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STATUS AND ECOLOGY OF MARINE TURTLES AT JOHNSTON ATOLL: 1987 ASSESSMENT

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INTRODUCTION

In 1983, a baseline assessment of sea turtles at Johnston Atoll (lat. 16°45'N, long. 169°31'W) was accomplished by the Southwest Fisheries Center Honolulu Laboratory (SWFC HL), National Marine Fisheries Service, NOAA, at the request of the U.S. Army Corps of Engineers (Balazs 1985b). This research was motivated by an absence of information on sea turtles at Johnston Atoll, by their protected status under the U.S. Endangered Species Act, and the army's plans to build an incineration facility (designated as the Johnston Atoll Chemical Agent Disposal System (JACADS)) at the atoll to dispose of chemical munitions presently stored there (U.S. Army Corps of Engineers 1983, 1988). 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 aggregation of green turtles consists of immature and adult animals. The most heavily utilized foraging area was found off West Peninsula on the south shore of Johnston Island, immediately adjacent to the planned construction site for the JACADS facility. Two kinds of benthic algae, *Caulerpa racemosa* and *Bryopsis pennata*, were identified as major food sources for the turtles. 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 undertaken in the 1983 study to document these previously 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 (Balazs 1985b) was that continued monitoring of sea turtles and their habitats be conducted as construction of JACADS progressed and the facility became fully operational. In accordance with this recommendation, the U.S. Army Corps of Engineers commissioned the SWFC HL to conduct a 14-day follow-up assessment in 1985 (Balazs and Forsyth 1986). At the time of that study, construction had not yet started on JACADS, except for the stockpiling of coral aggregate at the designated site. Compared with the 21 turtles tagged in 1983, 10 turtles were captured in 1985, none of which had been tagged previously. The capture of turtles per unit effort, using large mesh tangle nets, was very similar in the 1983 and 1985 studies. In June 1985, an adult female (No. 7461) tagged at Johnston in 1983 was observed nesting on East Island, French Frigate Shoals, in the Northwestern Hawaiian Islands. This constituted the first long-distance recovery ever made of a turtle tagged at Johnston Atoll. French Frigate Shoals is 830 km to the north and is the major breeding area for green turtles migrating from coastal marine habitats throughout the Hawaiian Archipelago (Balazs 1980, 1983).

The present report gives the results of a third monitoring assessment conducted for the U.S. Army Corps of Engineers during a 14-day period from 23 November to 7 December 1987. During 10-14 August 1987, a preliminary visit was made to Johnston to prepare for the actual fieldwork. A complete schedule and list of the personnel that conducted the research appears in Appendix A. At the time of the 1987 study, the greater portion of the external structure of the JACADS facility had been built, and work had started on internal installations. The need for continued monitoring of turtles at Johnston has recently been reiterated in the draft *Recovery Plan for Hawaiian Sea Turtles* (Hawaiian Sea Turtle Recovery Team in prep.).

ASSESSMENT METHODS

Large-mesh tangle nets identical to the ones used in 1983 and 1985 to capture turtles alive and unharmed were again employed in the 1987 monitoring assessment. The details of this technique have been previously described along with the methods for tagging, recording body measurements, obtaining food samples from the stomach, and electro-immobilization to prevent injury to turtles and personnel, as well as other procedures (Balazs 1985b; Balazs and Forsyth 1986). A modified procedure was used in 1987 to deploy the nets, thereby making it unnecessary to remove them from the water on a daily basis, as has been done in the past to prevent destructive entanglement of manta rays, *Manta birostris*, at night. Large metal "safety pins" were used to secure the webbing and lead line to the float line of the net at night. The nets were pinned up daily at sunset and removed the following morning shortly after sunrise.

In 1987, visual surveys and censuses were once again made from shore, as well as opportunistically while algae were collected underwater via scuba. A 6.5 m high, wooden observation platform was placed at the end of West Peninsula to aid in the sighting of turtles surfacing to breathe. In addition, a new censusing method developed by the resident U.S. Fish and Wildlife Service biologist (Douglas Forsell, U.S. Fish and Wildlife Service, Box 396, Johnston Atoll, APO San Francisco 96305) incorporated the use of a 7 m powerboat with observers positioned 2.7 m above the surface.

RESULTS

Capture Efforts

Only two turtles, both green turtles, were captured during the 14-day study (Table 1; Fig. 1). One had been previously captured and tagged in the same area during the October 1983 study. Nets were set out at nine locations, all of which were along the south shore of Johnston Island (Fig. 2). This area clearly 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 times hours fished), is presented in Table 2. Nets were usually deployed during the daytime, from early morning until sunset. This was done to help avoid the entanglement of manta and eagle rays identified as a serious problem during the nighttime netting attempted in 1983. However, the low number of turtles captured as the work progressed in 1987 made it necessary to leave the nets unfurled at night to determine whether a behavioral change had occurred to make the turtles more liable to nocturnal capture. However, this did not prove to be the case since no turtles were captured at night.

Although nets were set at nine locations, turtles were caught at only two of them (Tables 2 and 3). The two capture sites, as well as six other sites, were right off West Peninsula where turtles are always seen and had been captured in 1983 and 1985. Unlike the work conducted in 1983 and 1985,

nets in 1987 were not set to the west of West Peninsula along the Redhat shoreline (Fig. 2). This area was not deemed safe for personnel to work in the water because of the greater volume of raw human sewage being discharged from the outfall near West Peninsula (in contrast to lower levels in 1983 and 1985). Observations recorded during 27-29 November 1989 indicated that sewage was discharged every 14 minutes (Table 4). Previous netting sites off Redhat are directly downwind from this outfall. A case of infectious hepatitis was reported in an employee at Johnston during the 1987 study, hence, the need for additional precaution.

The overall catch per unit effort in 1987 (one turtle per 4,574 MH) was not nearly as good as in 1983 (one turtle per 1,172 MH) and in 1985 (one turtle per 1,269 MH). Netting efforts conducted at night were unsuccessful; instead 18 eagle rays became entangled (Table 5). The lower number of turtles captured in 1987 was at least partially due to the absence of netting off Redhat. Five of the 21 turtles in 1983 and 5 of the 10 turtles in 1985 were captured off Redhat. Tides during the 1987 study were similar to those encountered during the 1983 and 1985 fieldwork (Table 6).

Although fewer turtles were captured for the level of netting effort expended, this does not appear to have been due to a reduced turtle population in comparison with previous years. Censuses made from shore and by boat suggested that the concentration of turtles distributed along Johnston Island's south shore in 1987 was as high as in 1983 and 1985. Undetermined environmental factors or behavioral changes by the turtles may be responsible for the low catch rates experienced in 1987. No firm explanation can be offered at present to account for the reduced efficiency in netting turtles. Some possibilities worthy of mention would include 1) larger northwest swells, higher winds, and a generally rougher sea state than during previous netting; 2) a suspected higher proportion of smaller turtles present that might be less vulnerable to entanglement than larger ones; 3) modified foraging behavior in which *Caulerpa racemosa* growing at depth between coral heads was more heavily utilized than the *Bryopsis pennata* growing on top of the coral heads; 4) shock waves that resulted from small charges periodically detonated on Sand Island to demolish an abandoned facility; 5) the placement of the observation platform within sight of the nets, thereby somehow influencing the behavior of the turtles; and 6) the methodology of furling and unfurling the nets in the water, rather than removing them daily, made the turtles less vulnerable to entanglement.

Censuses from Shore

The placement of an elevated platform at the end of West Peninsula provided an excellent vantage site out to a distance of approximately 250 m to count turtles surfacing to breathe (Fig. 3). This area had previously been identified as heavily used foraging habitat rich with green algae, *Caulerpa racemosa* and *Bryopsis pennata* (Balazs 1985b; Balazs and Forsyth 1986). Because turtles tend to repeatedly surface over the same bottom site where they are foraging, it is possible to keep track of individuals over short (15-30 minutes) census periods without double counting. Factors that need to be considered during these censuses include the time of day, stage of

tide, degree of cloud cover and sun glare on the water, sea state, number of observers used and their level of skill, and potential disturbance factors in the area under observation.

Periodic censuses made from the platform at West Peninsula indicated that more turtles (up to 26) were present in the afternoon and that the number of turtles seen decreased by more than 50% when a boat entered the area to tend the nets (Table 7). Counts taken on the afternoon of 6 December 1987 near the end of the study, when all nets had been removed from the water, suggested an equivalent number of turtles to previous days when nets were still present. Censuses conducted from the Redhat shoreline, with observations being made 4 m above sea level from the top of a parked vehicle, suggested that generally fewer turtles (2-13) were present at this site (Table 8).

The submergence times exhibited by turtles sampled off West Peninsula and the Redhat shoreline ranged from 30 seconds to 10 minutes, with a mean of 4 minutes 3 seconds (Table 9). Their intervals at the surface ranged from only 3 to 15 seconds.

Censuses by Boat

As with counts made from shore, censuses of turtles by boat, taken over a specific pathway and within a certain time frame, provided useful indices of the numbers present and their distribution. The methodology developed by Douglas Forsell for Johnston is believed to be an effective means to accomplish this assessment. The results of four such boat censuses during August, September, October, and December 1987 resulted in counts of 57, 40, 45, and 54 turtles, respectively (Figs. 4-7). Boat censuses were made in the afternoon, usually after 1600 and along a path from southwest to northeast, so that the sun was behind the boat. The four censuses shown in Figures 4-7 lasted from 90 to 115 minutes.

It is important to point out that while shoreline and boat censuses are highly useful monitoring techniques, they nevertheless are unable to provide specific information such as growth rates, migration patterns, health status, and other critical factors resulting from capture, close examination, and tagging of turtles.

Food Sources

Stomach contents were collected from one of the turtles captured, and fecal matter was obtained from the other (Table 10). Feces were obtained after they had passed in a normal manner while the turtle was being measured and tagged. Analysis of these samples revealed that the two turtles were feeding almost exclusively on *Caulerpa racemosa* and *Bryopsis pennata*, respectively (Table 10). These benthic algae were identified in the 1983 and 1985 studies as the principal food sources for green turtles foraging along the south shore of Johnston Island. Of interest is the fact that the turtle (No. 7466-67) that had been feeding exclusively on *Bryopsis* in 1987 had the same diet when previously captured, tagged, and sampled in 1983. This

suggests the possibility that some turtles may feed entirely on *Bryopsis*, whereas others feed only on *Caulerpa*. Both kinds of algae are believed to be present throughout the year along Johnston Island's south shore. *Polysiphonia tsudana* was identified as the dominant epizoite among the 11 kinds of algae found on turtle No. 7466-67 (Table 11).

Rate of Growth

The turtle (No. 7466-67) that had been originally tagged at Johnston Atoll in 1983 and recaptured during the present study provides the first documentation of rate of growth for a green turtle at this location (Table 1). Over an interval of 4 years 2 months, the turtle increased in straight-line carapace length from 57.4 to 68.5 cm, or a mean of 2.7 cm/year. This can be compared with growth rates of green turtles found in the Hawaiian Archipelago where most recent data show slowest growth at more northerly foraging pastures (i.e., Pearl and Hermes Reef, lat. 27.5°N, 0.9 cm/year) and fastest growth at southerly pastures (i.e., Punaluu, Hawaii, lat. 19°N, 3.8 cm/year) (Balazs 1982; Balazs and Choy unpubl. data, SWFC Honolulu Laboratory, 2570 Dole Street, Honolulu, HI 96822-2396)). Johnston's location at lat. 17°N might therefore be expected to produce a more rapid growth rate than 2.7 cm/year. However, additional recaptures and remeasurements of turtles at Johnston are needed before any firm comparisons and conclusions can be drawn.

Injuries and Abnormalities

Neither of the two turtles captured showed any serious signs of injury, abnormality, or disease. By comparison, 1 of the 10 turtles captured in 1985 had a partially amputated hind flipper, probably the result of shark attack. In addition, two turtles seen in 1985 had small tumors, possibly fibropapillomas which now frequently occur in green turtles in the Hawaiian Islands (Balazs 1986). In 1983, an adult male among the 21 turtles captured at Johnston Atoll had a partially amputated tail, and 2 others had small tumors. The total number seen with tumors since monitoring started at Johnston is therefore 4 turtles or 12.5% of the 32 examined. At certain sites in the Hawaiian Islands, such as Kaneohe Bay, Oahu, the incidence of fibropapillomas in green turtle aggregations is 50%. In addition, the tumors found on turtles in Hawaii are often very large, to the point of severely interfering with swimming ability, vision, and foraging (Balazs 1986; Balazs et al. 1987). In contrast, the tumors seen at Johnston were all small, with no external indication of causing problems. Nevertheless, in view of the growing scope and magnitude of the tumor problem in Hawaii, the situation at Johnston warrants close attention. Unlike the Hawaiian Islands, turtles dead or debilitated by disease are not nearly as likely to be washed ashore and reported because of the cement seawall bordering most of Johnston Island. Consequently, detecting an increase of this disease would be difficult, if not impossible, without the capture of live turtles or meticulous observations with binoculars during the turtles' short surface intervals.

Migrations

Three long distance migrations have thus far been documented as the result of turtles tagged at Johnston Atoll. This represents a 9.4% recovery rate (3 out of 32), well above what is usually obtained in other sea turtle tagging studies worldwide (Meylan 1982). All three turtles were adults resighted at French Frigate Shoals in the Northwestern Hawaiian Islands (Table 12). French Frigate Shoals is 830 km to the north of Johnston and comprises the major breeding site for green turtles migrating from numerous foraging areas throughout the Hawaiian Archipelago (Balazs 1983). Two of the turtles from Johnston were females resighted while nesting; the third was a male seen basking ashore (Table 12). The recovery of these three tagged turtles demonstrates with a reasonable degree of certainty that French Frigate Shoals is the migratory breeding site for green turtles that reside at Johnston. Green turtles in the Hawaiian Archipelago and at Johnston may, therefore, be considered tentatively as comprising the same population. Further verification of this point could be obtained through mitochondrial deoxyribonucleic acid analysis, as recently performed on green turtles at French Frigate Shoals (Bowen et al. 1989). It should be noted that the commingling of adult green turtles from Johnston and Hawaii while copulating, nesting, and basking at French Frigate Shoals offers a potential route for the spread of disease such as tumors, if indeed, an infectious agent is involved in transmission.

Strandings, Baskings, and Nesting

During the 1987 study, no new observations were made of 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 work conducted in 1983 (Balazs 1985b).

Algal Forage Collection and Analysis

Samples of *Caulerpa racemosa* and *Bryopsis pennata* collected via scuba in the turtles' foraging pastures off West Peninsula (Table 13) were found to have nutrient (Table 14) and mineral (Table 15) compositions generally comparable to determinations made in 1983 (Balazs 1985b). Notable exceptions included lower levels of zinc found in both algae, and a substantially lower level of iron in *Caulerpa*, in contrast with the 1983 analyses. The reason for these differences is not known but is herein documented for comparison with future analyses that may be undertaken at this same location.

Observations of benthic habitat made off West Peninsula during algae collection indicated that a considerable reduction of up to 50% may have occurred since 1983 and 1985 in the amount of *C. racemosa* present. No explanation can be offered for this decline although it could be due to some normal seasonal variation. It is unlikely that increased grazing by turtles could account for this change, since barren areas were also devoid of algal holdfasts, which are not normally eaten by green turtles. No similar decrease was apparent in the standing crop of *Bryopsis*.

Plutonium Analysis

Plutonium concentrations were recently determined for the small pieces of bone and lamina that had been previously biopsied from the marginal scutes of the 10 turtles captured in 1985. The presence of plutonium 239 and 240 was detected in all 10 turtles (Table 16). Pooling of the samples by three size classes (juveniles, <65 cm; subadults, 65-82 cm; adults, >82 cm) showed no trend toward higher concentrations in larger and presumably older turtles. The highest (0.11 dpm/g) and lowest (0.0007 dpm/g) levels of plutonium were found in the two adults sampled. The smallest subadult sampled (68.1 cm) had the second highest level of plutonium (0.10 dpm/g; Table 16).

It should be noted that the turtle (No. 7466-67) recaptured in the present study had been previously sampled in 1983 for bone and lamina, which were used in heavy metal analyses (Balazs and Forsyth 1986). These wedged-shaped biopsy sites, identical to those taken for plutonium analysis, were found to be completely healed. The use of this biopsy procedure, therefore, appears to be safe and effective, with no long-term adverse effects.

Algal food sources used by the turtles along the south shore of Johnston Island may be the avenue by which plutonium enters the turtles. Benthic algae are known to concentrate certain radionuclides at rates higher than other plants and animals (Hines 1962). To test this potential route at Johnston Atoll, quantities of *Caulerpa* and *Bryopsis* were collected, fresh frozen, and sent to A. E. Nevissi (Laboratory of Radiation Ecology, University of Washington, Seattle, WA 98195) for analysis and interpretation. Elevated levels of plutonium in the environment at Johnston would be expected due to the 1962 malfunction of three missiles carrying nuclear devices that exploded at low altitudes over the atoll (Anonymous 1962a, 1962b, 1962c). The results of the algae analysis are given in Table 17.

Other Findings of Potential Importance

During the course of the 1987 assessment, several other findings of potential importance to marine turtles and their habitats at Johnston Atoll were made. These factors are briefly presented here for documentation and further evaluation, as appropriate.

On 4 December 1987, a tattered piece of sheet plastic (0.6 m by 4.6 m) was found floating off the Redhat area. The color and nature of this debris was identical to sheeting material being used extensively as protective covering at the JACADS facility. Persistent, buoyant plastics of this sort can be hazardous to sea turtles when mistakenly consumed for jellyfish or other natural food items (Balazs 1985a; Carr 1987). Shortly after the discovery that such debris was blowing into the sea from the JACADS construction site, Douglas Forsell arranged to have the problem corrected.

A pipe to discharge heated seawater from the JACADS facility was found to have been installed and functional on the east side of the peninsula, rather

than the west side as described in the Final Environmental Impact Statement (U.S. Army Corps of Engineers 1983). As a result, a reassessment will be needed of the dispersal characteristics of the thermal plume, and potential impacts on the turtles' algal foraging pastures. Prevailing easterly winds and currents might be expected to retain the discharged water on the east side of the peninsula, rather than disperse it rapidly to the west had the pipe been installed on the west side, as originally planned. Monitoring of the present thermal plume has already been initiated (Forsell and Bauer 1989); however, additional work will be needed during different weather conditions after the JACADS plant becomes fully operational.

The human "danger zone" for chemical munitions stored in the Redhat area on Johnston Island will be expanded to include the entire West Peninsula after JACADS becomes operational. In the event of chemicals being accidentally released into the atmosphere from the plant, the potential exists for turtles being affected as they surface to breathe in the West Peninsula area. The extremely toxic nature of these chemicals makes it imperative that this potential impact to the turtles be fully recognized so that an assessment can be instituted as soon as practicable following any accident.

CONCLUSIONS AND RECOMMENDATIONS

The assessment of sea turtles at Johnston Atoll in 1987 served to complement and strengthen the data base initially established in the 1983 study and further expanded upon in 1985. Nearshore waters along the south side of Johnston Island continue to be heavily utilized as foraging habitat by green turtles. The major food sources for the turtles here continue to be two kinds of green algae, *Caulerpa racemosa* and *Bryopsis pennata*. However, some decline was evident in the standing crop density of *C. racemosa* off West Peninsula, in contrast with what was seen during scuba surveys in 1983 and 1985. Censuses of turtles taken from land and by boat indicate that the population remained high (26 turtles sighted) off the south shore as the construction of the JACADS plant neared completion. The resighting of three tagged adult turtles at French Frigate Shoals demonstrates that this site in the Northwestern Hawaiian Islands is the migratory breeding area for turtles residing at Johnston Atoll. A juvenile turtle originally tagged at Johnston in 1983 and recaptured there in 1987 demonstrated a rate of growth similar to what has been found for turtles resident to the Hawaiian Islands.

The recommendations set forth in the earlier reports covering the 1983 and 1985 assessments are still valid. These suggested actions, covering both research and management actions, are restated in Appendix B.

ACKNOWLEDGMENTS

A number of individuals and agencies contributed to the success of the 1987 marine turtle assessment at Johnston Atoll. Food and fecal samples were identified by Dennis J. Russell of Seattle Pacific University. Nutrient and mineral compositions of *Bryopsis* and *Caulerpa* were determined by the Feed and Forage Analyses Program, University of Hawaii, Honolulu, Hawaii. Chris Balubar and other resident personnel again provided helpful information and logistical support. Douglas Forsell, resident biologist for the U.S. Fish and Wildlife Service at Johnston Atoll, supplied valuable assistance and interagency coordination throughout all phases of the fieldwork. 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. A. E. Nevissi conducted analyses of plutonium concentrations in bone and lamina collected in 1985 and algae collected in 1987. This work was accomplished with funds provided by the U.S. Fish and Wildlife Service to the Laboratory of Radiation Ecology, University of Washington.

The work at Johnston Atoll was allowed under an Area Clearance from the Defense Nuclear Agency and by a Special Use Permit (JHN-2-87) issued by the U.S. Fish and Wildlife Service.

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Table 1.--Body measurements and growth data of green turtles captured at Johnston Atoll in 1987.

Tag No.[a]	Date	Carapace length		Carapace width		Plastron length (cm)	Tail length (cm)	Head width (cm)	Weight (kg)
		Straight (cm)	Curved (cm)	Straight (cm)	Curved (cm)				
4174-78	11/4/87	80.5	86.0	64.3	80.8	64.4	18.0	11.5	--
7466-67 (4179-80)[b]	11/30/87	68.5	75.5	54.4	69.5	53.8	14.0	9.9	44.5
	10/5/83	57.4	63.0	46.3	58.0	44.0	9.5	7.1	--
Increase in 4 years and 2 months		11.1	12.5	8.1	11.5	9.8	4.5	2.8	--
Mean growth rate (cm/year)		2.7	3.0	1.9	2.8	2.3	1.1	0.7	--

[a]Tag series used:

1983 - 7451-7525
7551-7569

1985 - 4153-4169
7433-7448

1987 - 4174-4180

Tag inscription: WRITE HIMB
UNIVERSITY
HAWAII, 96744

[b]Newly applied tags.

Table 2.--Daily turtle netting effort in 1987.

Date	Net location[a]	Turtles captured (No.)	Duration (hours)	Length of net (m)	Netting effort (meter-hours)
24 Nov.	2	1	2.5	30	75
25 Nov.	2	0	6.5	30	195
	3	0	6.5	30	195
	15	0	6.5	18	117
26 Nov.	2	0	7.0	30	210
	3	0	7.0	30	210
	15	0	7.0	18	126
	5	0	7.0	18	126
	6	0	7.0	18	126
	13	0	7.0	18	126
27 Nov.	2	0	8.0	30	240
	3	0	8.0	30	240
	15	0	8.0	18	144
	5	0	8.0	18	144
	6	0	8.0	18	144
	13	0	8.0	18	144
28 Nov.	High wind warning. All nets left in "pinned-up" position.				
29 Nov.	2	0	8.0	30	240
	3	0	8.0	30	240
	15	0	8.0	18	144
	5	0	8.0	18	144
	6	0	8.0	18	144
	13	0	8.0	18	144
30 Nov.	2	0	7.5	30	225
	3	0	7.5	30	225
	15	1	7.5	18	135
	5	0	7.5	18	135
	6	0	7.5	18	135
	13	0	7.5	18	135
1 Dec.	2	0	8.0	30	240
	3	0	8.0	30	240
	15	0	8.0	18	144
	5	0	8.0	18	144
	13	0	8.0	18	144
	16	0	8.0	23	184
	19	0	8.0	18	144

Table 2.--Continued.

Date	Net location[a]	Turtles captured (No.)	Duration (hours)	Length of net (m)	Netting effort (meter-hours)
2 Dec.	2	0	8	30	240
	3	0	14	30	420
	15	0	14	18	252
	5	0	8	18	144
	13	0	8	18	144
	16	0	8	23	184
	19	0	8	18	144
	20	0	8	23	184
3 Dec.	2	0	14	30	420
	3	0	24	30	720
	15	0	24	18	432
	5	0	14	18	252
	16	0	14	23	322
	19	0	14	18	252
	20	0	14	23	322
4 Dec.	2	0	24	30	720
	3	0	24	30	720
	15	0	24	18	432
	5	0	24	18	432
	16	0	9	23	207
	19	0	24	18	432
	20	0	24	23	552
5 Dec.	2	0	24	30	720
	3	0	24	30	720
	15	0	24	18	432
	5	0	24	18	432
	19	0	24	18	432
	20	0	24	23	552
6 Dec.	2	0	9	30	270
	3	0	9	30	270
	15	0	9	18	162
	5	0	9	18	162
	19	0	9	18	162
	20	0	9	23	207
Total		2			18,296

[a]Net locations are shown in Figure 2.

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

Net location[a]	Meter-hours	Meter-hours per turtle	Turtles captured (No.)
2	3,795	3,795	1
3	4,200	--	0
5	2,115	--	0
6	549	--	0
13	837	--	0
15	2,520	2,520	1
16	897	--	0
19	1,566	--	0
20	1.817	--	0
Total	18,296	9,148	2

[a]Net locations are shown in Figure 2.

Table 4.--Observations of sewage outfall discharge at West Peninsula on the south shore of Johnston Island, 1987 (N = 10; $\bar{x}$ = 13.8 minutes).

Date	Time of discharge	Interval between discharge (minutes)
27 Nov.	0902	16
	0918	13
	0931	16
	0947	14
	1001	
28 Nov.	0802	13
	0815	18
	0833	14
	1433	9
	1457	
	1506	
29 Nov.	1344	10
	1354	15
	1409	

Table 5.--Eagle rays, *Aetobatus narinari*, caught in turtle nets deployed between sunset and sunrise.

Date	Net location[a]	No. caught (all released alive)
2 Dec.	3, 15	6
3 Dec.	15	2
4 Dec.	16	4
5 Dec.	2, 3, 5, 15, 19, 20	0
6 Dec.	20	6
Total		18

[a]Net locations are shown in Figure 2.

Table 6.--Times and heights of tides at Johnston Atoll, 23 November to 7 December 1987 (approximate time of sunrise and sunset, 0630 and 1845, respectively; height in feet).

	High		Low		High		Low	
Date	Time	Height	Time	Height	Time	Height	Time	Height
23 Nov.	0702	3.0	1451	0.2	1849	1.0	2346	-0.2
24 Nov.	0800	2.9	1553	0.1	2001	1.0	--	--
25 Nov.	0853	2.8	1649	0.1	2135	1.0	0035	0.0
26 Nov.	0951	2.7	1738	0.0	2326	1.2	0135	0.2
27 Nov.	1047	2.5	1821	0.0	--	--	0300	0.4
28 Nov.	1156	2.2	1855	-0.1	0049	1.5	0457	0.6
29 Nov.	1238	2.0	1927	-0.1	0151	1.8	0647	0.6
30 Nov.	1337	1.8	1959	-0.2	0240	2.4	0822	0.6
1 Dec.	1427	1.6	2028	-0.2	0320	2.4	0938	0.5
2 Dec.	1511	1.4	2055	-0.2	0357	2.6	1043	0.4
3 Dec.	1557	1.2	2122	-0.2	0436	2.8	1139	0.3
4 Dec.	1714	1.1	2222	-0.2	0547	2.9	1228	0.2
5 Dec.	1753	1.0	2254	-0.2	0622	2.9	1358	0.2
6 Dec.	1838	1.0	2327	-0.1	0659	2.8	1443	0.2
7 Dec.	1927	1.0	--	--	0736	2.7	1523	0.2

Table 7.--Results of green turtle censuses conducted from an observation platform 6.5 m above sea level at West Peninsula in 1987 (approximate time of sunrise and sunset, 0730 and 1845).

Date	Duration of census (minutes)	Time of day	No. of observers	Estimated No. of different turtles sighted
24 Nov.	60	0845-0945[a]	2	1
25 Nov.	30	0805-0835	2	3
	20	1335-1355	2	7
	18	1507-1525	1	8
	15	1637-1652	2	11
26 Nov.	30	0815-0845	2	1
	15	1330-1345	2	8
	24	1504-1528	2	6
27 Nov.	30	0755-0825	5	3
	59	0902-1001	2	4
	15	1210-1225	1	4
	30	1410-1440	2	9
	15	1637-1652	2	6
28 Nov.	31	0802-0833	5	4
	31	1442-1513	5	10
29 Nov.	15	0811-0826	5	1
	30	1326-1356	2	7
	30	1550-1620	2	19
	16	1709-1725	2	14
	20	1735-1755[b]	2	7
30 Nov.	15	1324-1339	2	4
	15	1540-1555	2	9
	15	1720-1735	2	10
	15	1740-1755[b]	2	4
1 Dec.	20	1110-1130	1	10
	30	1350-1420	2	18
	15	1553-1608	3	13
	15	1611-1626	3	17
	15	1727-1742	3	8
	15	1750-1805[b]	3	3
3 Dec.	15	0850-0905	1	1
	15	0907-0922	1	0
	15	1237-1252	2	11
	15	1257-1312	2	11
	15	1515-1530	4	20

Table 7.--Continued.

Date	Duration of census (minutes)	Time of day	No. of observers	Estimated No. of different turtles sighted
3 Dec.	15	1530-1545	4	26
	15	1746-1801	3	12
4 Dec.	15	1301-1316	3	6
	15	1553-1608	2	10
	15	1608-1623	2	11
5 Dec.	17	0934-0951	2	5
	15	1655-1710	2	15
	15	1711-1726	2	13
6 Dec.	15	1703-1718[a]	2	11
	15	1720-1735[a]	2	20

[a]Census taken while no nets were present in the observation area.

[b]Census taken while a 5 m motorboat was present with personnel tending nets.

Table 8.--Results of green turtle censuses conducted from the Redhat shoreline at an observation point 4 m above sea level in 1987 (approximate time of sunrise and sunset, 0730 and 1845).

Date	Duration of census (minutes)	Time of day	No. of observers	Estimated No. of different turtles sighted
28 Nov.	16	1153-1209	5	6
	30	1600-1630	5	13
1 Dec.	15	1509-1524	3	11
	15	1525-1540	3	9
3 Dec.	15	1448-1503	4	7
5 Dec.	15	1245-1300	2	2
	15	1300-1315	2	6

Table 9.--Submergence times of green turtles foraging off the south shore of Johnston Island in 1987. (N = 21 at West Peninsula and N = 22 at Redhat.)

	West Peninsula		Redhat	
Date	Minutes	Seconds	Minutes	Seconds
28 Nov.	--	--	3	56
	--	--	9	18
	--	--	5	52
29 Nov.	2	41		
	9	23		
	--	--	2	30
	--	--	7	20
	--	--	3	53
	--	--	5	40
	--	--	3	20
	--	--	6	41
	--	--	4	45
	--	--	3	28
	--	--	3	53
	--	--	3	17
	--	--	5	02
30 Nov.	6	30	--	--
	10	00	--	--
1 Dec.	4	26	5	53
	1	00	4	45
	1	45	4	15
	4	31	2	56
	2	00	1	45
	0	30	7	28
	10	00	7	00
	1	30	--	--
	7	00	--	--
	4	11	--	--
3 Dec.	5	14	2	03
	2	12	--	--
	2	15	--	--
	5	41	--	--
	2	30	--	--
	1	20	--	--
4 Dec.	5	00	--	--
Mean	4	16	4	46

Mean for both areas combined = 4 minutes 3 seconds
Range = 30 seconds to 10 minutes

Table 10.--Identification of stomach and fecal contents sampled from green turtles captured at Johnston Atoll.

Tag No.	Straight carapace length (cm)	Capture (net location[a])	Contents
4174-78	80.5	2	Stomach *Caulerpa racemosa* - 100% *Schizothrix calcicola* - trace
7466-67 (4179-80)	68.5	15	Fecal *Bryopsis* sp. - 100%

[a]Net locations are shown in Figure 2.

Table 11.--Identification of epizoites sampled from tagged green turtle 7466-67.

Epizoite	Percentage of sample
Polysiphonia tsudana	95
Sphacelaria sp.	5
Achrochaetium sp.	Trace
Achrochaetium sp.	Trace
Arthrospira sp.	Trace
Bryopsis sp.	Trace
Crinalium sp.	Trace
Oscillatoria sp.	Trace
Dermocarpa clavata[a]	Trace
Dermocarpa sp.[a]	Trace
Leptochaeta hansgirgi[a]	Trace
Unidentified copepod	
Unidentified nematodes	

[a]Epiphytic on other algae.

Table 12.--Long distance migrations of green turtles tagged at Johnston Atoll.

Tag No.	Straight carapace length (cm)	Sex	Date tagged	Date resighted	Interval (years, months)	Location recovered	Status
7513	89.0	M	10 Nov. 1983	22 Jun. 1985	1,7	Whale-Skate Island, French Frigate Shoals	Basking ashore
7461-64	90.9	F	5 Oct. 1983	21 Jun. 1985	1,8	East Island, French Frigate Shoals	Nesting
7560-62	87.0	F	12 Nov. 1983	16 Jun. 1987	3,7	East Island, French Frigate Shoals	Nesting

Table 13.--Diving surveys and algal collections made via scuba.

Dive No.	Date	No. of dives	Time (minutes)[a]	Maximum depth (m)	Dive area (net location)[b]
1	2 Dec.	3	52	6.1	13, 19
2	2 Dec.	3	20	5.5	2, 15
3	5 Dec.	2	22	4.6	5, 6
4	5 Dec.	2	20	6.1	2, 15

[a]Total of 5 man-hours of bottom time.

[b]Net locations are shown in Figure 2.

Table 14.--Percent nutrient composition[a] of principal food sources used by green turtles at Johnston Atoll.

Algae	Dry matter	Crude[b] protein	Ether extract	Ash	Neutral detergent fiber[c]	Acid detergent fiber[c]	
						Permang. lignin	Cellulose
Bryopsis pennata	8.8	26.8	2.3	38.9	23.7	2.0	9.7
Caulerpa racemosa	4.6	6.6	0.7	72.0	17.4	4.6	4.3

[a]Reported on a dry matter basis as determined by the "proximate analysis" method commonly used for terrestrial animal forage.

[b]Nitrogen × 6.25.

[c]Present in benthic algae as a complex polysaccharide; not true lignin or cellulose as found in terrestrial plants.

Table 15.--Mineral composition[a] of principal food sources used by green turtles at Johnston Atoll.

Algae	Percentage					Parts per million			
	Ca	P	K	Mg	Na	Fe	Cu	Mn	Zn
Bryopsis pennata	1.30	0.30	1.90	1.20	11.0	75.0	7.5	14.0	6.5
Caulerpa racemosa	0.85	0.09	1.50	0.42	25.0	40.0	5.5	7.5	6.8

[a]Reported on a dry matter basis. Ca = calcium; P = phosphorus; K = potassium; Mg = magnesium; Na = sodium; Fe = iron; Cu = copper; Mn = manganese; and Zn = zinc.

Table 16.--Plutonium concentrations in the carapacial bone and lamina[a] of green turtles sampled at Johnston Atoll in September 1985.

Tag No.	Straight carapace length (cm)	Weight of turtle (kg)	Weight of bone/lamina (g)	Plutonium 239,240 (dpm/g[b])
		Adults		
7445	88.4	105.0	6.6	0.0007 ± 0.002
4165	86.5	102.3	8.9	0.11 ± 0.007
		Subadults		
4153	73.9	58.2	5.6	0.03 ± 0.002
4170	71.8	52.3	8.7	0.005 ± 0.001
7441	69.8	50.0	3.7	0.004 ± 0.001
7433	69.1	48.0	3.6	0.003 ± 0.001
7449	68.1	43.2	2.5	0.10 ± 0.030
		Juveniles		
4161	61.9	37.7	4.6	0.02 ± 0.004
4157	58.5	27.7	5.9	0.01 ± 0.003
7437	50.4	18.0	2.4	0.01 ± 0.004

[a]Biopsies of bone with the overlay of lamina were obtained by cutting two small triangular pieces from the edge of the 10th and 11th marginal scutes.

[b]Disintegrations per minute per gram.

Table 17.--Plutonium concentrations in algae sampled at Johnston Atoll on 5 December 1987.

Algae	Dive area (net location[a])	Total wet weight of sample (g)	Plutonium 239 pci[b]/g dry	Plutonium 238 pci[b]/g dry
Bryopsis pennata	2, 14	556.6	0.016±0.002	0.002±0.001
Caulerpa racemosa	5, 6	222.3	0.0043±0.003	--
Caulerpa racemosa	5, 6	219.3	No plutonium detected. However, a large unresolved peak was detected with energies lower than plutonium, similar to neptunium 237.	

[a]Net locations are shown in Figure 2.

[b]1 pico curie (pci)/g = 2.22 dpm/g dry.

Figure 1.--Two green turtles captured off the south shore of Johnston Island.

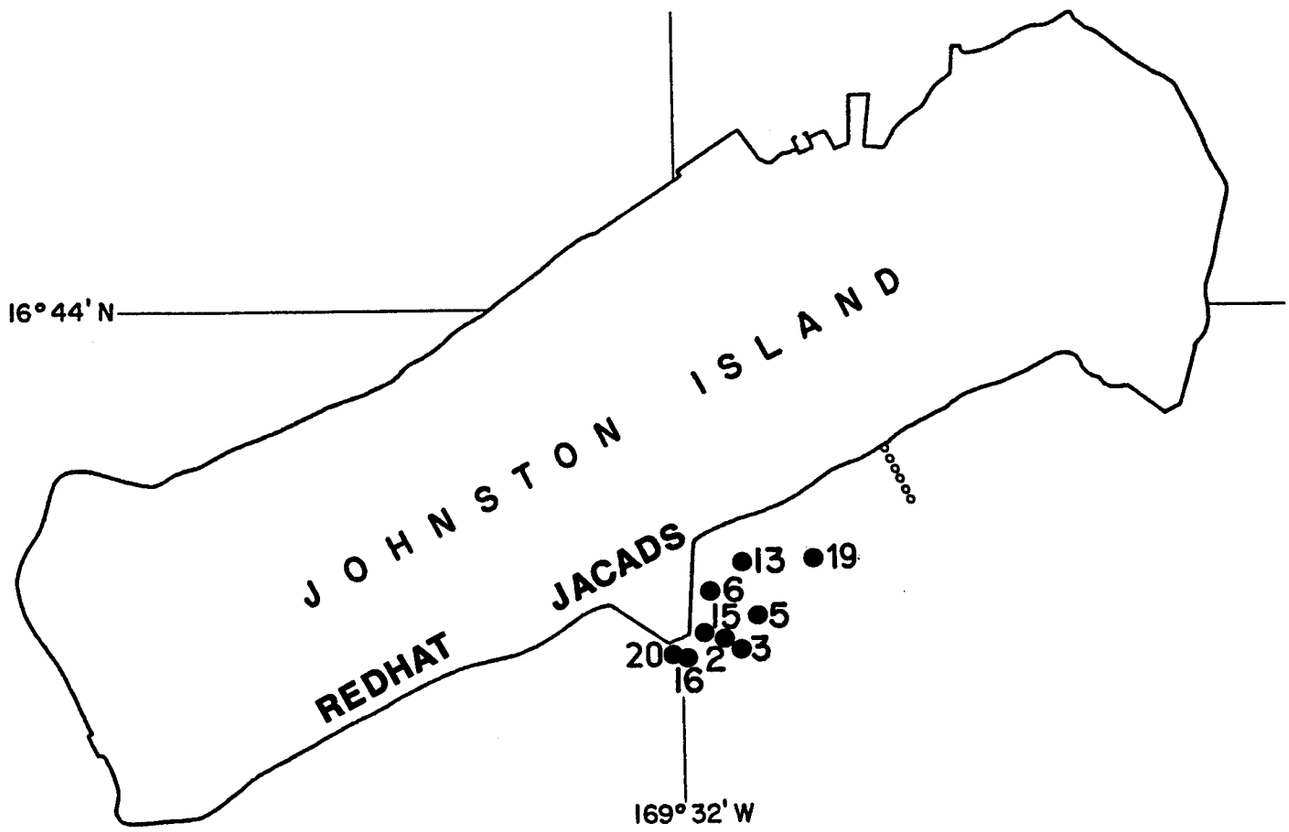

Figure 2.--Location of turtle nets in foraging pastures along the south shore of Johnston Island.

Figure 3.--Observation platform used at West Peninsula to census turtles.

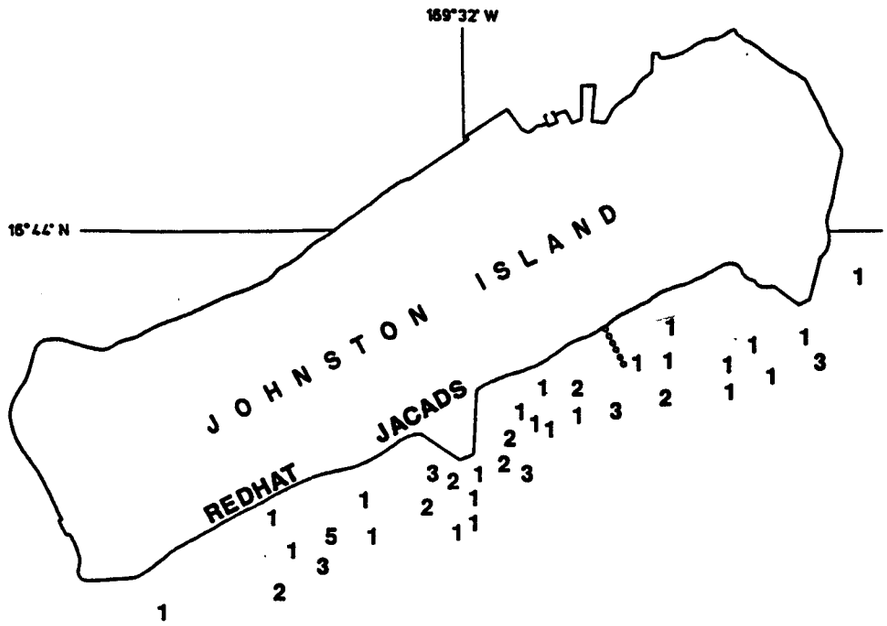

Figure 4.--Distribution of 57 turtles censused by 2 observers during a 90-minute (1600-1730) boat survey off Johnston Island on 11 August 1987. A high tide of 2.6 feet occurred at 1915.

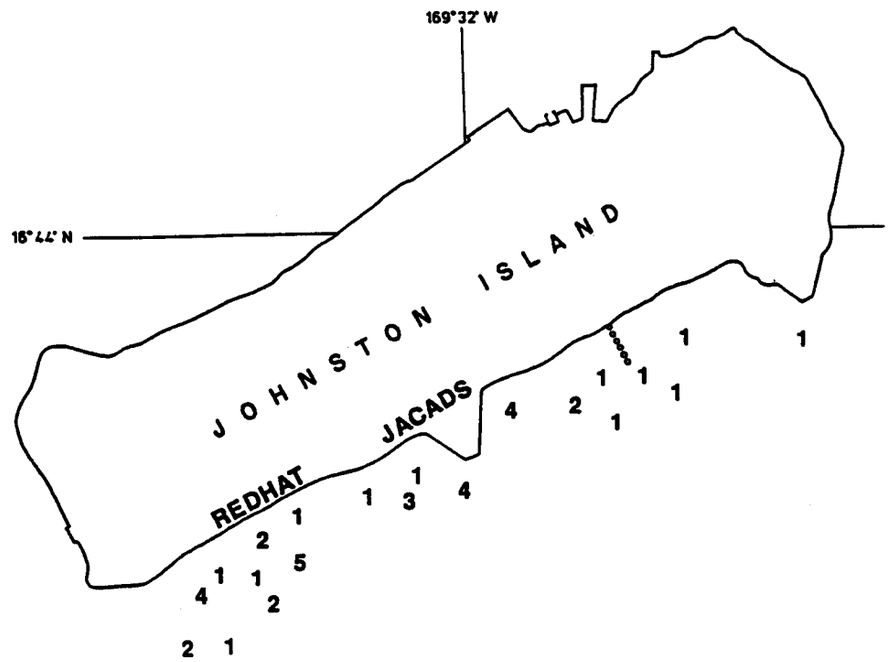

Figure 5.--Distribution of 40 turtles censused by 2 observers during a 110-minute (1615-1805) boat survey off Johnston Island on 2 September 1987.

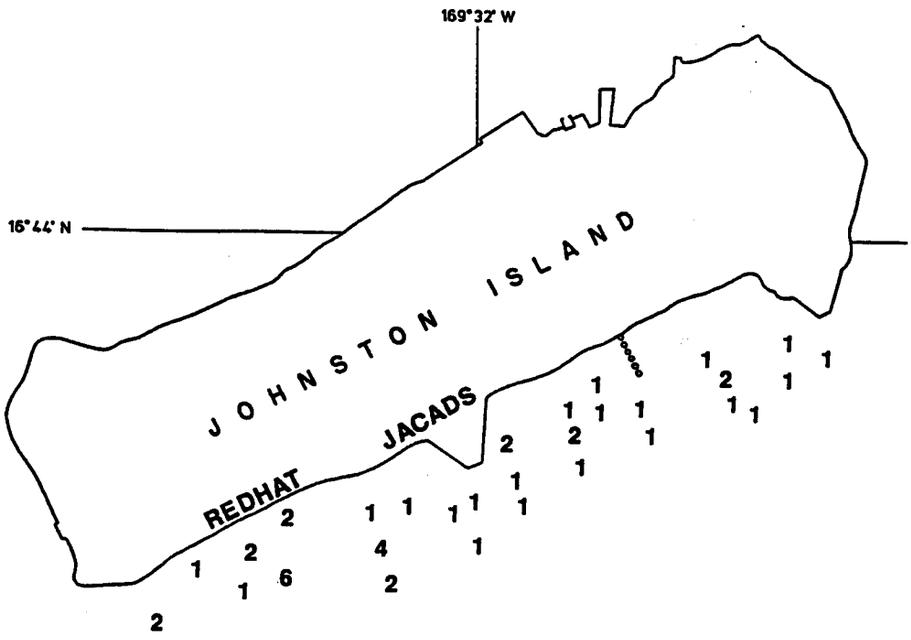

Figure 6.--Distribution of 45 turtles censused by 2 observers during a 105-minute (1450-1630) boat survey off Johnston Island on 25 October 1987.

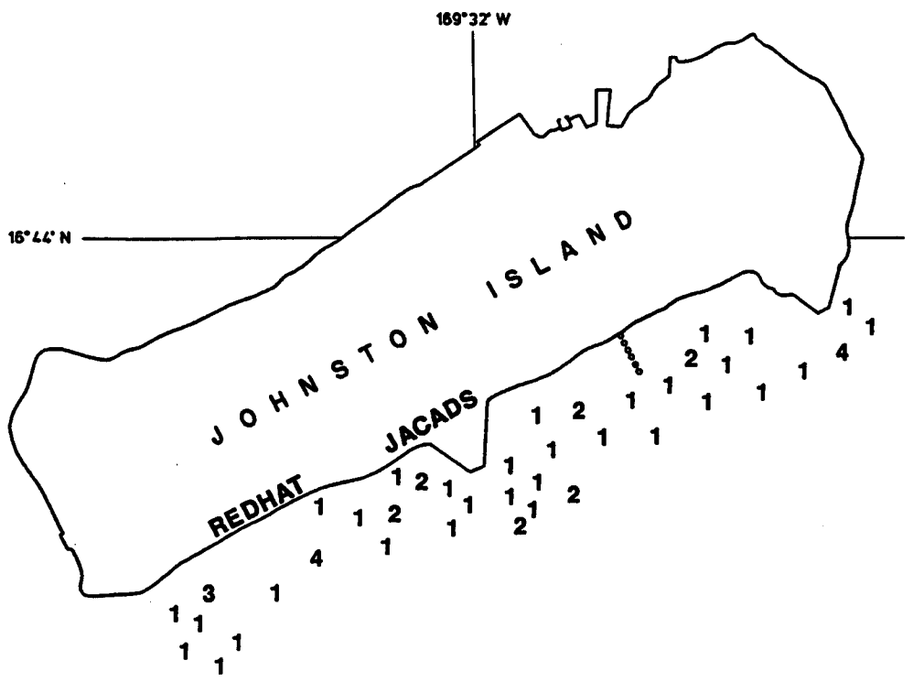

Figure 7.--Distribution of 54 turtles censused by 3 observers during a 115-minute (1555-1750) boat survey off Johnston Island on 4 December 1987. A high tide of 1.1 feet occurred at 1714.

Appendix A.--Schedule of personnel conducting fieldwork at Johnston Atoll in 1987.

Name	Time period
George H. Balazs Zoologist	10-14 Aug. 23 Nov.-7 Dec.
Brenda L. Becker Research Assistant	23 Nov.-7 Dec.
Barry K. Choy Research Assistant	30 Nov.-7 Dec.
Robert G. Forsyth Research Assistant	23 Nov.-7 Dec.
Thea C. Johanos Wildlife Biologist	23 Nov.-7 Dec.
Robin L. Westlake Research Assistant	23 Nov.-30 Nov.

Appendix B.--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 as follows:

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, along with 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.

Appendix B.--Continued.

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.

Appendix B.--Continued.

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 must be 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 under way 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 transferred 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.