.64
1995	1.72	0.27	4.8	3.26	0.4	2.33	12.78
AVERAGE RAINFALL FOR NESTING SEASON							12.92

TABLE 5 lists the total rainfall recorded on Tern Island, FFS for the years of 1986 to 1995 during the green turtle nesting seasons. It is important to note that the total rainfall for October 1995 is only recorded until 17 October 95 when the study was completed. The average rainfall during the nesting season over the ten years shown has also been calculated.

RESULTS

After randomly searching East Island by way of 49 quadrates, a total of 6 hatchlings were found. Based on the total estimated area of the island covered with vegetation (15,200 square meters) and the area searched in the vegetation (160 square meters), approximately 1 percent of the vegetation on East Island was searched randomly (see tables 1 and 2). These quadrates do demonstrate the overall distribution of plant species, substrata, and burrow density. Via the thirteen transections, samples of the entire island were included in the quadrate searches.

The green turtle nesting season for 1995 in French Frigate Shoals showed an average amount of precipitation. Rainfall was recorded on Tern Island, FFS and totalled each month. This was then compared with the previous 9 nesting seasons (see table 5). Rainfall for the 1995 season totalled 12.76 inches of rainfall as of 17 October 1995. The average rainfall for the period between 1986 and 1995 during the nesting season was 12.92 inches. Therefore, it should be noted that this study was completed during a time of average rainfall. The abundance of vegetation was at an average level compared with other seasons. This study was completed during a time when the island was still very lush with vegetation, in order to demonstrate the level of mortality occurring when there was an average amount of vegetation posing a threat.

A total of 4 different substrate types were observed during the study (see table 3). Generally larger coral rubble was found near the berm and smoother coral sand or gravel was found near the interior of the island. Twelve different plant species were encountered during the quadrate searches. The most abundant were *Malva parviflora, Setaria verticillata,* and *Portulaca lutea.* On the SE side of the island *Tribulus cistoides* was also commonly found. *Eleusine indica* was more common on the NW side of the island. Table 4 shows the distribution and relative abundance of each substrate and plant species for each quadrate. Four of the five hatchlings found dead in the vegetation were found nearer the NW side of the island, tangled in the vegetation. Looking solely at the vegetation data it would seem that the presence of larger and taller plants as is found on the NW side of the island (*Lepturus repens var. repens, Setaria verticillata, Malva parviflora*) causes much more of a problem for hatchling entrapment than does the smaller ,vining plants seen on the SE side of the island (*Portulaca lutea, Tribulus cistoides, Boerhavia repens*). However, it should be noted that more nesting activity also occurs on the NW side of the island. So the greater number of trapped hatchlings found on this end of the island could correlate with a larger number of hatch pits present in the area.

During the study a total of 12 burrows were encountered (see table 4). Seven of these were inactive burrows which were thoroughly excavated to search for trapped hatchlings. Of these seven burrows only one hatchling was found dead, and no hatchlings were recovered alive. Five active wedge-tailed shearwater (*Puffinus pacificus*) burrows were encountered and searched by looking into the burrow. No live or dead hatchlings were found in any of these burrows. However, because active burrows were not thoroughly excavated, there is a possibility that a hatchling could have been present and not detected. The middle to NW side of the island showed the greatest burrow density (transect 8 through 11). The results show that with only 1/12 of the burrows encountered causing an entrapment problem, that they do not seem to pose too great of a entrapment problem, that they do not seem to pose too great of a threat to hatchlings. However, it should be noted that 5/12 of these burrows were active, and therefore not completely searched.

The vegetation seems a greater threat than does seabird burrows. The interior of the burrows in most cases are made up of a soil or coral sand substrate, which would be a smooth surface for a hatchling to crawl through if it did wander in, making for an easier escape. Whereas the vegetation, in some cases has the ability to get entangled around their flippers, preventing the hatchlings from crawling, resulting in death. Possibly the hatchlings exert too much energy trying to maneuver through the vegetation, causing them to become exhausted and eventually die.

In conclusion, the seabird burrows do pose a threat to hatchlings, however the impact seems to be minimal in comparison with the vegetation. Entrapment in the vegetation, although it poses a greater threat to hatchlings than do the seabird burrows, does not seem to cause the hatchling mortality to be a high level. With a total of only 6 hatchlings found in 196 square meters searched, it can be deducted that the impact of lush vegetation and seabird burrows on hatchling mortality is minimal. Most hatchlings are in fact able to maneuver through and find their way to the ocean safely, even with these obstacles.

ACKNOWLEDGMENTS

Thank you to Steve Barclay for his help in organizing this project. To Steve and Anthony Viggiano for editorial assistance in the preparation of this paper, as well as help in data collection on East Island. Thank you also to Allison Veit, and Suzanne Romain for their help in collecting data during the transect study.

LITERATURE CITED

Tern Island Field Station, French Frigate Shoals 1993 and 1994 annual narrative.

Tern Island Field Station, French Frigate Shoals weather logs for the years of 1986 to 1995.

George-

The project went well, thank you for the idea. I will be in Honolulu on Nov. 16 to 21 and am interested in meeting with you and talking about my report and Turtle camp '96. I will call you then. Take care.

Kimberly Berger

P.S.- Thank you for the article and post card!

Date: Mon, 5 May 1997 06:35:58 -1000 (HST)
From: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
To: Marc Webber <marc_webber@mail.fws.gov>
Cc: Chuck Monnett <chuck_monnett@mail.fws.gov>,
Beth Flint <beth_flint@mail.fws.gov>,
Jerry Wetherall <jwethera@honlab.nmfs.hawaii.edu>
Subject: Suggested protocol for recording tagged turtles nesting on Tern Island

Corrected copy-- please use this version.

As promised, I present here protocol guidelines for achieving our high-priority Tern Island green turtle research objective for the 1997 nesting season, as agreed upon at our recent meeting. The objective can be stated as follows: "To estimate the number of turtles that change their island of nesting within French Frigate Shoals between nesting seasons as well as within a nesting season." Jerry Wetherall will use the resulting information to modify, as may be needed, certain assumptions in his model to monitor trends in the Hawaiian green turtle nesting population.

One of the factors motivating us to immediately pursue this work is the present near disappearance of Whale-Skate Island due to erosion, and the fact that a considerable number of nesting turtles had been tagged there during the 1980's. Nesting turtles have been extensively tagged on East Island since 1973. However, during recent years no checks have been made of turtles nesting on Tern Island to determine the degree of switching from East Island.

Protocol: One person should monitor the Tern Island south shore beach once nightly throughout the 1997 nesting season to encounter and examine as many nesting turtles as possible and appropriate. No disturbance to monk seals should occur. Each turtle will be checked for the presence of flipper tags. Tags that are found should be scrapped clean of fouling growth and the number (including alphabet prefix, if present) positively read and recorded. Only one tag on each turtle needs to be read, if there is no doubt as to the accuracy of the reading. Tags present on the hind flippers (when present) will be easier to read. The date, time and stage of nesting by the turtle should be recorded, along with any tumors that may be noted during the brief encounter to check for and read tags. It is not envisioned that it will be necessary for the person to wait for a particular stage of nesting to accomplish the tag check.

Each turtle encountered will also be examined briefly for the presence of a mototool engraved number on the fourth lateral scute of the right side of the carapace. Such numbers may be found any time after monitoring starts on East Island during late May or early June. If a fresh mototool number is seen, it should be recorded and no examination for the presence and reading of tags will be required.

All turtles that are encountered that do not have a fresh mototool number, whether flipper tags are present or not, should be given a mototool number. The number should be approximately 3-4 cm in height on the fourth lateral scute on the right side of the carapace. The numbers will be consecutive with a "T"-prefix. Paint will be applied to the engraving in the same manner as routinely conducted on East each season. The Dremel mototools, chargers and small containers of paint will be supplied to Marc Webber by GHB for immediate transport to Tern Island.

The monitoring walks on Tern should occur approximately one hour after high tide, except when high tide comes before dark (dark= sunset + 50 minutes). When the high tide comes before dark, the walk should occur 1-2 hours after dark. Note that tides at FFS are almost equal (8 minutes difference) to the basic tide values commonly published for Honolulu Harbor.

All of the above recommendations are subject to modification pending feedback from FWS personnel as the monitoring on Tern progresses and additional experience is gained doing the work.

****
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****

Green Sea Turtle Nesting Summary
Tern Island, French Frigate Shoals, 1995

INTRODUCTION

This document is a summary of green sea turtle (*Chelonia mydas*) nesting activity on Tern Island for the 1995 nesting season. Comparisons are made to studies conducted from 1986-1994. The main objectives for this monitoring were to approximate the number of nests laid as well as the nesting phenology for the season, map nest locations, excavate and release trapped hatchlings, determine clutch size, incubation period and hatching success of confirmed nests and check for entangled or entrapped adult turtles.

The work done since 1992 is a reduction of past monitoring efforts by refuge staff (see Niethammer 1991 report). It may be advisable to duplicate the more extensive monitoring effort in the future for comparative analysis.

STUDY AREA

Tern Island (23° 52'N, 166° 17'W) is located on the Northwestern edge of French Frigate Shoals, an atoll 490 nautical miles from Honolulu. Tern Island is approximately 3000 feet long by 120-200 feet wide, encased on the West, North and East sides by a sheet pile sea wall. The majority of nesting occurs on the south beach. There are two small coral rubble/sand beaches on the north side that allow limited access to nesting turtles. There is also a continually shifting sand beach located at the East end of the Island, see map.

METHODS

Dawn nest walks were conducted throughout the nesting and hatching season (May through December). These walks took 45 to 90 minutes to complete depending on nesting/hatching activity. Turtle nesting activity occurs primarily from sunset to sunrise, therefore, direct visual evidence of nesting (eggs seen or "pattycaking") was rarely seen. Nests were defined somewhat subjectively based on the type of diggings and tracks seen; evidence of a "backfill" with tracks leading directly back to the water was the strongest indication of a nest. The southern half of Tern Island has been mapped on a grid system: 10 meters increments East to West and 4 meters increments North to South. Nests were numbered and staked 1.5 meters inland from the nest, and the location was approximated on the above mentioned grid map. Any nests laid in an area of shifting sands (East Beach or either end of South Beach) were moved to a more stable beach area. Pre- and post-hatch pits were also noted during the morning walks. The emergence of hatchlings was indicated by a distinct depression in the sand, a post-hatch pit. The nests were excavated three days following discovery allowing hatchlings four nights to emerge. In some cases nests were not excavated after four nights due to seal activity in the area. Any trapped hatchlings found were removed and released after dark the same day they were found. A nest was confirmed as hatched when it was excavated as a post-hatch pit and egg shell fragments and/or trapped hatchlings were found. Only nests that indicated signs of hatching, a post-hatch pit, were excavated. Nest contents were examined and counted to estimate clutch size and hatching success. The clutch size was determined by counting shell fragments, undeveloped eggs and fully and partially developed eggs. Hatching success was calculated by dividing the number of eggs that hatched by the total number of eggs laid. Appendices A was the data sheet used to record nesting information for the 1995 season.

RESULTS & DISCUSSION

The first known nest for the 1995 season was laid on 2 May, the last known nest was laid on 30 September. The first known hatching occurred on 27 July, the last known hatching occurred on 19 December (Table 1). There were an estimated 282 nests laid during 1995. Two hundred and fifty-one possible nests were identified and staked and 31 unmarked nests were discovered throughout the season. These unmarked nests were found through hatching evidence seen during morning walks. Of the 251 staked nests, 121 were confirmed hatched. Including the unmarked nests, the total number of confirmed nests was 152. The mean incubation length for 116 of the hatched nests was 68.6 days with a range of 44 - 88 days. Nest contents were not examined for 13 of the 152 confirmed nests due to seal activity. The mean clutch size for 139 of the nests was 88.5 eggs with a range of 40 - 168 eggs per nest. Hatching success for these nests was 81.8 (Table 2). Hatching success was also estimated for the 1993 and 1994 seasons by using mean clutch size data from the 1986-1991 and 1995 nesting data. (Tables 2 and 3). Of the 152 nests excavated, 93 had trapped hatchlings (61% of nests; range 1 - 21 per nest). A total of 329 trapped hatchlings were recovered and released during 1995. A comparison of the confirmed nests from 1986-95 is illustrated in Figure 1. The methods used for the 1986-91 Neithammer study were different than those used in 1992-95. The Neithammer study found a higher percentage of nests laid on the island due to the intensity of the follow-up procedures, excavating every staked nest. In 1992-95, only nests with post-hatch pits were excavated. Due to seals, nesting turtles and bird activity, pre- and post-hatch pits became rapidly obscured. It is highly likely that hatching evidence was missed on some nests during the past four seasons.

Throughout the months of July, August and September disoriented turtle hatchlings were occasionally found and removed from the runway.

There were no entangled turtles seen on Tern Island during the nesting season. However, six adult turtles were aided and one was found dead on Tern Island during the nesting season. Following are the descriptions of the individual situations:

On 18 June an untagged adult female turtle was found overturned on Crab Beach. Tracks indicated that she had tried to climb over the seawall and toppled over. The turtle was immediately righted and appeared unharmed as she quickly returned to the water.

On 19 June a dead adult female turtle was found wedged between the double seawall at the east end of Tern Island. The turtle was apparently swept through a hole at sea level in the outer seawall by strong waves. Aluminum grating covers the entire top portion of the double wall, ruling out the possibility that the animal fell into the cavity. The sands of East Beach continually shift along the entire east end of Tern, resulting in the occasional exposure of the eroded seawall which resembles a picket fence. The gaps in the wall are not wide enough for a turtle to access unless the animal was turned on its side. The body was torn open in the process of removing the carcass, releasing fully developed eggs. It appeared the turtle had been dead for at least 24 hours when found and powerful waves had heavily damaged the carcass. The curved carapace measured 99 centimeters.

On 23 June an adult female turtle was removed from the runway and released on South Beach. The animal had accessed the island from South Beach at meter marker 416, crossed the runway, dug a body pit on the north side, and was proceeding to wander aimlessly on the runway. Tags already present were: W866 LFL, W867 RFL. New tags placed on the turtle were: F630 LFL, F629 LHF, F628 LHF. An additional left front tag was attached due to the poor condition of the primary tag site.

On 28 June two adult female turtles were found just south of the runway on the east side of the woodshop. Both animals were guided back to South Beach. The first turtle had a small tumorous growth on the lower portion of the left eye. Tags placed on the animal were: F633 LFL, F632 RFL. Tags placed on the second animal were: F634 LFL, F635 RFL.

On 1 July a tagged adult female turtle was found crossing the runway. The tracks indicated that the turtle accessed the island at Shell Beach. The turtle was tagged and released on South Beach. The tags were as follows: F636 LFL and F637 RFL. On 3 July, the same turtle was found on the runway heading in a westerly direction. It appeared to have accessed the island from South Beach. The turtle was removed and released on South Beach. The turtle did not return to the water as normally observed but remained on the beach. Several hours later the turtle was found dead. A necropsy was performed and the results were sent to the NMFS Lab in Honolulu.

On 5 July a tagged adult female turtle was found along the seawall approximately 100 meters from the east end of the island. Her tracks indicated that she accessed the island at Shell Beach and traveled along the seawall. The turtle was released on South Beach. The turtle was previously tagged and moto-tooled indicating that she had been marked on East Island during turtle camp. The ID #s were as follows: moto-tool # : 166; A218 RFL, A217 LFL, G231 RHF, G229 LHF, A357 L3,4.

ACKNOWLEDGEMENTS

Thanks to the following volunteers and paid staff who contributed to data collection during the 1995 season: Steve Barclay, Anthony Viggiano, Allison Veit, Kim Berger, Nick Palaia, Kellie Mitsue Takimoto, Yonat Swimmer, Suzanne Romain, Grace Hubenthal, Susan Tobias, Todd Carpenter and Leona Laniawe. This report was prepared by Allison Veit.

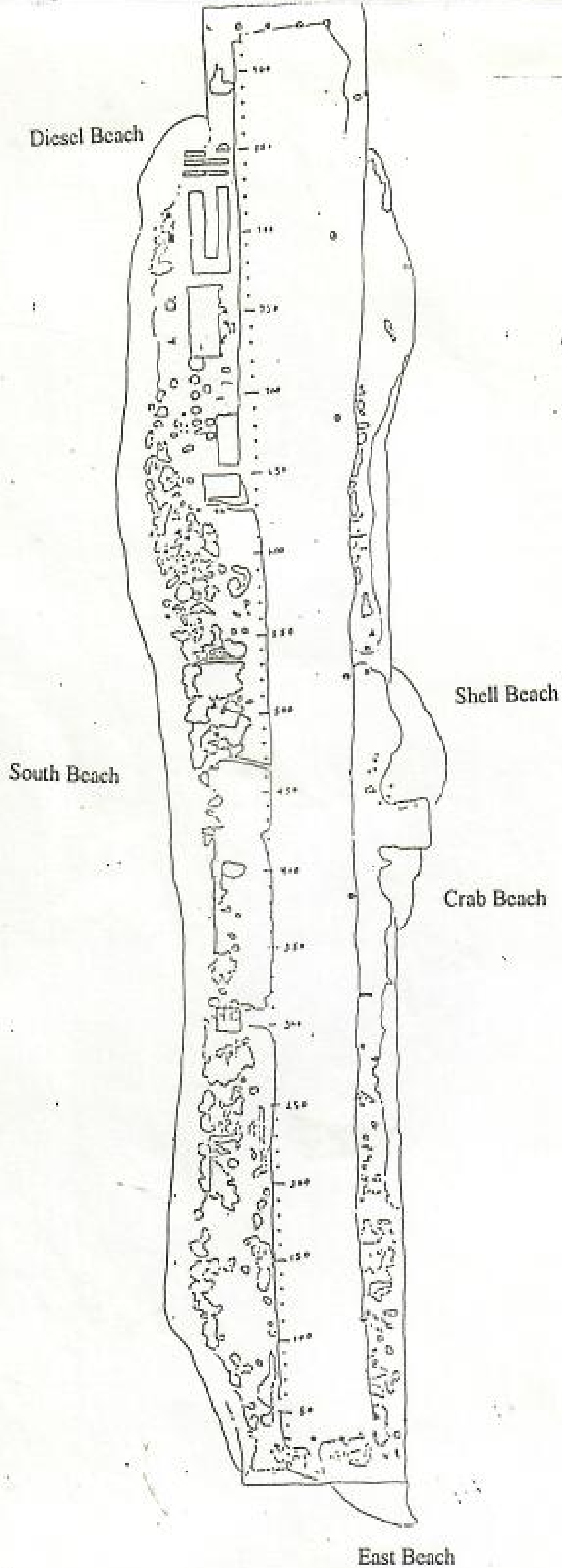
Diesel Beach
Shell Beach
South Beach
Crab Beach
East Beach

Table 1: Dates for the first and last nests laid and hatchling emergences for green turtles on Tern Island, French Frigate Shoals, Hawaii, 1986-95.

YEAR	LAY DATES		HATCHLING EMERGENCES	
	FIRST	LAST	FIRST	LAST
1986	6 June	22 September	15 August	16 November
1987	25 May	20 October	29 July	26 December
1988	26 April	1 October	8 July	9 December
1989	28 April	28 September	19 July	27 December
1990	9 May	25 September	13 July	17 December
1991	29 April	3 September	11 July	5 November
1992	27 April	11 October	20 August	22 January
1993	8 May	14 September	15 July	10 November
1994	4 May	5 September	25 July	11 January
1995	2 May	30 September	27 July	19 December

Table 2: Hatching success of green turtle nests at Tern Island, FFS, 1992-1995, calculated as a percentage by dividing the number of eggs hatched by the total number of eggs laid. Italized % show estimates of nest contents by using the mean clutch size data from the 1986-1991 and 1995 nesting seasons.

CATEGORY	1992	1993	1994	1995
Number of Confirmed Nests	81	51	69	152
Number of Eggs	*7,371*	*4,641*	*6,279*	12,041*
% Hatched Emerged	no data	*82.1*	*83*	79.0*
% Hatched Live-left in nest	*5.2*	*5.3*	*6.4*	2.5*
% Hatched Dead-left in nest	no data	*1.7*	*1.0*	0.3*
% Total Hatched		***89.1***	***90.4***	**81.8***
% Unhatched Developed	no data	*2.4*	*0.5*	5.6*
% Unhatched Undeveloped	no data	*8.5*	*9.1*	12.6*
% Total Unhatched		***10.9***	***9.6***	**18.2***

***Number based on the contents of 139 nests.**

Table 3: Data from green turtle nests at Tern Island, FFS, 1992-1995. No data indicates data was not collected for that category for that year.

CATEGORY	1992	1993	1994	1995
Number of Confirmed Nests	81	51	69	152
Number of Eggs	no data	no data	no data	12,041*
# Hatched Emerged	no data	no data	no data	9,514*
# Hatched Live-left in nest	385	244	403	294*
# Hatched Dead-left in nest	no data	78	64	37*
# Unhatched Developed	no data	113	29	675*
# Unhatched Undeveloped	no data	396	572	1,521*

***Number based on the contents of 139 nests.**

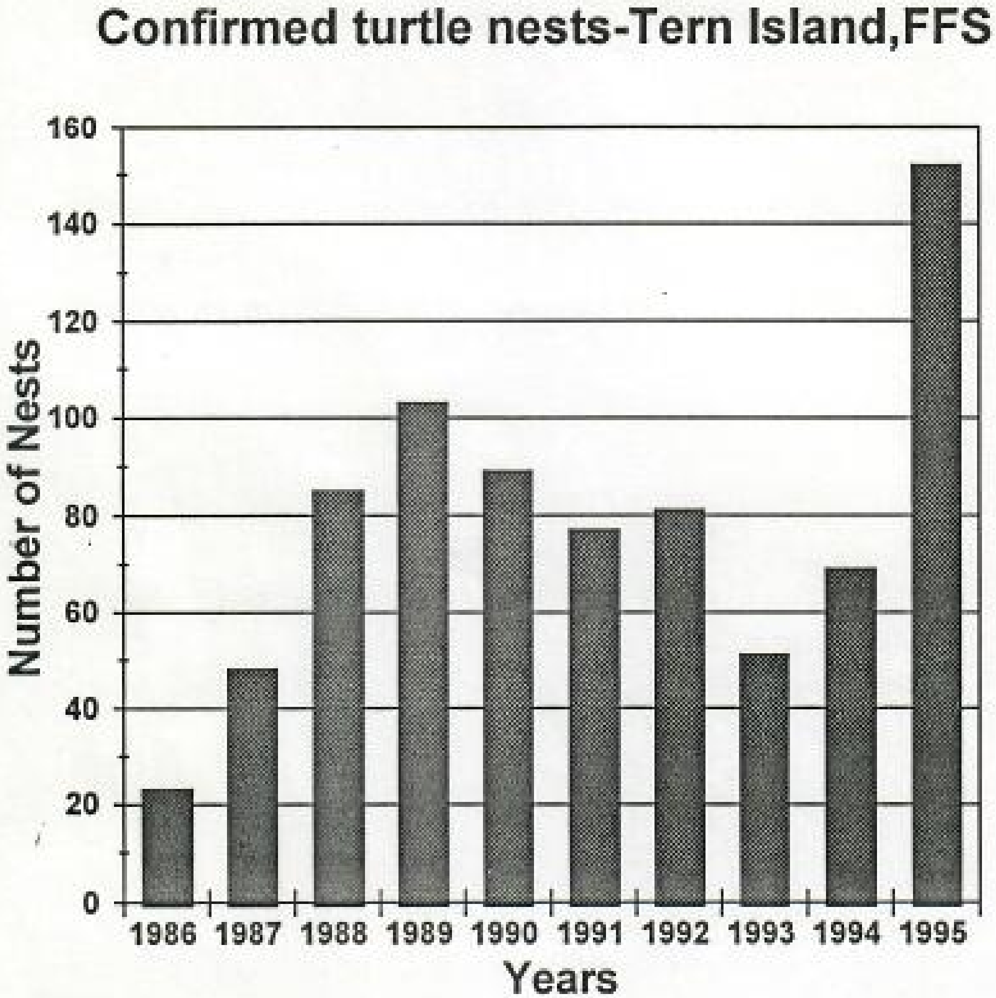

Figure 1: Comparison of confirmed hatched turtle nests from 1986-1995

GREEN TURTLE NEST/HATCHING SUCCESS FORM ed.II

Island____________ YEAR__________ PAGE #___OF___

NEST #	LAY DATE	LOCATION EW	NS	HATCH DATE	PRE PIT?	#TRAP TURTS	#DEAD-DEVELPD FULL	<FULL	#ROT EGGS	INCU TIME	COMMENTS

1995

Green Turtle (Chelonia Mydas) Hatchling Carapace Measurements
Tern Island, French Frigate Shoals

Hatch Date	Hatchling Number	Nest Number	Straight Carapace Length (SCL) in mm	Curved Carapace Length (CCL) in mm	East-West Meter Mark	North-South Meter Mark
12 NOV	1	243	54.85	58.[illegible]	44	41
12 NOV	2	243	51.47	56.51	44	41
12 NOV	3	243	54.99	57.2	44	41
12 NOV	4	243	54.6	57.5	44	41
12 NOV	5	243	54.5	58.0	44	41
12 NOV	6	243	52.93	58.5	44	41
17 NOV	7	245	55.17	58.0	409	28
19 Dec	8	251	46.83	55.0	Shell Beach	Shell Beach
19 Dec	9	251	49.15	58.0	Shell Beach	Shell Beach

1995 (rows 1–9)

20 February, 1996

Hello George,

Here is a copy of our 1995 Tern Island turtle summary. I look forward to any feedback you or Jerry may have on our work. Perhaps a nice correlation between East and Tern Island nest numbers will become evident.

Also enclosed are additional turtle hatchling measurements that were taken following Kimberly's departure in mid November '95.

I'll be in Honolulu purchasing supplies for the East Is turtle camp in early April and look forward to catching up with you then. Any plans to personally come to Tern in June with the turtle techs to deploy more satellite transmitters or data loggers?

I hope all is well George.

Aloha, Steve

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

May 22, 1981 F/SWC2:GHB

TO: William G. Gilmartin, Leader, Marine Mammal and Endangered Species Investigation, Honolulu Laboratory

FROM: George H. Balazs, Fishery Biologist

SUBJECT: Entanglement of a green turtle in the mooring line of a lobster-larvae collector in Kaneohe Bay, Oahu

On the morning of May 19, 1981, a green turtle was found entangled in the 3/8-in. nylon mooring line of a lobster-larvae collector situated near the east side of the Kaneohe Bay Sampan Channel. The turtle was recovered alive floating at the surface by Jason Akamine, an employee of Sea Grant researcher Craig MacDonald. Based on information provided by Mr. Akamine, the line was entangled only around the neck, with numerous tight loops present. The turtle was subsequently transferred to one of my sea turtle holding cages at the Hawaii Institute of Marine Biology on Coconut Island.

On May 20, 1981, I measured, photographed, tagged, and released the turtle back into Kaneohe Bay. The turtle was found to be 62 cm in straight carapace length, 48 cm in width, and weigh 28 kg (60 lb). Tissue damage was confined to the neck region, with abraded open lesions exhibiting moderate swelling. Overall, the turtle appeared to be in good condition except for a slightly concave configuration to the plastron. This may have been due to total evacuation of the gastrointestinal tract as a result of having been restrained by entanglement for 48 hours or longer.

The lobster-larvae collector under discussion measures 2 ft x 2 ft and was floating at the surface over a depth of approximately 15 ft. The apparatus is normally serviced once every 2 weeks, but in this instance it had not been examined for about 1 month. Various invertebrates and algae were growing on the collector, as normally occurs with any object placed in the ocean environment for a period of time. It seems likely that the turtle was attracted to the collector for feeding purpose, although this is admittedly somewhat speculative. However, a green turtle recovered whole from a tiger shark at Midway was found to have been feeding heavily on gooseneck barnacles, cirripeds that are normally found growing on floating objects.

It is my understanding that approximately 20 of these lobster-larvae collectors will soon be moored at French Frigate Shoals, some of which will be placed within 1/2-mile of the various islets. The monitoring schedule apparently only calls for inspection and servicing once each month. In view of the recent sea turtle/line interaction in Kaneohe Bay (along with other documentations around the world), it would seem prudent to examine the collectors at French Frigate Shoals at shorter periodic intervals, particularly during the early phase of the project which coincides with the turtle breeding season.

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NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

June 9, 1981 F/SWC2:GHB

TO: William G. Gilmartin, Leader, Marine Mammal and Endangered Species Investigation

FROM: George H. Balazs, Fishery Biologist

SUBJECT: Low-level overflights of French Frigate Shoals by military aircraft

At 1140 on June 1, 1981, a Navy four-engine propellor aircraft made two overflights of East Island at 500-800 feet. The aircraft came into the Shoals from the east at this same approximate altitude, and departed in the direction of Whale-Skate Island. No radio contact was made with U.S. Fish and Wildlife Service personnel on Tern Island.

The passes over East Island where I was camped caused most of the adult seabirds to take flight. I was not at a location to observe the responses, if any, of monk seals or basking green turtles. On June 1st, there were at least 14 monk seals with pups present on or in waters adjacent to the island.

John Andre, resident biologist at Tern Island, has informed me that several of these low-level overflights involving military aircraft have taken place since last December. If this is developing into a regular practice, as appears to be the case, then some action needs to be taken to have it terminated. I believe that U.S. Fish and Wildlife Service regulations pertaining to National Wildlife Refuges prohibit low-level transiting of aircraft. I do not know if this restriction currently appears on both civilian and military aeronautical maps.

If the flights over French Frigate Shoals are being undertaken to keep a lookout for shipwreck victims, it seems likely that the same objective could be accomplished at a much higher altitude where the possibilities of wildlife disturbance would be greatly reduced.

Six action projects for the enhancement of green turtle nesting habitat at French Frigate Shoals and the possible increase in the numbers of green turtles in the Hawaiian population

by

George H. Balazs

September 1980

1. East Island has 10 concrete foundations from an abandoned U.S. Coast Guard facility which constitute obstructions to turtles and render the habitat unusable for nesting purposes. The largest slab covers 134 m^2, while the combined area of all 10 slabs is 165 m^2 or 0.4% of the 4.0 ha comprising East Island. The destruction of these slabs could be accomplished using sledge hammers and a portable jack hammer obtained from a rental agency in Honolulu. The resulting concrete rubble could be transported by a small boat to deep water for marine disposal.

   Erosion which continues to occur along the northeast shore of East Island has resulted in the loss of 6,000 m^2 of land or 13% of the island since 1948. Over 50% of nesting by green turtles in the Hawaiian Archipelago presently takes place on East Island. It would therefore be desirable to make all remaining areas of the island suitable as nesting habitat.

2. In addition to concrete foundations, East Island also contains considerable abandoned debris in the form of wood, stakes, iron, electrical cables, and antenna ground wire. The removal of these obstructions would further enhance this important nesting habitat.

3. Ghost crabs, Ocypode ceratophthalmus and O. laevis, are known to prey on hatchling turtles at French Frigate Shoals. While this predation is low in comparison to many other sea turtle rookeries, it nevertheless involves an estimated 5% of all hatchlings emerging from nests. Further investigations are necessary, and such work could include an experimental ghost crab control program, ideally on Tern and Whale-Skate Islands where the greatest numbers exist. The experimental elimination of ghost crabs along select beach areas could be accomplished with little adverse impact to other entities by using baited traps and a BB gun.

4. Analysis of natural nests at French Frigate Shoals has found that 76.7% of the eggs in each clutch hatch, but only 70.8% of the eggs yield hatchlings that reach the surface and emerge. The remaining turtles, an average of six per nest, remain hopelessly trapped underground where they eventually die. The excavation, salvage, and release of many of these hatchlings could take place with only a modest effort. In order to measure the ability of these salvaged turtles to survive, small rearing studies could be conducted on Tern Island for periods of 5 to 10 days.

5. At French Frigate Shoals, tiger sharks, Galeocerdo cuvier, are known to prey on resident juvenile turtles, as well as mature adults that seasonally migrate to the area for breeding purposes. Experimental shark fishing conducted at this location during recent years has shown that 31% of the tiger sharks captured had been feeding on turtles. An experimental control program designed to coincide with the turtle breeding season could reduce mortality to turtles and provide further data on the nature and magnitude of this predation.

6. Predation on hatchlings by frigatebirds, Fregata minor, has never been recorded at French Frigate Shoals, however, such mortality is known to occur at some sea turtle rookeries. In order to confirm this absence of predation at French Frigate Shoals, a short-term but intensive food sampling program could be carried out concurrent with the peak months of hatchling emergence. If predation is discovered, appropriate experimental management steps could be taken to reduce this loss.

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Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

May 13, 1981 F/SWC2:GHB

TO: Bill Gilmartin

FROM: George H. Balazs

SUBJECT: Ocean dumping of radioactive waste materials in the vicinity of the Northwestern Hawaiian Islands

This subject has recently come to my attention through an EPA report prepared in November 1980 for the Committee on Merchant Marine and Fisheries, U.S. House of Representatives. The available information shows that during 1959-60 seven containers were dumped by the Military Sea Transport Service at 34°58'N, 174°52'W, approximately 300 miles north of Pearl and Hermes Reef. The report states that the depth of disposal was 5,490 m. The wastes are listed as "by-product materials" with an activity of 14 Ci at the time of packaging. The specific isotopic content is not stated, although such data may exist somewhere in military records. "By-product materials" are defined in the report as wastes that contain isotopes such as cobalt-60, strontium-90, iron-55, tritium, and cesium-137. The report further states that waste materials were generally either packaged in special containers which were then placed in concrete-filled steel drums, or mixed directly in concrete which were in turn placed in the steel drums. At a 900- to 1,700-m dump site in the Farallon Islands off California, approximately 25% of these drums were found to have imploded.

The agency and location where the waste material originated are not listed in the report. The proximity of Midway to the dumping area suggests this site as a possible origin.

N-Waste Ocean Dumping Study

SAN FRANCISCO (UPI) — A congressional subcommittee has been told there is no evidence that thousands of barrels of radioactive waste dumped off the Atlantic and Pacific coasts pose a serious health hazard.

According to the EPA, the United States has about 15 major nuclear waste dump sites off the East and West coasts, and one 20 miles northeast of Honolulu.

There were no new revelations in the controversy about dumping of nuclear waste in the oceans by the United States from 1946 to 1970 during a day-long hearing yesterday, which drew about 100 spectators, many of them representing anti-nuclear groups.

There was criticism, however, over the lack of government documentation of the dump sites, one of which is the Farallon Islands 50 miles west of San Francisco where about 47,500 55-gallon drums of radioactive waste were dumped.

BUT EVEN A GROUP of scientists opposed to such dumping said there was no evidence radioactivty from the sites had caused any signifigant environmental damage.

The group, a committee of five scientists of the Oceanic Society, concluded in its report to the House Subcommittee on Environment, Energy and Natural Resources that studies "indicate the presence of radioactivity above natural background and fallout.

"However," the report said, "we conclude that these studies contain no convincing evidence of a serious present or future threat to aquatic or human health."

Thirty-nine barrels of nuclear wastes were dumped at the Hawaii site in waters 3,500 meters deep. In addition, at a site 300 miles north of Midway Island, seven containers were dumped in waters 5,490 meters deep.

A-4 Honolulu Star-Bulletin Wednesday, October 8, 1980

29 April 1983

Hi George,

Everything's going fine here -- hopefully am acquiring a bit of turtle savvy .... John and I have been motoring around the Shoals counting seals and turtles; will set up camp on Whale-Skate early next week. 26 April counted 9 turtles on East, 18 on Whale-Skate.

In addition to collecting nesting data, I'm interested in trying to monitor the male population at Whale-Skate for the next 3 or so months. The project would enable me to record use of the island (basking and nearshore activity) by individual males during the breeding season and hopefully to track the departure of those males which remigrated to FFS from elsewhere. The project would entail:

1. Marking as individuals 20 males with spray paint, probably using a letter code. (I would also like to experiment with painting some kind of mark on top of the carapace to see if it would be visible while the turtle was in the water.) The sample of 20 would be chosen by starting at one end of the island and marking turtles consecutively until reaching 20 or 2 days having elapsed.

2. Noting marked individuals in regular daily censuses (which would include all turtles on Whale-Skate).

3. Assuming paint remains readably visible 10-15 days, 10 days later marking another sample of 20 males with a different color paint. (Adequate supply of paint is up here.) The new sample would be chosen in the same manner as the first and therefore might contain previously marked individuals. I would repeat marking new samples every 10 days until I could no longer make regular censuses of Whale-Skate.

I believe paint can be applied to many of the basking males with little or no disturbance (I've been practicing approaching basking turtles and think I'm getting a good feel for it). However, for an unbiased sample I think that those males basking in association with or aggregated with other turtles must also be marked, and right now I can't assess the degree of disturbance -- albeit a disturbance every 10 days -- I would incur trying to paint those turtles. Although ideally my short-term identification markings should be backed up by tag numbers, I would not attempt to read tags or tag the turtles in my samples except under appropriate conditions.

John has been helping me design the project and would help me in marking my initial sample and assessing how it goes in general. Keeping disturbance of the turtles to a minimum on Whale-Skate during this breeding season is my main concern and if marking the turtles seems to cause undue disturbance the first time we try, I'll abandon the project.

I'd really like your comments, suggestions, or whatever on all this;;;;;;;.. (Typewriter is giving out...) Hope everything is going o.k. back there in Honolulu for you and looking forward to hearing from you on all this and talking with you once you get up here.

Sincerely,

Sue

29 April 1983

FOR YOUR INFO.....

TAG RECOVERIES

1. 19 April 83, Whale-Skate

   2825 Adult female, left flipper

   John Henderson

2. 24 April 83, Tern

   6361, Adult male, right flipper

   Sue Lautenslager

   (I noticed in a log journal up here that this turtle was tagged at Tern 7 Jan 83.)

3. 27 April 83, Laysan

   5917 sex?

   Doris Alcorn

   (This was relayed over radio)

TURTLES TAGGED

1. 28 April 83, Triglet (Trig has split into 2 islets, this is the easternmost islet)

   Subadult, Sex? (took a photo for you)

   6362 left flipper
   6363 right flipper (both tags in "flap" area)

   measurements:

   69.8 cm straight carapace length
   51.9 cm straight carapace width

   Sue Lautenslager

4/29

Hello George,

Thought I'd get a few words off in case communication from my end continues to be difficult to hear over the radio. If pressing needs arise, a P.M. schedule might be necessary.

Spoke with WGG tonight...regarding lobster FMP proposed modification for trap size, he said he had no problems with it. I also relayed to him the status of things at Kure regarding the outboard...believe he concurs with your and Ed's determination that the best course is to somehow make the short leg workable up there.

The work up here goes well. The logistics of boat use have been no problem so far, though the system may get stretched a little thin in June. I envision NMFS having one boat for both seal & turtle work in that time, but think that should suffice, with you being on East & Sue on Whale Skate...there should be ample boat support to get the seal work done and still shuttle you bakk and forgh.

I've not talked turtle stuff with Steve F. up here. I know he sent a proposal to Jerry and/or Rob, but don't know if it's made its bureaucratic way to you. I was able to get the pliers from him, though sensed some reluctance on his part. I suggest that if you haven't seen the proposal before you get up here, it would be a good idea to get a copy so you have an idea of what he wants to do so you can talk about it. I sort of feel (my opinion only) that the reason he hasn't spoken with you directly is that he feels he should go up FWS channels requesting to do things. (I've not seen his proposal).

Anyway, things here are conducive to getting alot done...have been making quite a few forays out to the other islets. Got down to Disappearing last week...lots of seals but no pups nor turtles there.

It's late, so will hele on...see you in a few weeks.

SUMIMM-6.GHB

Summary of immature green turtles tagged and resighted at French Frigate Shoals, Northwestern Hawaiian Islands, 1974-1980

by
George H. Balazs
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
2570 Dole Street
Honolulu, Hawaii 96822-2396

Study dates	Island/ Reef	Total no. captured	No. newly tagged	No. tag resightings	Total no. tagged to date	Original tag dates and location for turtles resighted
7/74	East	2	2	0	2	
7/74	WS	3	3	0	5	
8/74	East	3	3	0	8	
8/74	WS	1	1	0	9	
9/74	East	2	2	0	11	
9/74	WS	1	1	0	12	
10/74	East	1	0	1	12	8/74-East
2/75	WS	7	7	0	19	
2/75	East	4	4	0	23	
2/75	Tern	1	1	0	24	
5/75	WS	3	2	1	26	2/75-WS
6/75	East	5	4	1	30	9/74-East
6/75	WS	8	8	0	38	
7/75	East	3	2	1	40	8/74 and 10/74-East
7/75	WS	4	3	1	43	2/18-WS
8/75	WS	9	7	2	50	6/75, 2/75, and 8/75-WS
8/75	Trig	1	1	0	51	
8/75	Tern	1	1	0	52	
12/75	WS	3	1	2	53	2/75, 7/75-WS
12/75	East	3	3	0	56	
1/76	WS	27	18	9	74	7/74, 6/75, 6/75, 8/75, 7/75, 8/75, 12/75, 12/75, 7/75, and 12/75 (all WS)
1/76	East	2	1	1	75	7/75-East
4/76	WS	41	26	15	101	7/74 and 1/76, 2/75, 2/75 and 7/75, 6/75 and 1/76, 6/75, 6/75, 6/75 and 8/75, 7/75-12/75-1/76, 8/75 and 1/76, 12/75 and 1/76, five 1/76s (all WS)
4/76	East	12	6	6	107	9/74 and 6/75, 2/76, 2/75, 6/75, 6/75, 12/75 (all East)

Study dates	Island/ Reef	Total no. captured	No. newly tagged	No. tag resightings	Total no. tagged to date	Original tag dates and location for turtles resighted
5/76	WS	10	2	8	109	7/74-1/76-4/76, 6/75-1/76-4/76, 6/75 and 4/76, 12/75-1/76-4/76, 1/76 and 4/76, 1/76, 1/76, 4/76 (all WS)
6/76	East	3	1	2	110	2/75 and 4/76, 6/75 (both East)
7/76	East	2	0	2	110	4/76, 8/74-10/74-7/75 (both East
7/76	WS	2	0	2	110	12/75-1/76-4/76-5/76, 1/76 and 5/76 (both WS)
1/77	Tern	1	1	0	111	
6/77[a]	East	1	0	1	111	4/76 and 6/77-East
7/77	East	1	0	1	111	6/75 and 4/76-East
9/77	WS	2	0	2	111	1/76, 1/76-WS
6/78	East	6	3	3	114	2/75 and 4/76, 6/75-4/76-7/77, 4/76 and 6/77-East
7/78	Tern	1	1	0	115	
5/79	WS	4	4	0	119	
5/79	East	4	1	3	120	6/76, 6/78, 6/78-East
5/79	Tern	3	3	0	123	
5/79	Trig	1	1	0	124	
6/79	East	5	3	2	127	2/75-4/76-6/76, 5/79 (both East)
6/79	Tern	2	2	0	129	
6/79	Trig	1	0	1	129	5/79-Trig
6/80	East	2	0	2	129	5/79, 6/79 (both East)
9/80	Tern	1	0	1	129	5/80-Tern
12/80	East	1	1	0	130	
6/81	East	1	0	1	130	6/79 and 6/81-East
6/82	East	1	0	1	130	6/79-6/80-6/81 East
3/82	Tern	1	0	1	130	5/79 and 9/80-Tern
6/82	Tern	2	1	1	131	7/78-Tern
6/83	East	2	1	1	132	6/79-6/80-6/81-6/82 East
12/83	East	1	0	1	132	6/79-6/80-6/81-6/82-6/83 East
6/85	East	1	0	1	132	6/79-6/80-6/81-6/82-6/83-12/83 East
1/89[b]	Tern	2	2	0	134	
2/89[b]	Tern	3	3	0	137	
3/89[b]	Tern	1	1	0	138	

Study dates	Island/ Reef	Total no. captured	No. newly tagged	No. tag resightings	Total no. tagged to date	Original tag dates and location for turtles resighted
7/89[c]	East	1	0	1	138	6/79-6/80-6/81-6/82-6/83-12/83-6/85 East
11/89[b]	Tern	3	1	2	139	1/89, 3/89 Tern
1/90[b]	Tern	2	2	0	~~140~~ 141	

Notes: [a] Inconel alloy tags used starting 6/77. Prior to 6/77 only Monel alloy tags were applied. All turtles were double tagged.

[b] Captured and tagged by Ken Niethhammer.

[c] Originally tagged 3135, 3136 during June 1979. Increase in curved carapace length over the 10-year period equalled 12.8 cm or 1.3 cm per year.

Number of turtles tagged at:

East = 37
WS (Whale Skate) = 83
Tern = ~~18~~ 19
Trig = 2

SUMIMM-6.GHB

11/20/91

George -

Here's some turtle sightings information USFWS folks collected on Laysan after the NMFS field camp left in July. I just received this yesterday.

Also, here are the tags from the turtle that we necropsied this summer on Laysan.

Brenda B

Laysan Island Field Camp 1991

Green Sea Turtle

July 9	Nest found south of camp, between trashcan and cenchrus study plots. The disturbed area has a steep-faced edge on the east side as if the turtle had been covering eggs. The nest was marked with a piece of orange flagging tape and a gray plastic container tied to a naupaka bush 10' northeast of the nest.
July 23	Nest found 4 meters north of flag marking the nest found on July 9. One false pit and one nest found.
August 7	Nest found 235 meters South of dead snag which is ~300 meters South of camp. The nest can also be paced 75 meters South of the point South of the above mentioned snag. The pit is ~2 meters toward the sea from the trail and is marked with many bottles at the upslope side of the pit.
August 19	1800. Five hauled out together on NW point; frequently see one or two there in the evenings.
August 23	East of NRL (north rock ledge) by ~0.5 km. Two large ~100cm animals basking just above water
August 25	NMFS 8/9 area. One animal hauled out and basking (large) ~100cm
–	As August 23. One 50-75cm basking above water line.
August 26	Turtle in beach position #1 ~75cm. (Sector #2)
August 27	(Sector #2) 5 animals hauled out in beach position #1 in tight group. 1715
September 1	Sector #8, ~1900: large animal hauled out on sand up from wet sand by ~3 meters
September 8	Sector #2 at 1730: 5 animals hauled out.
September 16	0700. Found hatched turtle pit which was found on July 9. Tracks led all the way to the surf in a path which was 4 meters wide and well traveled with many flippers.
September 24	Dug up pit which hatched on or before 9/16. Dug down ~60-70c before reaching shells. Estimate 72 shells - all hatched. Found no unhatched eggs or any dead or alive turtles.
–	Turtle pit 2 north had depression. I think it was there on 9/18 or so.

October 9 Dug pit layed on July 23. 53 egg shells
no rotten eggs or dead turtles.

April 30, 1980

Mr. Dale Coggeshall
Pacific Islands Administrator
U.S. Fish and Wildlife Service
P. O. Box 50167
Honolulu, Hawaii 96850

Dear Dale:

One of the points that I considered mentioning during our recent symposium, but for reasons of appropriateness decided to postpone until the present time, deals with the Fish and Wildlife Service's contribution to the green turtle research program under the Tripartite Cooperative Agreement. As you know, an outline of my research project constitutes Appendix J of the Tripartite document. In the Tripartite narrative, under Responsibilities of the Signatories, it was agreed that all parties have an interest in the green turtle and therefore would provide support for the necessary research of this wildlife component. During the first half of the Tripartite study, financial backing for this work has been equally derived from the State of Hawaii (MAC Office and University of Hawaii) and the NOAA Sea Grant College Program. For the second half of the study, principal support is anticipated, if not assured, from the Honolulu Laboratory, National Marine Fisheries Service.

I realize that the Fish and Wildlife Service has experienced some internal difficulties in obtaining proper funding for seabird research, and that consequently financial assistance for the research of sea turtles has been in abeyance. I should, however, point out that over the past three years I have periodically made appeals for partial support in discussions with Palmer Sekora, Brent Giezentanner, and you. At this point, it is probably unrealistic to expect funds earmarked for turtles to be forthcoming from the Fish and Wildlife Service. Nevertheless, I hope it will be possible during the remaining portion of the study for some assistance to be offered. One contribution might be logistical support on chartered aircraft and vessels scheduled by your agency for future use in the Northwestern Hawaiian Islands. Another possible form of assistance could be the facilitation of a short-term investigation of sea turtles at the Johnston Atoll Refuge. This was one of the priority items mentioned in my symposium paper due to the possibility of the site being used by Hawaiian *Chelonia* as a migratory stepping stone. I would, of course, be pleased to discuss other possible and appropriate forms of assistance with you at your convenience.

I appreciate having the opportunity to bring this matter to your attention. I also applaud and endorse your continuing stand to retain the Hawaiian Islands National Wildlife Refuge as a refuge for wildlife.

Sincerely,

GEORGE H. BALAZS
Assistant Marine Biologist

GHB:ec

Need Admin for Glynnis

Table 3.—Dates of surveys of nesting female population at East Island, number of turtles seen during these periods, estimated coverage rates, and estimated total nesting populations. Based on data of G. Balazs.

Year	Period	Survey dates From	Survey dates To	Number of nights	Estimated coverage rate	Number of turtles seen	Estimated nesting population
1973	1	1 June	19 July	43	0.81	66	81
1974	1	1 June	19 July	19			
	2	27 June	17 July	21	0.84	104	124
	3	27 July	14 Aug.	19			
1975	1	21 May	21 May	1			
	2	6 June	24 June	19	0.65	104	161
	3	19 July	27 July	19			
1976	1	28 June	11 July	14	0.32	28	88
1977	1	24 June	2 July	9	0.25	44	175
1978	1	9 June	19 June	11	0.39	66	167
1979	1	16 June	28 June	13	0.40	55	136
1980	1	10 June	29 June	20	0.54	45	84
1981	1	26 May	17 June	23	0.58	127	220
1982	1	6 June	24 June	19	0.56	111	199
1983	1	4 June	20 June	16	0.54	28	52
1984	1	3 June	27 June	24	0.63	157	248
1985	1	11 June	29 June	18	0.52	131	252

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Number Range From	To	Location	Date
2205	2422	FFS	1977
2576	2625	FFS	1978
2651	2829	FFS	1978
2997	3007	NECKER	May-79
3008	3087	FFS	May-79
3117	3277	FFS	Jun-79
3351	3450	FFS	1984
3531	3534	KAHALA	
3535	3550	FFS	Apr-82
3535	3550	FFS	1984
3551	3575	FFS	Jun-80
3682	3685	KAHALA	
3686	3700	FFS	Apr-82
3701	3750	FFS	May-81
3726		SLP	Jan-81
3751	3775	FFS	Jun-80
3851	4250	FFS	Jun-83
4251	4286	FFS	1984
4951	4953	FFS	Apr-82
4951	4953	FFS	Apr-82
5059	5450	FFS	May-81
5107	5108	SLP	Jan-81
5459	5464	KAHALA	
5471	5475	TERN	May-82
5602	5773	SLP	<1982
5777	5787	FFS	Apr-82
5777	5787	FFS	Apr-82
5855	5875	LIS	
5855	5875	P&H	
5857	5975	KURE	Apr-83
5876	5950	LAYSAN	
5976	6274	FFS	Jun-82
6276	6350	LIS	Jul-82
6351	6375	TERN	May-82
6359	6375	FFS	1986
6651	6700	FFS	Jun-83
6701	6750	LAYSAN	Apr-83
6751	6950	LIS	Apr-83
6951	7150	P&H	Apr-83
7151	7201		Jun-83
7202	7250	FFS	Jun-83
7251	7275	FFS	Jun-83
7351	7432	P&H	Apr-83
7951	8000	FFS	1984
8001	8100	GALVESTON	
8101	8198	FFS	1984
8144	8222	FFS	1984
8231	8250	FFS	Jun-85
9251	9350	FFS	Jun-85
9351	9392	FFS	Jun-85
9651	9725	FFS	Jun-86
9726	9750	TERN	Jun-86
9751	9789	FFS	Jun-86
10027	10450	FFS	1988

10454	10500	FFS	1988
10501	10550	FFS	1988
10560	10750	FFS	1988
11051	11350	FFS	1988
15019	15020	FFS	Jun-86