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STATUS AND ECOLOGY OF MARINE TURTLES AT JOHNSTON ATOLL: 1985 ASSESSMENT

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INTRODUCTION

In 1983 an assessment of sea turtles at Johnston Atoll (lat. 16°45'N, long. 169°31'W) was accomplished by the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, at the request of the U.S. Army Corps of Engineers (Balazs 1985). This research was motivated by an absence of information on sea turtles at Johnston Atoll, the protected status of sea turtles under the U.S. Endangered Species Act, and the Army's plans to build an incineration facility (designated as JACADS) at the atoll to dispose of chemical agents presently stored there. The initial 28-day assessment in 1983 determined that the herbivorous green turtle, Chelonia mydas, is the principal, if not sole, species of sea turtle resident to the atoll. The most heavily utilized foraging area was found off West Peninsula on the south shore of Johnston Island, immediately adjacent to where the JACADS plant will be constructed. Two kinds of benthic algae, Caulerpa racemosa and Bryopsis pennata, were identified as major food sources. Since nesting does not occur at Johnston Atoll, and possibly never did, the adult turtles must periodically migrate to breed at some distant location. Tagging with alloy flipper tags was, therefore, undertaken to document these unknown movements, and also to gather data on population size, structure, and natural rates of growth.

One of several recommendations resulting from the 1983 study was that continued monitoring of sea turtles and their habitat be conducted as construction of JACADS progresses and the facility becomes operational. This report presents the results of an assessment carried out for 14 days in 1985 during the period 29 August to 12 September. A list of the personnel that conducted the research appears in Appendix 1. Thus far no construction has begun on JACADS, except for the piling of sand and coral aggregate at the designated site.

ASSESSMENT METHODS

Turtles were captured alive and unharmed with large-mesh tangle nets identical to the ones successfully used in the 1983 study. The details of this capturing technique have already been described, along with the method of tagging, paint-marking for short-term identification, recording of body measurements, and obtaining food samples from the stomach (Balazs 1985). Procedures similar to the 1983 assessment were also used to obtain blood samples and small biopsies of bone and lamina.

A new method to restrain turtles during data collection on land involved the use of a portable electro-immobilizer (Feenix Stockstill Mark I, Feenix International Ltd., Lake Wylie, South Carolina). Electroleads were clipped to the inguinal region of a hind flipper and the axial portion of a front flipper on the opposite side. Immobilization and recovery of the turtle's normal movements were immediate when the unit was switched on and off. Immobilization results from minute electrical pulses affecting the nervous system which cause muscles to contract and pain to be blocked. The unit is made for large domestic livestock, but has been tested successfully by Wood and Wood (1983) as a surgical anesthesia on captive

green turtles. The present study and other work carried out by the Honolulu Laboratory during 1985 represent the first use of the unit to routinely control wild-captured sea turtles for collecting data and reducing injury to researchers and turtles.

In 1985 visual surveys were once again made from shore, as well as underwater using scuba and snorkel gear to gather ecological data. Personal interviews were conducted with fishermen, divers, and other resident personnel to obtain anecdotal information on recent sightings of sea turtles.

FINDINGS

Results of Capture Efforts

A total of 10 turtles were captured during the 14-day study (Table 1; Figs. 1-10). All were green turtles, and no recaptures or resightings were made of tagged or paint-marked individuals. Nets were set out at five locations, all of which were along the south shore of Johnston Island (Fig. 11). This area continues to host the highest concentration of turtles in the atoll.

The daily netting effort at each location, expressed in meter-hours (MH = length of the net x hours fished) is presented in Table 2. Nets were only deployed during the daytime (usually early morning until sunset) due to the entanglement problem by manta and eagle rays experienced during nighttime netting in 1983. Entangled rays are capable of accidentally drowning turtles that may be caught along with them in the net. Rays can also snarl the net with great force thereby rendering it useless. Even with the precaution of only setting nets in the daytime, one manta ray (at location 2) and two eagle rays (at location 7) became entangled. Although segments of net were destroyed, it was possible to release all three animals alive. During the first 5 days of the study, up to eight large mantas were regularly seen during the daytime swimming close to the south shore. These sightings tended to coincide with southeasterly winds that may have concentrated plankton along the island and offered enhanced feeding conditions for mantas.

Although nets were set at five locations, turtles were caught at only three of them (Tables 2 and 3). Two of these sites (2 and 3) were right off West Peninsula, and one (7) was between West Peninsula and the southwest corner of the island (Fig. 11). All three of the netting locations were adjacent to prominent coral heads. They were also major sites where turtles had been caught in 1983.

The overall catch per unit effort in 1985 (1,269 MH per turtle) was similar to that obtained in 1983 (1,172 MH per turtle). However, compared with that in 1983, catch per unit effort at capture sites 2 and 7 was only about half as good in 1985. In the 1983 study, netting was tried at 17 locations, but no turtles were caught at 13 of them. The catch per unit effort should have been better in the 1985 study, since netting effort was focused mostly at sites with a record of heavy usage by turtles. It is

therefore reasonable to assume that fewer turtles were present at the time of the 1985 assessment. Observations from shore of turtles surfacing to breathe tended to support this conclusion.

Population Structure

Carapace measurements and weights (Table 1) indicate that 20% of the turtles captured were mature adults (>82 cm), 50% were subadults (65-82 cm), and 30% were juveniles (35-65 cm). Green turtles under 35 cm in carapace length have not been found at Johnston Atoll. As at most other locations, green turtles in this small size class are almost never seen in benthic coastal habitat. Instead, residency occurs away from shore in pelagic habitat where the hatchlings are transported by oceanic currents.

The proportion of adults sampled in 1985 was substantially less than what was present in 1983 (20% vs 60%). In 1983 the sex ratio of the 14 adults captured was 2.5:1 in favor of females. In 1985 the two adults examined consisted of one female and one male. Differences in the adults sampled in the two studies may possibly be due to the time of year the assessments were conducted. The 1983 work was done in early October (Phase 1) and again in early November (Phase 2). This was 1-2 months later in the year than the 1985 study. The breeding season in the Northern Hemisphere for the migrant green turtle extends from approximately May through August. However, the peak months for nesting, such as in Hawaii (see Migrations section), are June and July, and most males depart for their resident areas by late June. Nevertheless, the reduced percentage of adults seen at Johnston in early September may have been due to migrant breeders not yet returning to the atoll. Cris Balubar, a former turtle fisherman and resident employee at Johnston for 24 years, indicated that turtles are more abundant during the months of July to December.

Food Sources

Samples of stomach contents were acquired from all 10 of the turtles captured (Table 4). However, for unknown reasons, only small quantities of food material could be obtained. Possibly only a limited amount of foraging had occurred before the time each turtle was captured.

Nine of the samples contained the green benthic algae, Caulerpa or Bryopsis, similar to what was found during the 1983 assessment. However, three samples also contained the seagrass, Halophila ovalis, a marine angiosperm. This item was not previously identified as a food source used by green turtles at Johnston Atoll. In fact, Halophila has apparently never been recorded at Johnston Atoll during any of the earlier ecological investigations (Amerson and Shelton 1976). The distribution and abundance of Halophila at Johnston Atoll needs to be determined, since it offers a potentially important food source for resident green turtles.

Five of the stomach samples (Table 4) contained trace amounts of algae (Polysiphonia tsudana, Sphacelaria furcigera, and Acrochaetium sp.) that are usually only found as epizoic mats on the skin and certain external hard surfaces of green turtles. A possible explanation for the presence of

this material in the stomach would be that, as part of grooming behavior, turtles are grazing on their own, or another turtle's, epizoic mat. Trace nutrients important to the turtles' nutrition may possibly be obtained in this manner.

Injuries and Abnormalities

Evidence of significant injury, possibly resulting from shark attack, was only seen on 1 of the 10 turtles captured. Adult male No. 4165 had the distal portion of its right hind flipper amputated; however, the wound was completely healed (Fig. 2).

Two other turtles, juvenile No. 4161 and subadult No. 7433, had small healed tears in the axillary region of their right front flippers where tags are normally attached. These injuries may have resulted from tags that tore off. However, these turtles could not have been part of the earlier study at Johnston Atoll. All turtles captured in 1983 received two or more tags, as well as having triangular pieces cut from the edge of the carapace during the bone biopsy. Consequently, even if a tag had been shed, these turtles would still be recognizable.

Subadult No. 4153 had a small healed piece missing from its right hind flipper (Fig. 3). Again, this may possibly have been due to tag loss in a turtle tagged elsewhere, but the injury more likely resulted from other causes.

A neoplastic growth 2-3 cm in diameter was present on juvenile No. 4161 in the axillary region of the right front flipper adjacent to the healed injury. What appeared to be the start of small tumors were also present bordering both eyes of adult male No. 4165 (Fig. 2). Neoplasms were found on two adult males among the 21 turtles captured in 1983. Similar growths have been recorded in Hawaiian and other populations of green turtles, but their etiology remains unknown (Balazs 1980).

Two scales present on the ventral surface at the base of the tail seemed to be abnormally large on juvenile No. 4157. However, there was no deformity to the shape or size of the tail. On juvenile No. 4161 (Fig. 8), the postcentral scute consisted of two distinct scutes instead of one.

Strandings, Basking, and Nesting

During the 1985 study, no new observations were made on turtles stranding, basking, or nesting, nor were any new reports received during interviews with resident personnel. All earlier historical records of this nature that could be uncovered were compiled during the work in 1983.

Migrations

On 21 June 1985 one of the adult females (No. 7461) tagged at Johnston Atoll on 5 October during the 1983 study was observed nesting on East Island at French Frigate Shoals in the Northwestern Hawaiian Islands. This constitutes the first long-distance recovery ever made of a turtle tagged

at Johnston Atoll. It also suggests that French Frigate Shoals may be the breeding area for green turtles resident to Johnston. French Frigate Shoals is 830 km to the north, and comprises the major rookery for green turtles migrating from islands throughout the Hawaiian Archipelago. However, it should be noted that ample opportunities have existed in the past for a migratory link to be demonstrated between Johnston Atoll and French Frigate Shoals. Over the past two decades more than 1,600 adult green turtles have been tagged at French Frigate Shoals. None have ever been recovered at Johnston Atoll, including the time when turtle fishing was legal there before 1976. The recovery at East Island is an ecologically interesting and potentially important finding, but additional resightings of tagged turtles will be needed to draw firm conclusions.

Blood Analysis

Whole blood samples from two juveniles (No. 7437 and 4161) and two subadults (No. 4170 and 7437) were collected and shipped frozen to the Charleston, South Carolina, Laboratory of the National Marine Fisheries Service. Analysis will be conducted using specific enzyme stains on isoelectrofocused gels to obtain genetic information. Blood samples from green turtles resident to the Hawaiian Islands (Oahu and Molokai) have also been submitted for this experimental analysis. The results will be incorporated into a larger research project aimed at identifying genetic differences in geographically separated populations of green turtles. The outcome of this work will be reported at a later date.

Bone Analysis

Small triangular pieces of bone and lamina were taken from the 10th and 11th marginal scutes on both sides of the carapace from all 10 turtles captured. The resulting 40 samples were frozen in glass vials with the objective of eventually having them analyzed for radionuclide content. The possibility of such uptake by green turtles arises from the history of nuclear accidents at Johnston Atoll in which radioactive particles were spread over portions of the islands and surrounding waters. Benthic algae, the principal forage for green turtles, concentrate certain radionuclides at rates higher than other plants and animals (Hines 1962). In addition, at Johnston Island the effluent from a desalination plant situated on the north shore is reported to enrich, by an undetermined process, the existing radionuclide contamination in nearshore waters (U.S. Army Corps of Engineers 1983). It is unknown if cooling water to be discharged from the JACADS plant will have the same effect.

Algal Forage Analysis

Fresh samples of Caulerpa and Bryopsis were collected in the turtles' foraging pastures and frozen for eventual analysis at the University of Guam Marine Laboratory. An effort will be made to detect naturally occurring toxic metabolites present in certain green algae. The results of this work will be reported at a later date.

Heavy Metals (Results of 1983 Sampling)

Seventeen bone and 14 fat biopsies collected in 1983 were subsequently analyzed at John Carroll University in Ohio for concentrations of six heavy metals consisting of copper, nickel, cadmium, chromium, lead, and zinc. The results are presented in Table 5 in parts per million on a wet weight basis. It is difficult to determine the significance of these findings because little is known about baseline levels and physiological effects of heavy metals in sea turtles (Coston-Clements and Hoss 1983). Nevertheless, comparatively higher levels of copper and nickel were found in four adults (No. 7485, 7500, 7512, and 7495). Three of these same animals (7485, 7512, and 7495) had notably higher concentrations of lead and zinc. In addition, zinc alone was comparatively higher in the fat of one adult (No. 7500) and, to a lesser degree, copper and zinc in the bone of a subadult (No. 7481).

CONCLUSIONS AND RECOMMENDATIONS

Monitoring of sea turtles at Johnston Atoll in 1985 served to complement and strengthen the data base initially established in the 1983 study. The catch per unit effort with nets indicated that fewer turtles may have been present in 1985 than when sampling was conducted in 1983. Also, the structure of the population sampled in 1985 was different in that fewer adults were present. A new food item, Halophila ovalis, not seen in 1983, was identified from stomach samples. However, the green algae, Bryopsis and Caulerpa, commonly used as forage in 1983 were again found in the stomachs sampled in 1985. Natural fluctuations, probably due to seasonal variation, are most likely responsible for differences seen in population size, structure, and forage utilization. The absence of any construction having started at the time of the 1985 study rules out the possibility of the JACADS project being an influential factor.

The recommendations set forth in the earlier report for the 1983 work are still valid. These suggested measures, covering both research and management actions, are restated in Appendix 2.

ACKNOWLEDGMENTS

A number of individuals and agencies contributed to the success of the 1985 sea turtle assessment. Food samples were identified by Dennis J. Russell of Seattle Pacific University. Cris Balubar, and other resident personnel of Holmes and Narver Inc., provided helpful information and logistical support. Gail Pieterson resighted the tagged turtle nesting on East Island at French Frigate Shoals while employed by the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. William Cooke, resident biologist for the U.S. Fish and Wildlife Service at Johnston Atoll, supplied valuable assistance and agency coordination throughout all phases of the field work. Grateful appreciation is also given to Bill Lennan and James Maragos of the U.S. Army Corps of Engineers, Pacific Ocean Division, for coordination and help during the project. Robert Hoste and Edward Skoch of John Carroll University conducted analyses of heavy metals in bone and fat samples collected in 1983.

The work at Johnston Atoll was allowed under an Area Clearance from the Defense Nuclear Agency, and by a Special Use Permit (JHN-2-85) issued by the U.S. Fish and Wildlife Service.

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Table 1.--Body measurements and weights of 10 green turtles sampled at at Johnston Atoll.

Tag No.	Carapace length		Carapace width		Plastron length (cm)	Tail length (cm)	Head width (cm)	Weight (kg)
	Straight (cm)	Curved (cm)	Straight (cm)	Curved (cm)				
			Adult					
7445-48	88.4	93.0	70.3	87.7	70.6	24.5	12.0	105.0
4165-69	86.5	91.0	65.1	86.0	69.6	34.0	12.7	102.3
			Subadult					
4153-56	73.9	80.1	57.2	72.5	59.2	15.0	10.2	58.2
4170-73	71.8	76.5	55.3	71.5	58.3	14.5	10.1	52.3
7441-44	69.8	74.0	52.2	66.7	57.5	16.0	10.1	50.0
7433-36	69.1	74.3	55.9	70.5	55.8	14.5	10.2	48.0
7449-50, 4151-52	68.1	72.6	54.2	68.6	55.3	11.5	9.9	43.2
			Juvenile					
4161-64	61.9	66.8	50.7	61.8	51.5	13.5	9.3	37.7
4157-60	58.5	63.2	46.6	56.1	45.4	12.5	9.3	27.7
7437-40	50.4	53.8	41.4	49.0	41.3	9.5	8.0	18.0

Table 2.--Daily turtle netting effort.

Date 1985	Net location	No. captured	Duration in hours	Length of net (m)	Netting effort (meter-hours)
30 Aug.	2	0	5	38	190
30 Aug.	3	0	5	37	185
31 Aug.	7	0	11	38	418
1 Sept.	7	0	9.5	93	883
2 Sept.	7	2	10.5	93	976
3 Sept.	7	1	10.5	75	788
3 Sept.	3	1	10.5	38	399
4 Sept.	7	0	8	75	600
4 Sept.	2	0	8	37	296
5 Sept.	7	1	11.5	57	656
5 Sept.	3	0	11.5	38	437
5 Sept.	18	0	11.5	18	207
6 Sept.	6	0	10.5	38	399
6 Sept.	2	0	10.5	38	399
6 Sept.	7	0	10.5	55	578
8 Sept.	7	1	11	55	605
8 Sept.	2	0	11	38	418
8 Sept.	3	1	11	36	396
9 Sept.	2	2	11	38	418
9 Sept.	3	1	11	56	616
9 Sept.	18	0	11	37	407
10 Sept.	2	0	11	76	836
10 Sept.	3	0	11	55	605
11 Sept.	2	0	7.5	55	413
11 Sept.	3	0	7.5	76	570
Total		10			12,695

Table 3.--Results of turtle netting effort in meter-hours.

Net location	Meter-hours	Meter-hours per turtle	No. captured
2	2,970	1,485	2
3	3,208	1,069	3
6	399	--	0
7	5,504	1,100	5
18	614	--	0
Total	12,695	1,269	10

Table 4.--Identification of stomach contents sampled from 10 green turtles at Johnston Atoll.

Tag No.	Straight carapace length (cm)	Capture site (net location)	Contents
7445	88.4	3	Halophila ovalis (50%) Caulerpa racemosa var. peltata (50%) Polysiphonia tsudana (trace) Lyngbya sp.
4165	86.5	3	Caulerpa racemosa (trace) Sphacelaria furcigera (trace) Acrochaetium sp. (trace)
4153	73.9	7	Polysiphonia tsudana (trace) Caulerpa racemosa (trace)
4170	71.8	2	Polysiphonia tsudana (trace) Halophila ovalis (trace) Lyngbya sp.
7441	69.8	7	Caulerpa racemosa var. peltata
7433	69.1	7	Polysiphonia tsudana (trace) Caulerpa racemosa (trace)
7449	68.1	7	Halophila ovalis (60%) Bryopsis pennata (40%) Griffithsia sp. (trace) Ceramium sp. (trace)
4161	61.9	2	Bryopsis sp. (trace) Amphipods* (3)
4157	58.5	3	Caulerpa racemosa var. peltata Amphipods* (2)
7437	50.4	7	Bryopsis pennata (trace) Griffithsia sp. (trace)

*Originated from the mouth or esophagus, likely Hyachelia tortugae.

Table 5.--Heavy metal concentrations (ppm wet weight) in the bone and fat of green turtles sampled at Johnston Atoll in 1983.

Tag No.	Straight carapace length (cm)	Copper		Nickel		Cadmium		Chromium		Lead		Zinc	
		Bone	Fat	Bone	Fat	Bone	Fat	Bone	Fat	Bone	Fat	Bone	Fat
7451	100.1	0.447	—	0.268	—	0.000	—	0.030	—	0.060	—	0.171	—
7485	95.9	6.390	43,70	1.208	11.15	0.002	0.000	0.031	0.000	0.210	0.557	1.588	5.147
7565	92.5	0.847	3.665	0.344	1.423	0.001	0.000	0.013	0.000	0.120	0.091	0.252	1.044
7461	90.9	1.061	—	0.288	—	0.001	—	0.006	—	0.053	—	0.395	—
7590	89.7	1.131	9.905	0.458	3.410	0.001	0.000	0.015	0.000	0.131	0.239	0.295	2.615
7500	89.5	—	22.41	—	10.09	—	0.000	—	0.016	—	0.136	—	6.133
7512	89.0	10.70	12.73	1.841	4.359	0.000	0.000	0.300	0.000	0.320	1.080	2.040	4.239
7468	88.2	1.210	—	0.165	—	0.001	—	0.011	—	0.011	—	0.384	—
7560	87.0	1.534	0.646	0.479	0.258	0.000	0.000	0.010	0.000	0.110	0.015	0.304	0.164
7473	84.0	0.780	—	0.240	—	0.000	—	0.000	—	0.010	—	0.183	—
7521	83.7	4.624	6.878	0.709	2.081	0.000	0.000	0.169	0.006	0.200	0.018	0.327	1.435
7517	83.3	0.197	0.111	0.033	0.155	0.000	0.000	0.000	0.000	0.014	0.016	0.052	0.078
7495	82.9	8.443	38.96	2.046	9.614	0.003	0.003	0.020	0.008	0.228	0.585	1.588	>10.00
7555	79.1	1.853	3.475	0.525	1.524	0.001	0.000	0.000	0.007	0.002	0.146	0.911	1.076
7476	77.2	5.922	—	0.615	—	0.000	—	0.006	—	0.084	—	1.217	—
7505	75.2	—	2.373	—	1.249	—	0.000	—	0.002	—	0.106	—	0.873
7551	75.2	1.769	5.686	0.475	2.079	0.000	0.000	0.008	0.028	0.099	0.152	0.324	1.660
7481	72.8	8.539	6.825	1.154	2.873	0.002	0.000	0.042	0.000	0.212	0.237	2.224	1.802
7466	57.4	4.585	6.825	1.381	2.873	0.000	0.000	0.032	0.000	0.033	0.237	1.601	1.802

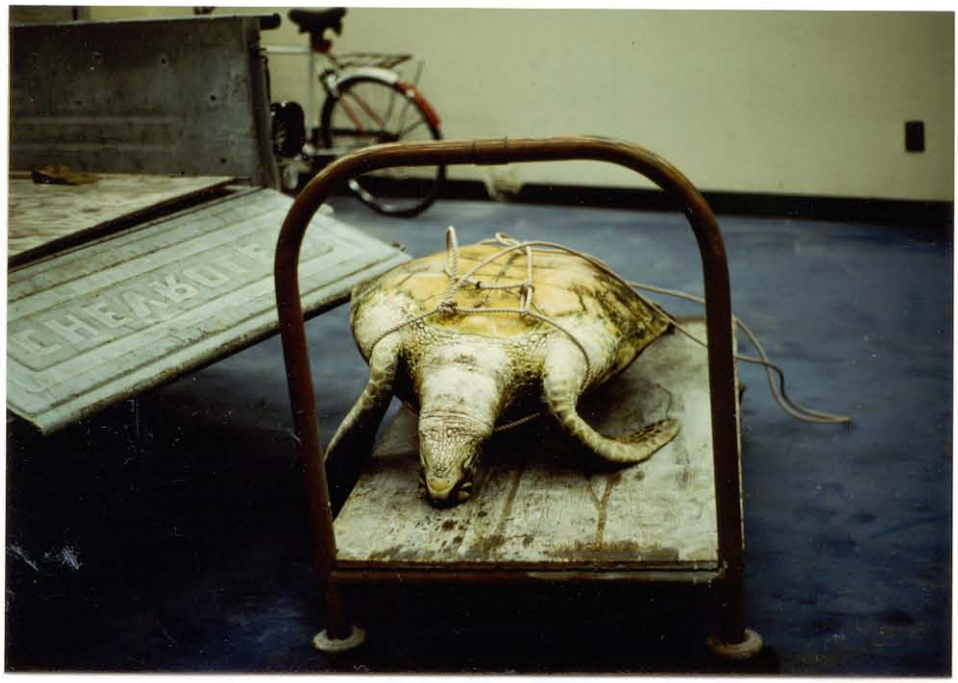

Figure 1.--Adult female, tag No. 7445-48, straight carapace length 88.4 cm, caught on 3 September 1985 at net location 3.

Figure 2.--Adult male, tag No. 4165-69, straight carapace length 86.5 cm, caught on 9 September 1985 at net location 3.

Figure 3.--Subadult tag No. 4153-56, straight carapace length 73.9 cm, caught on 8 September 1985 at net location 3.

Figure 4.--Subadult tag No. 4170-73, straight carapace length 71.8 cm, caught on 9 September 1985 at net location 2.

Figure 5.--Subadult tag No. 7441-44, straight carapace length 69.8 cm, caught on 3 September 1985 at net location 7.

Figure 6.--Subadult tag No. 7433-36, straight carapace length 69.1 cm, caught on 2 September 1985 at net location 7.

Figure 7.--Subadult tag No. 7449-50, 4151-52, straight carapace length 68.1 cm, caught on 5 September 1985 at net location 7.

Figure 8.--Juvenile tag No 4161-64, straight carapace length 61.9 cm, caught on 9 September 1985 at net location 2.

Figure 9.--Juvenile tag No. 4157-60, straight carapace length 58.5 cm, caught on 8 September 1985 at net location 3.

Figure 10.--Juvenile tag No. 7437-40, straight carapace length 50.4 cm, caught on 2 September 1985 at net location 7.

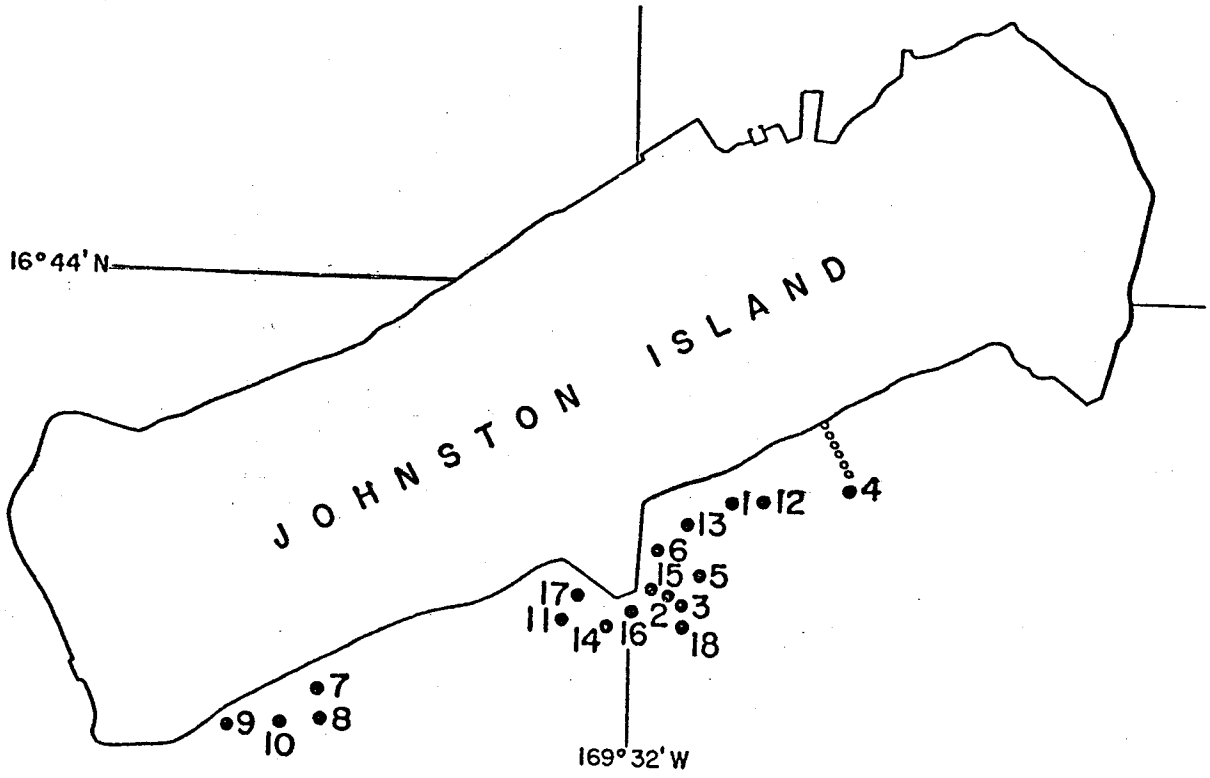

Figure 11.--Location of turtle nets in foraging pastures along the south shore of Johnston Island.

APPENDIX 1

List of persons conducting field work at Johnston Atoll in 1985

George H. Balazs Zoologist	8/29-9/1/85
Doris J. Alcorn Wildlife Biologist	8/29-9/12/85
Robert G. Forsyth Research Assistant	8/29-9/12/85
Robin L. Westlake Research Assistant	9/5-9/12/85
Rodney T. Watson Research Assistant	8/29-9/12/85
Lewis D. Consiglieri Lt., NOAA Corps.	8/29-9/12/85

APPENDIX 2

Recommendations Resulting From the 1983 Study

Management Measures

The synthesis of information contained in this report provides a basis for offering recommendations of management measures that could be taken immediately to ensure the conservation of turtles at Johnston Atoll. These actions are:

1A. A specific management zone for marine turtles should be established by the Defense Nuclear Agency, with the advisory assistance of the National Marine Fisheries Service and the U.S. Fish and Wildlife Service. The area should encompass marine habitat extending seaward for about 1 km along the entire south shore of Johnston Island, as well as a contiguous band extending about 1.5 km to the northeast of the main ship channel. The purpose of this zone would be to give special attention to the turtles concentrated there and the habitat upon which they depend. An appropriate and distinct mechanism would then exist to manage the area soundly on a continuing basis. The designation would be particularly helpful for identifying and evaluating any potential impacts to turtles and habitat that might arise in the future. The zone would be fully consistent with the environmental goals of the JACADS project and, in fact, the project would likely benefit from the special management attention given to the turtles.

2A. A management action needed at present is the curtailment of any recreational boats transiting or anchoring in the area described above. The rapid diving response when turtles are approached by boats indicate that normal foraging behavior is easily disrupted. This may be the result of previous human harassment including fishing efforts to hook them and/or continuing regular encounters with small boats.

3A. A formal system should be implemented to deal with any future strandings of dead or live turtles. Rapid reporting, and the appropriate immediate response by interested parties, is absolutely essential for these cases. Valuable specimens and data can be acquired in this manner; for example, bones for age determination, whole stomach contents, tissue samples, and a determination of the cause of death or debilitation. The presence of a tag further increases the worth of the specimen. The system should also include turtles or their parts found in the stomach of sharks and other predators.

4A. An informative, interesting and inexpensive brochure, preferably with illustrative photographs, should be prepared telling about the turtles at Johnston, where they principally occur, and their protected status under the U.S. Endangered Species Act. The brochure should be specific for turtles, and not done in descriptive combination with other wildlife or marine resources of the atoll. The brochure should be distributed at the air terminal to each new person upon arrival.

5A. A formal response plan should be prepared describing the actions to be taken in the event of a petroleum spill involving the area described for a turtle management zone. Special attention should be given to sites around West Peninsula where spillage may concentrate.

6A. A plan to assess the effects, if any, of newly installed lights on the foraging behavior and other use patterns of green turtles off West Peninsula should be developed. This should encompass the temporary lights needed during active construction of JACADS, as well as permanent security lights planned for the completed facility.

Future Research Activities

The successful long-term management of these reptiles is, to a large extent, dependent upon a certain amount of future research being accomplished. The turtles at Johnston have long been neglected as the subject of any investigation. However, from this present assessment it is apparent that they constitute an ecologically important, scientifically challenging, and historically interesting part of the atoll's fauna. In addition, Johnston's turtles are most likely used for food by native people somewhere in the Pacific islands, since it is doubtful they nest at French Frigate Shoals where full protection would be afforded. A major research and management goal should be to determine the international migrations made by these turtles, including their ultimate destination and island areas of transit where fishing may occur. The only way to achieve this objective at an early date is to capture and tag more turtles at Johnston. The relatively high proportion of both adults and females found in the population will be an advantage to understanding the movement patterns, since it will increase the probability of long-distance recoveries.

The following recommendations relate to research that should be accomplished to facilitate a better understanding of the biology of this turtle population. The information developed in these studies will also serve as a basis to formulate future management measures for Johnston's turtles. While this research is clearly needed, it is outside the scope of this report to indicate specific agency responsibility or priorities for support of this work.

1B. A standard monitoring program should be established to assess and tag turtles periodically in a manner similar to the present study. This action will be particularly important during the active construction phase of the JACADS project. During this period, three 10-day study visits per year are deemed necessary. Thereafter, one or two visits per year would be sufficient.

2B. Diving surveys with scuba should be made between West Peninsula and the southwest corner of Johnston Island to search for sleeping areas used by turtles. To accomplish the dives safely, formal arrangements mustbe made to delay, for 2 h daily, the interval pumping of sewage from the outfall over a 3-4 day period. This appears feasible at present during midmorning when water usage is normally low. However, it must be done prior to the large increase in personnel scheduled for the JACADS project.

3B. The blood analysis used in the present study to measure cholinesterase should be evaluated and, if needed, modified to obtain accurate measurements. Routine testing of cholinesterase in turtles should be conducted as part of the periodic monitoring suggested in recommendation 1B. The normal range for green turtles should be determined from blood sampling currently underway in Hawaii.

4B. The enrichment of radionuclide contamination by effluent from the desalination plant should be elucidated. The possible role of heat and heavy metals in this process should be examined to ascertain if discharge water planned for JACADS will produce similar enrichment, which in turn may be tansferred to turtles through algal food sources.

5B. Aerial photographs taken over Johnston Atoll should be located and examined to determine the past distribution of benthic algae and if nesting occurred during the period prior to large scale inhabitation by man.