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STATUS AND ECOLOGY OF MARINE TURTLES AT JOHNSTON ATOLL

BY

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INTRODUCTION

The aim of this paper is to consolidate all available information on marine turtles at Johnston Atoll, and to present the results of a short-term tagging study recently conducted there. The importance of this work rests on the fact that it has never been done before, that marine turtles are listed under the U.S. Endangered Species Act (since 1978), and the atoll is a National Wildlife Refuge. The Defense Nuclear Agency has operational control of Johnston with the primary mission of maintaining nuclear readiness for the resumption of atmospheric testing, should it be so directed. Several other organizations are present under Defense Nuclear Agency stewardship, including an Army chemical storage facility, a Coast Guard loran station, a NOAA weather station, and a civilian support contractor, Holmes and Narver, Inc. The U.S. Fish and Wildlife Service in Honolulu cooperatively manages the area as part of the National Wildlife Refuge System.

Johnston Atoll is located at lat. 16°45'N, long. 169°31'W, and is one of the most isolated atolls in the world. The land area consists of four islands (Johnston, Sand, Akau, and Hikina) totaling only about 2.8 km^2, most of which is man-made. The surrounding reef covers an area 11 by 22 km. Johnston is one of the best studied atolls in the central Pacific, due to its small size and extensive use for military purposes over the past 45 years. A comprehensive summary of the atoll's natural history, including all known scientific studies up to 1973, has been compiled by Amerson and Shelton (1976). The ecological significance of the atoll is described separately in this publication (p. 361-368) by four prominent ecologists.

Much of the previous research conducted at Johnston has been on the terrestrial fauna and flora, with major emphasis on seabirds. The studies on the marine environment and biota have been mainly centered in the lagoon. Virtually no work has been done off the south shore of Johnston Island. This has been due in part to safety and security restrictions, and poor diving conditions. Since most of the turtles found at the atoll occur in this region, it is perhaps not surprising that they have received so little attention over the years.

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The Army plans to construct a large-scale incineration facility on Johnston Island to destroy chemical agents and munitions stored there. The storage bunkers are along the south shore of the island adjacent to West Peninsula, the site where the plant will be constructed. Comprehensive information on this project, Johnston Atoll Chemical Agent Disposal System (JACADS), has been presented (U.S. Army Corps of Engineers 1983). Construction of the facility is planned to begin in late-1985, and take 3 years to complete. The number of personnel on the island will double from the present 350. Factors that have not yet been decided, or are classified for security reasons at present, include the life of the facility, the total number and kinds of munitions to be incinerated, and the disposition of certain nontoxic byproducts. Initially, at least 72,000 rockets containing 345 metric tons of nerve agent (GB and VX) are scheduled to be processed.

This paper is the culmination of work commissioned by the U.S. Army Corps of Engineers, Pacific Ocean Division, to obtain baseline data on marine turtles at Johnston Atoll. The study was prompted by the absence of information on these reptiles, their protected status under Federal law, and the proximity of the JACADS project. Recommendations given in this paper will help ensure the conservation of Johnston's turtles, as requested in the terms of reference for the study.

HISTORICAL OVERVIEW OF TURTLES

There are few accounts of sea turtles at Johnston Atoll in the literature. Amerson and Shelton (1976) summarized, as follows, all information known to them as of late 1973 (p. 112):

"Reptiles, Species Accounts - There are no general references that illustrate the reptiles of Johnston Atoll. Taxonomy of the turtles follows Carr (1972) and Amerson (1971).

"BLACK SEA TURTLE *Chelonia agassizi*

"*Status* - Regular uncommon visitor; known from the lagoon, offshore Johnston Island, and Sand Island.

"*Observations* - Brooke (MS.), who visited Johnston Atoll in March 1859, commented about the lack of turtles: 'The reefs are covered with fish of various kinds. Mullet abound, but there are no turtles.' Wetmore (MS. a and b) likewise, recorded no turtles at Johnston Atoll in July 1923.

"POBSP [Pacific Ocean Biological Survey Program] personnel recorded sea turtles in the shallow marginal reef area west of Johnston Island in July 1963. An adult (USNM 163581) was collected 20 November 1966 on the beach of Sand Island. Island personnel in 1973 reported seeing 10 to 12 turtles offshore of Johnston Island throughout the year. A longtime resident estimated harvesting 12 to 15 per year.

"*Annual Cycle* - The Black Sea Turtle apparently visits Johnston Atoll year-round. No records exist of it breeding on the atoll, although perhaps it did in small numbers prior to inhabitation by man. This species breeds during the summer in the northwestern Hawaiian Islands, especially at French Frigate Shoals (Amerson, 1971)."

The validity of the species account by Amerson and Shelton (1976) will be a subject of discussion later in this report.

In December 1892, Captain John Cameron of the schooner Ebon stayed at Johnston Atoll for a month after sailing directly from Laysan Island in the Northwestern Hawaiian Islands. The account of this visit (Farrell 1928) mentions sea turtles, but was not cited by Amerson and Shelton (1976). The relevant sections of Farrell (1928) are as follows (p. 402-405):

"Our first call was at Johnston or Cornwallis Island, five hundred and sixty miles south of Laysan and southwest of the eight islands of Hawaii proper. We found a good berth in its lagoon, and in a pretty little cove, on a beach of white sand, was an ideal spot for our tent. Near by were ruins of shanties built years before by a guano company; there also was a well, with pumps and pipes intact, which we cleaned and put in order.

"Signs of men, signs of shipwreck! We stumbled across two boats, both hauled above high water, one in fair condition, the other badly smashed; and in the craft were harpoons and lances and some bird shot in bags. The condition of the better boat, which was well worth the repairs I decided to give it, indicated that the men who left it there had been rescued. Else why should they have abandoned a tolerably seaworthy craft on a desert island?

"Our catches of sharks at Johnston were only fair, because our bait was principally sea birds, which the brutes did not relish as they had the flesh of hair seals; but our hauls almost filled our containers with liver oil. Now and then we took things more easily: 'Spell O!' was passed, and we hunted turtles. One of the men employed the Kusaie method of taking them by anchoring a few captive females near the beach to attract the bulls. It succeeded admirably and helped us greatly with attractive bait for shark fishing.

"We were standing to sea, bound to Fanning Island, when from the mate, who was at the masthead, came a cry of 'Sail O!' A bark under full sail was heading for us. Through the telescope we could see that she was a whaler: that was made evident by boats hanging from her davits ready for immediate use. I lost no time in pulling to her with some turtles and two pigs, welcome additions to the fare of a vessel long at sea and especially for Christmas dinner, as the day was December 24."

Votaw (1943) included some of Captain Cameron's comments about turtles in a short historical paper on Johnston Atoll. Turtles were also mentioned, but again not cited by Amerson and Shelton (1976), in a Honolulu newspaper article by Benson (1953). Describing the dynamiting necessary from 1939 to 1942 to clear out coral heads in the lagoon, Benson (1953) stated that:

"Interest was added to the process by the presence of numerous huge sharks. There was one monster in particular who demonstrated his prowess one day by swallowing a sea turtle - whole - at one gulp."

In recent years, sea turtles at Johnston Atoll have been discussed by Balazs (1978, 1980b, 1980c, 1982d). Two of these papers (Balazs 1980b, 1982d) made recommendations that stressed gathering baseline data on this little-known and isolated turtle population. A brochure describing National Wildlife Refuges in the Pacific briefly mentions that the green sea turtle is among the marine life found at Johnston (U.S. Fish and Wildlife Service, MS.).

Except for the single specimen in the U.S. National Museum listed by Amerson and Shelton (1976), there is no indication of scientific personnel having examined, tagged, or studied sea turtles at Johnston Atoll. Starting in 1978, turtle sighting report forms have been sent to resident personnel at the atoll, but only limited information could be acquired by this method (Balazs 1982d). Casual observations and counts of turtles from shore have recently been recorded in trip reports by Ludwig (1982), Ludwig et al. (1982), and Nitta (1982). Applied Eco-Tech Services (1983) included a discussion of turtle sightings in their consultancy report on water quality.

ASSESSMENT METHODS

Two field studies, totaling 28 days, were conducted at Johnston Atoll to accomplish the assessment. The first phase of study was September 29-October 13, 1983 and involved two workers. The second phase was November 3-17, 1983 involving five workers. In addition, a preliminary 2-day planning visit was made by one worker on August 30-September 1, 1983.

Capture Efforts

Efforts to capture turtles alive and unharmed were undertaken using large-mesh tangle nets, scoop nets, and scuba to facilitate capture by hand. All three of these methods have been successfully employed to study green turtles in coastal waters of the Hawaiian Islands (Balazs 1976, 1982b).

The tangle nets were made of 2-mm diameter nylon line, with a stretched mesh of 46 cm (23 cm square mesh), and a depth of 3.5 m. The length of the nets ranged from 9 to 40 m. The nets were set at the surface extending vertically through the water column. They were deployed and retrieved close to shore using a small boat at sites recommended by resident personnel, or where turtles were seen foraging or in transit. Up to five nets were set at one time at different locations. All nets were checked from land with binoculars every 1-2 h diurnally to see if a turtle had been caught.

Large scoop nets were used by approaching turtles at the surface with a boat. Efforts with scuba were directed at locating and catching turtles by hand during the course of underwater surveys.

Following their capture, turtles were taken ashore for tagging and examination for a period requiring up to 2 h. Before being released, color photographs were taken to help document morphological features.

Tagging and Body Measurements

Turtles were tagged for long-term identification with numbered Inconel[2] alloy tags, size 681, custom made by the National Band and Tag Company of Newport, Kentucky. Balazs (1980c, 1982a, 1983) describes the history of these tags used in Hawaii and their superior corrosion resistance compared with Monel alloy. The tags measure 25 x 9 x 8 mm, weigh 3.5 g, and are self-piercing and self-locking when applied with special applicators. Depending on the turtle's size, from two to five tags were applied to offset tag loss. Tagging sites were the trailing edges of both front flippers in the webbing between the third and fourth scales counting proximal to distal, in the axillae close to the first scale, and on a hind flipper on the inside trailing edge well under the carapace. A secondary and potentially long-lasting mark in the edge of the carapace resulted from the bone biopsy (described later).

Short-term visual recognition of tagged turtles after their release was made possible by painting a white number on each side of the carapace using Dupont Lucite spray paint. Based on studies elsewhere, it was estimated that these numbers would remain visible for at least 10 days.

Observations on the turtles consisted of: straight-line (SCL) and curved (CCL) carapace length from the center of the precentral scute to the posterior tip of a postcentral scute; straight-line carapace length from the center of the precentral to the notch between the postcentrals; straight-line and curved carapace width at the widest point (the sixth marginal scute); straight-line plastron length along the midline; straight-line head width at the widest point; tail length from the posterior rigid edge of the plastron to the tip of the tail; straight-line flipper width from the claw scale to the sixth scale on the trailing edge; and body weight.

Food Sources and Epizoites

Food sources were determined by sampling the turtles' stomachs with a plastic tube inserted through the esophagus. Small amounts of water were introduced and aspirated to obtain food material. In addition, unswallowed particles of food were removed from the mouth, and fecal material that could be collected was rinsed to isolate incompletely digested food. These three field techniques for sampling dietary components are discussed in detail in Balazs (1980a). Observations made of turtles feeding at specific sites also permitted the direct collection of algal forage during underwater surveys.

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[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Food items were preserved in dilute Formalin and identified to the lowest taxon possible. Frozen bulk samples collected from the foraging habitat were biochemically analyzed to determine major nutrients and mineral composition.

Epizoites found on the skin and hard parts of the turtles were scraped off, preserved in dilute Formalin, and identified to the lowest taxon possible.

Biopsies and Blood Sampling

Biopsies of bone and lamina were taken with a saw by cutting a small triangular piece from the edge of the 10th left marginal scute. Depot fat was sampled from directly under the skin by making a 2-3 cm incision in the inguinal region. Tissue sampling procedures described by Rainey (1981) and Menzies et al. (1983) were used as a guide for this work. Bone and fat samples were frozen in glass vials and stored for future analyses of radionuclides and heavy metals.

Blood collection followed the methods described by Owens and Ruiz (1980) and Bentley and Dunbar-Cooper (1980). A needle and syringe were used to draw blood from the paravertebral sinus on either side of the midline of the dorsal neck surface. The blood was centrifuged and separated into packed cells and serum. Sera were frozen and analyzed for testosterone levels to determine sex. Packed cells were refrigerated and analyzed within a few hours for cholinesterase activity. The 17-Minute Manual Method, routinely used at the Johnston Island medical facility to detect anticholinesterase intoxication in humans, was used for analysis of turtle blood.

Underwater Surveys

Underwater scuba surveys were made to census turtles, locate and assess prominent foraging and resting habitat, and gather other ecological data. Two or three divers working together within visual range carried out the surveys. All surveys took place during the daytime.

Terrestrial Surveys

Terrestrial surveys were conducted along the coastlines of all four islands for the purpose of locating possible nesting and basking habitat. Systematic observations from shore were also made of coastal waters.

Personal Interviews

To compile anecdotal information, fishermen and divers, especially those who have been at Johnston for many years, were interviewed. Requests were also made to examine photographs in private collections showing turtles caught during past years.

Literature Search

The published and unpublished literature pertinent to Johnston Atoll was reviewed. This search included articles in the two major Honolulu newspapers. All known historical reference to turtles at the atoll have been presented in the previous section of this report. However, the literature review also encompassed articles on perturbations to the environment that could be of significance to turtles or their habitat.

An inquiry was made to the U.S. National Museum (Washington, D.C.) to obtain further data on the specimen mentioned by Amerson and Shelton (1976) as having been collected in 1966 "...on the beach of Sand Island."

FINDINGS

Results of Capture Efforts

A total of 21 turtles were captured (Table 1). All were green turtle, *Chelonia mydas*, taken with nets, and no repeat captures were made. There were no scars indicative of old tags being shed. No turtles were caught with scoop nets or by hand, due mostly to turbid water conditions and the rapid diving behavior of the turtles when approached by boat. The locations selected for the nets were exclusively off the south shore of Johnston Island (Fig. 1). Nearly all of the turtles sighted during the surveys were in this area. The high concentration along this side of the island was also confirmed by everyone interviewed. The water off the south shore is silt-laden resulting in poor underwater visibility. Reasonably good water clarity was found at other sites in the atoll.

The daily netting effort at each location, expressed in meter-hours (MH) (length of net by hours fished), is shown in Table 2. During phase 1 of the field study, nets were regularly set at locations 1-5 and left both day and night. However, this sampling procedure proved unworkable because of the high incidental capture of eagle ray, *Aetobatus narinari*, and large manta ray, *Manta birostris*. The entanglement of rays occurred only at night or during twilight hours. Once caught, manta rays were able to twist with such force that sections of the net became snarled and useless. Eagle rays caused less of a problem, but were still able to pull sections of floatline underwater and hold them there. Most turtles caught with rays under these conditions would have drowned. During the times the nets were left out at night, only one turtle was caught, apparently at morning twilight (Table 3, tag No. 7451). Although eagle rays were also in the net, the turtle escaped injury due to its large size and place of entanglement away from the rays. All netting during phase 2 was conducted diurnally (Table 2) to eliminate the problem of accidentally catching rays. Shore observations during the daytime indicated that at least some turtles avoided the nets. Avoidance would probably not have been possible at night.

Nets were set at 17 sites, but turtles were caught at only 4 of them (Table 1). Three of these locations (1, 2, and 3) were close to or immediately east of the West Peninsula, and one location (7) was between West Peninsula and the southwest corner of the island (Fig. 1). Eight of the 21 turtles were caught at location 2; 5 each were caught at locations 1 and 7; and 3 were caught at location 3. Catch per unit effort was considerably better at locations 2 and 7 (589 and 550 MH per turtle, respectively; Table 1). A similar catch per unit effort was obtained during phase 1 and phase 2 field studies (1,123 and 1,197 MH), although twice as many turtles were caught during phase 2 (14 versus 7).

Species Present

The turtles captured displayed no clear characteristics that would justify their designation as *C. agassizi*, the black turtle of the east Pacific. The large size of the adults, the contour of the carapace, and the color of the plastron were all mostly consistent with *C. mydas*. An exception was a specimen that had a strongly tapered posterior to the carapace, and a moderate amount of gray pigment in the ventral surface of the marginal and postcentral scutes (tag No. 7551). These features are pronounced in *C. agassizi*, including dark pigment throughout much of the plastron. This turtle therefore seems to be intermediate between *agassizi* and *mydas*. None of the other turtles captured, nor those remembered by Cris Balubar, a resident employee and former turtle fisherman, had dark pigment in the plastron.

Carapace color and pattern varied considerably, ranging from predominantly tan with brown radiations (tag No. 7451) to olive with black flecks (tag No. 7517). When seen in the water before capture, the carapace of most turtles at Johnston is masked by a layer of silt. Carapace coloration within other green turtle populations, such as in Hawaii, is known to vary with stage of maturity, sex, and possibly even environmental factors (Balazs 1980c). However, the carapace and dorsal skin surface of adult *C. agassizi* is always predominantly black.

The observation by Amerson and Shelton (1976) that the black turtle occurs at Johnston is invalid based on findings of this present study. Amerson and Shelton's (1976) nomenclature appears to have been founded almost completely on their citation of Carr (1972), who stated (p. 25):

> "...The black turtle of the eastern Pacific lacks the numbers to withstand that abuse, and may well become an incidental casualty along the American mainland shores. To my eye, however, the black turtle stock occurs elsewhere--in the Galapagos Islands, among the mid-Pacific Islands, and in parts of the Indian Ocean. With its range extending through so much territory, the complete loss of the Mexican and Central American colonies might not obliterate *Chelonia agassizi*; but here again, the name, as I am using it, surely covers a number of hitherto unnamed races. The sooner these are properly defined, the sooner concern over their plight will be generated."

No other species of sea turtle was seen during the field studies. An unverified sighting of a hawksbill turtle, *Eretmochelys imbricata*, is listed by the U.S. Army Corps of Engineers (1983). In addition, four turtles, thought to be hawksbills, were reported in shallow water off the northeast corner of Johnston Island in September 1980 (R. J. Novak in litt. to G. H. Balazs). Cris Balubar and others interviewed indicated that only green turtles have ever been seen by them within the atoll.

The leatherback turtle, Dermochelys coriacea, has been observed on several occasions by personnel trolling for fish outside the atoll. Cris Balubar saw one about 11 km to the north of the atoll. In 1981, a large decapitated (but still moving) leatherback was seen, apparently after being accidentally hit by a boat. Efforts to gaff the turtle and bring it aboard proved unsuccessful.

Population Structure

Body measurements and weights presented in Tables 3, 4, and 5 indicate that 60% (14) of the turtles captured were mature adults. Turtles <82.9 cm SCL were estimated to be immature (see Balazs 1980c for a discussion of size categories). The proportion of adults in the Johnston population is therefore substantially greater than at coastal areas studied in Hawaii. At a comparable foraging area on Molokai, Hawaii only 9% of 81 green turtles sampled with nets were adults. The sighting of turtles during surveys at Johnston, along with information resulting from interviews, confirmed that the population is composed of mostly large turtles. The smallest turtle captured was 57.4 cm SCL; however, a few others estimated to range down to 35 cm SCL were seen during the surveys.

The age structure and growth rates of turtles at Johnston are presently unknown. In the Hawaiian Islands, green turtles are estimated to take 11-59 years to grow to an adult. Growth rates have been found to differ significantly among resident foraging areas within the archipelago (Balazs 1982b). The high percentage of adults at Johnston could be caused by several factors, including rapid growth rates, low recruitment of small turtles to the population, high predation and mortality of small turtles, and low predation and mortality of adults.

The 15 turtles that were weighed ranged from 63.6 to 151.4 kg (Table 5). The mean weight of three adult males was 104.8 kg (range 84.5-115.9 kg). The mean weight of six adult females was 112.0 kg (range 87.7-115.4 kg). The largest turtle ever caught by Cris Balubar was a 186 kg male.

Testosterone levels were determined from blood samples of 12 turtles for sex determination. The sex of six other turtles, all adults, could be determined by external features (i.e., a long, large tail for males). The sex ratio of this 18-turtle sample was 2.6:1 in favor of females (Table 6). If only immature turtles are considered, the ratio was still 3:1 in favor of females. Of special interest among the immature turtles was a fairly large specimen (79.1 cm SCL, 74.1 kg) that still had a short tail (18.2 cm). The testosterone level showed this turtle to be a male.

Abundance and Distribution

Capture and tagging efforts were focused at principal aggregation sites of turtles. Seven turtles were tagged during phase 1 from this area. After an interval of 20 days, phase 2 capture efforts yielded 14 more turtles, none of which had been tagged earlier. Because no recaptures were made, these data alone do not permit an estimate of the number of turtles present along Johnston Island's south shore.

Only one paint-marked turtle was resighted. This turtle was observed at the surface near dive location I (Fig. 2) by a resident employee sailing a Hobie cat. The turtle dove vigorously when approached. Turtles have been occasionally seen in this general area, which consists of a dredged turning basin and ship channel along the eastern portion of Johnston Island's north shore. This turtle (tag No. 7485), had been captured 6 days earlier on November 6 at net location 2, and released shortly thereafter at the port facility on the north shore (Fig. 1). All 7 turtles captured during phase 1 and 12 caught during phase 2, were released at this site. The other two turtles (tag No. 7560 and 7565) from phase 2 were transported by truck and released at the south shore. The short distance (2 km) around the island, in relatively calm water between the north and south shores, should not have presented an obstacle to the turtles. Biotelemetry has shown that immature green turtle have a well-developed homing ability on their resident habitat (Ireland 1979a, 1979b). Furthermore, adults can find their way across hundreds of kilometers of ocean when migrating between resident areas and nesting beaches (Hirth 1971; Carr 1972).

Only three turtles were seen during 26 diving surveys with scuba totaling over 22 h, or 46 man-h, of bottom time (Fig. 2). All three turtles were swimming when sighted. While it was not possible to approach close enough to capture them, the turtles nevertheless did not flee in the manner seen when encountered by boat at the surface. The turtles were sighted at dive locations D, J, and P off the south shore in the same general area where nets were set. Most of the dive surveys (18 of 26) were made here, but poor underwater visibility, ranging from at best 10 m to as low as 1.5 m, greatly limited the possibility of seeing swimming turtles. However, careful systematic searches of the bottom were made at all locations to find places where turtles were sleeping, hence less liable to flee from a diver. None was found, although most areas surveyed, from just several meters offshore out to 1.8 km (dive location U), appeared well suited as sleeping habitat. Sleeping sites repeatedly used by green turtles have recognizable marks in the substrate. Except for two possible minor sites at dive locations C and P, no habitat was found showing such usage. The major sleeping areas for turtles along the south shore remain undiscovered, but it seems unlikely they are commuting very far.

As shown in Figure 2, no diving surveys were made to the southwest of West Peninsula in the waters downwind of the sewer outfall. In addition to raw human sewage, the outfall discharges wash water from the decontamination procedure used at the chemical storage facility. Other effluent, a dense black discharge, was regularly seen from shore during phase 1. This was reported to result from flushing of old sewer lines. The discharge point of the sewer outfall is immediately southwest of dive location J (Fig. 2). No turtles have been seen underwater during the few dive surveys previously made downwind of the outfall (Ludwig et al. 1982; Applied Eco-Tech Services 1983). However, from shore, turtles are commonly seen in this area while at the surface. It is possible that the sleeping areas are located somewhere along here. Recreational swimming and scuba diving are not permitted in waters off the entire south shore of Johnston Island.

Sightings of individual turtles at the surface, other than along Johnston's south shore, were made once at dive location O, and four times in the ship channel at the east end of Johnston Island. In addition, three immature turtles were seen over the tops of coral heads in the vicinity of dive location X. No turtles were seen in coastal waters by observers placed on Akau and Hikina Islands from 0800 to 1700 on November 10, and at Sand Island from 0800 to 1700 on November 11. No turtles were seen during snorkel surveys made by two observers for 80 min on November 9 in shallow water off the east and north end of Sand Island. No turtles were seen by two observers during 30 min of observation on October 12 from the abandoned tower near dive location L. These findings, which suggest low numbers of turtles and sparse distribution at sites other than Johnston's south shore, are consistent with information gathered during interviews. For example, Armyman Tim Snover stated that, over the past 10-month period, he had never seen a turtle during six scuba and eight snorkel dives in the northern portion of the atoll at Donovan's Reef (Fig. 2). Other personnel have seen turtles there, but only occasionally.

The reports of turtles in abundance along Johnston's south shore, and especially off West Peninsula, contrast sharply with the low numbers seen elsewhere in the atoll. For example, Ludwig (1982) saw an estimated 30 turtles during 1 h of observation from West Peninsula at 1800 on September 15, 1981. Up to five at a time were seen around the tops of individual coral heads. When Ludwig (1982) visited here again on September 17, he spotted eight turtles during 30 min. Ludwig (1982) also reported that personnel frequently visit West Peninsula to watch turtles. During 3 days in July 1982, Nitta (1982) saw 8-11 turtles while viewing from West Peninsula in the late afternoon. Applied Eco-Tech Services (1983) made the following comments from surveys conducted along the south shore during June 2-11, 1983.

> "Although the survey team was not directing their efforts to turtle observations, nearly every head bearing Bryopsis was seen to have one to perhaps four specimens of Chelonia mydas in the immediate vicinity....Upon sighting the dive boat, these turtles would sound rapidly, move away from the area and resurface 20-40 m away. This behavior and the uncertainty of the general movements of the turtle population during the course of the day precludes an accurate estimate of the total number of turtles present off the south shore at any given time. The algae survey team typically noted 20-25 turtles during each morning's efforts (3 h) and a similar number during each afternoon. It should also be noted here that this estimate is conservative since it represents sightings of surfacing animals only, the water clarity being sufficiently poor to prevent sightings of submerged organisms."

At the beginning of phase 1, four to six turtles were commonly sighted off West Peninsula, usually within a few hours of high tide. However, the number spotted varied considerably (0-13) while motoring along the entire south shore at various times throughout the study. These counts were undoubtedly influenced by tide stage, changes in visibility due to sun angle, and probably a greater awareness by the turtles of an approaching boat. At the end of phase 2, on November 16, an observer was stationed at West Peninsula for an hour during an incoming high tide. No fewer than five and possibly as many as eight turtles were seen; none of which appeared to have painted numbers. These data suggest there may be a considerable turnover in turtles using the area, and that the total number may be many times larger than what can be seen during a several day period.

Food Sources

Samples of stomach contents, mouth contents, or feces were acquired from 13 of the 21 turtles captured. Stomach contents from eight turtles contained five kinds of benthic algae, diatoms, filamentous bacteria, unidentified fibers, and a single amphipod (Table 7). The green algae, Bryopsis pennata var. secunda, was prominent in samples from three turtles and Caulerpa racemosa var. uvifera prominent from one turtle. All other items were present only in relatively small or trace amounts. Mouth contents from five turtles contained five kinds of benthic algae (including unidentified blue-green algae), diatoms and a single amphipod (Table 8). A stomach sample had already been taken from one of these turtles and the mouth contents were identical. Of the four turtles sampled only for mouth contents, B. pennata var. secunda was prominent from two C. racemosa var. macrophysa prominent from the other two. Identification of fecal contents from the single turtle sampled revealed a composition of 75% C. racemosa var. uvifera, and 25% B. pennata var. secunda (Table 8). Differences in the digestibility of the two species could have affected these percentages, therefore, the actual ratio ingested is unknown. Based on the limited sample data presented for stomach, mouth and fecal contents, the size of the turtle does not appear to be a factor in the kind of alga eaten. The turtles' major food sources (Bryopsis and two varieties of Caulerpa) grow in prime foraging habitat near the West Peninsula. Turtles were commonly seen surfacing and diving in typical foraging behavior over coral heads having dense Bryopsis. Interestingly, Bryopsis is not among the 56 known species of algae used as food by Hawaiian green turtles, nor has it been recorded anywhere else as green turtle forage. However, C. racemosa is eaten at several locations, but seems to be poor forage yielding very slow growth rates in green turtles (Balazs 1980c, 1982b).

Cris Balubar stated that the turtles he recalls cutting open and cleaning only contained the two common types of seaweed (Caulerpa and Bryopsis) found along the south shore of Johnston Island.

An unidentified cuboidal jellyfish (Cubomedusae) was abundant along Johnston's south shore during the early part of phase 1. The bell of these animals measured about 13 cm long. Many of them settled into the numerous depressions between coral heads where torn pieces of Bryopsis also collected. No evidence was found that green turtles feed on these jellyfish. However, other hydrozoans, such as Physalia and Velella, are eaten on an opportunistic basis by green turtles in Hawaii (Balazs 1980c).

Kitchen waste is dumped into the ocean daily at the southwest corner of Johnston Island. Pritchard (1982) reports that some green turtles scavenge regularly for food scraps discarded in a similar manner at the military facility on Kwajalein Atoll. No evidence was found that this food source is utilized by turtles at Johnston.

The circumstances in which a fecal sample was collected from a turtle (Table 8) are of interest. This turtle was captured at net location 7 at 1700 h on November 8 along with another turtle (Table 3). A section of the net had become snagged on a nearby coral head, thus preventing it from reaching the surface to breathe. The turtle was comatose when recovered. Except for contraction of the tail when pulled straight, there were no signs of life. Periodic compression of the plastron for 1 h in an attempt to ventilate the lungs gave no apparent results. The movement of air by this method seemed to only take place through the esophagus, since the glottis remained tightly closed. A small diameter plastic tube was therefore pushed though the glottis to hold it open and afford passage of air. The lungs were then gently ventilated by blowing into them at irregular intervals for the next hour with the turtle in a prone position. The turtle raised its head and opened its mouth to breathe for the first time after being seemingly lifeless for over 2 h. The tube was removed as breathing gradually became more frequent, and movement of the flippers resumed. The turtle was subsequently left prone overnight to give it more time to recover before release. In the morning, 1.5 kg of fecal matter were found to have been passed. The turtle swam off and dove in a normal manner when released.

Foraging Habitat

The principal foraging habitat for turtles at Johnston Atoll consists of a narrow band of heterogeneous algal pasture immediately off and along the south shore of Johnston Island. To a lesser extent, this feeding zone also exists contiguously on the northeast side of the ship channel (dive location X, Fig. 2), where Bryopsis alone is present on the tops of coral heads. Based on published literature, personal interviews, and surveys conducted during the present study, the standing crop densities of benthic algae suitable as forage for green turtles are extremely low at most all other sites in the atoll. Many kinds of benthic algae occur at Johnston (Brock et al. 1966, Buggeln and Tsuda 1966, 1969; summarized by Amerson and Shelton 1976). From this literature, Balazs (1982d) previously noted that C. racemosa, Codium arabicum, and Gelidium pusillum might serve as algal forage for Johnston's turtles, since green turtles elsewhere feed on these three species. However, the apparently sparse quantities of the latter two species negate any significant benefit that could be derived. There are small areas of Caulerpa racemosa var. uvifera in shallow water around Sand, Hikina, and also possibly Akau Island that could be used by turtles, but no turtles were seen feeding at these locations.

Four kinds of benthic algae collected during diving surveys along Johnston's south shore comprise nearly all of the standing crop that exists there (Table 9, dive location J). Three of these, B. pennata var. secunda, C. racemosa var. macrophysa, and C. racemosa var. uvifera, were identified as major food sources from the stomach, mouth, and feces of turtles. The fourth alga, *C. serrulata* (Förskal), was commonly seen in many areas close to the south shore, often growing in proximity to the two varieties of *C. racemosa*. Since *C. serrulata* was not found in any of the food samples, the turtles must be actively ignorning this species. Such an aversion could be due to metabolites known to be present in some *Caulerpa* that can act as toxic feeding deterrents (Paul and Fenical 1982; Paul 1983). This deterrence has not been demonstrated in turtles, but the subject warrants investigation. Certain algae of the Order Caulerpales are food sources for green turtles at a number of locations worldwide. More than 100 species are known, and at some atolls in the Pacific very dense populations of the algae are present (Meinesz et al. 1981).

Bryopsis and the two varieties of *C. racemosa* sampled fresh from foraging habitat off West Peninsula were found to differ considerably in nutrient composition (Table 10). *Bryopsis* contains 2 to 3 times as much protein as *Caulerpa*, and only about 60% the ash content. *Bryopsis* also has 2 to 4 times greater lipid content (ether extract). It should be noted that the protein percentages shown in Table 10 were obtained by a standard analytical procedure used for terrestrial forage (proximate analysis), where total nitrogen is multiplied by a value of 6.25. This may be an overestimate for certain marine benthic algae. For example, Dawes and Goddard (1978) measured protein in *C. racemosa* (variety not stated) from Florida by a direct protein extraction technique that gave a content of 4.8%. Protein content for *racemosa* in the present study was calculated to be 8.0% (for *uvifera*) and 9.1% (for *macrophysa*).

The nutrient composition of *Bryopsis* collected from two different environments is also presented in Table 10. In one, *Bryopsis* was sampled off the top of a coral head where turtles were commonly seen feeding. The other collection was made nearby from a depression between coral heads where drifts of naturally torn *Bryopsis* had collected due to low water movement. *Bryopsis* in these depressions is not visible from the surface due to high turbidity. Consequently, it is unknown if turtles ever feed on this loose material. It was theorized that attached *Bryopsis* repeatedly cropped by turtles might contain higher protein and less fiber (complex polysaccharides) due to the constant new growth taking place at the grazed ends. Protein levels shown in Table 10 do not support this hypothesis, since the loose material is almost 2% higher (25.7% versus 23.8%) in protein content than the attached alga. However, attached *Bryopsis* is slightly lower in all the fiber components. It is worth noting that the drifts of loose *Bryopsis* can probably remain healthy and unattached indefinitely, so long as nutrients are sufficient, and currents weak enough, to prevent the drifts from being washed away (D. J. Russell, pers. commun., December 1983).

The mineral composition determined for the two different collections of *Bryopsis* is very similar (Table 11). The one prominent value for the nine minerals measured in these algae is the iron content of *C. racemosa* var. *macrophysa* (2,558 ppm). This level is many times higher than that of the *uvifera* variety (90 ppm) or either sample of *Bryopsis* (88 and 110 ppm). No firm explanation can be offered for these data. However, it is possible that *macrophysa* has a high requirement for iron, which therefore may be a limiting nutrient to growth. Iron pilings and pipes along the south shore of Johnston may supply this nutrient and allow the alga to proliferate as it does. This explanation is supported in part by data discussed in Russell and Carlson (1978) concerning shipwrecks and the concomitant vigorous growth of certain green algae.

Surveys to characterize and define the habitat limits for the different algae comprising the turtle foraging zone along the south shore resulted in the following findings. The occurrence of attached *Bryopsis* is confined almost entirely to the tops of coral heads that range from not more than 2 m beneath the surface, to those that are fully exposed at low tide. This environmental range appears to be a necessity for lush *Bryopsis* growth off the south shore. Only a limited number of coral heads fulfill the requirement. Many of the *Bryopsis* covered heads have growth 1-2 m down their slope, but thereafter the alga is sparse. A few small patches of attached *Bryopsis* were found on the sides of some heads as deep as 7.5 m.

The number of coral heads with *Bryopsis* was censused off the south shore at low tide from a boat on November 16. Between East Peninsula and the row of iron pilings (Fig. 1), 30 individual heads were counted, as well as a narrow broken ridge in shallow water parallel to shore. Between the iron pilings and the southwest side of West Peninsula, 31 heads were counted. From West Peninsula to the southwest corner of the island, 18 were counted. A total of only about 80 heads therefore occur in this narrow zone, and most (62) are between East and West Peninsulas. The greatest distance of any coral head from shore is about 600 m. Six of the heads that were believed to be representative of all the various sizes were selected and measured to determine vertical surface area where *Bryopsis* occurs. The heads were irregular and difficult to measure. Nevertheless, the areas ranged from approximately 9 to 127 m^2; the mean was 47 m^2. An "average" size coral head hosting *Bryopsis* is therefore only about 7 x 7 m. It was estimated that *Bryopsis* covered 80% of the surface area, the remainder being bare coral rock. This surface coverage could very well change with season. The distribution of *Bryopsis* off Johnston's south shore as portrayed in a map prepared by Applied Eco-Tech Services (1983: Fig. 24) greatly overrepresents the habitat area where this alga actually occurs.

As previously mentioned, there are coral heads to the northeast of East Peninsula where environmental conditions are conducive to *Bryopsis* growth and turtles were seen feeding. This area was not as thoroughly surveyed. There are probably not more than 15 coral heads there that host *Bryopsis*.

Turtles foraging on the tops of coral heads with *Bryopsis* are highly visible due to the shallow depth, and the contrasting color of the turtle's silty-brown shell against the green-black mat of *Bryopsis*. Because turtles are so apparent when foraging at these sites, it was possible to ascertain that some heads were being used more heavily than others. Cris Balubar also confirmed this point. For many heads, it is essential for the tide to be high enough for turtles to swim over the top to forage. At a few sites, this condition is never met. Two prominent coral heads off West Peninsula, are emergent much of the time, and even at high tide waves break with sufficient force to prevent turtles from feeding on top.

The growth of Caulerpa in the foraging habitat along Johnston's south shore is more difficult to characterize and define because, unlike Bryopsis, most of it cannot be seen from the surface. The extensive diving surveys with scuba devoted to examining habitat between the East and West Peninsulas helped to elucidate Caulerpa distribution. The macrophysa variety was far more abundant than uvifera or serrulata. The greatest Caulerpa coverage, approaching 100% on all hard substrate, occurred between the iron pilings and West Peninsula. Drifts of loose Caulerpa (again mostly macrophysa) covered nearly all of the silt bottom areas between the pinnacles and other hard substrate. There was a considerable decline in Caulerpa growth seaward from the outer iron pilings and the end of West Peninsula. At a point <100 m from the end of West Peninsula, in the area of net location 2 (Fig. 1), the growth of Caulerpa nearly disappears. Throughout this transition zone, the Caulerpa coverage declines first on the seaward sides of the underwater pinnacles. With the disappearance of Caulerpa, the hard substrate consists of bare rock, an increasing amount of live corals, and the Bryopsis previously described. A consistent salinity of 34‰ was recorded from nine water samples taken throughout the area, including one taken at the greatest bottom depth of 8 m. The seawater temperature ranged from 27.5° to 28.5°C.

The findings in this study relating to Caulerpa coverage between the iron pilings and West Peninsula are considerably different from those presented by Applied Eco-Tech Services (1983). Figure 23 in their report shows 80% to 100% coverage of Caulerpa on hard bottom substrate extending 200 m seaward of West Peninsula, twice the distance described in the present report. Possibly there was a radical seasonal change, since the survey by Applied Eco-Tech Services (1983) was done in June 1983, 5 months before the present study. Confirmation of this important point is needed.

The history of the marine environment off Johnston's south shore is virtually unknown due to the paucity of research conducted there. Sections of marine habitat have been filled in with the island's periodic expansion. When Cris Balubar arrived in 1962, he recalls many turtles being present off the south shore, along with clear water and "nice reefs." He does not remember the status of algal cover. Lee Gohr helped to lay the existing sewer outfall in 1964 and recalls seeing benthic algae, but not in the density that exists at present. None of the personnel interviewed was able to tell where the outfall existed before 1964.

The exact role of sewage discharge in facilitating, or possibly depressing, algal growth remains speculative. Aerial photographs of the island taken over the years may help to answer this question. It may be that nutrients from guano in the brackish-water lens of the island historically served as fertilizers for algae.

Epizoites and Abnormalities

Epizoic algal mats found mostly on the inguinal skin, plastron, and ventral surface of marginal scutes were sampled from five of the turtles captured. An analysis of this material revealed eight kinds of algae, roundworms, foraminifera, amphipods, and black "mites" (Table 12). One of the algal species (Pilina sp.) may possibly be a new record for the tropical Pacific. The red alga, Polysiphonia tsudana, was present on all five turtles, and is also common on Hawaiian green turtles. Acrochaetium, Sphacelaria, and Lygbya have also been recorded on green turtles in Hawaii, but for the latter two genera as different species. Urospora sp., found on three turtles, has never been reported from turtles in Hawaii. Amphipods found on two turtles and in the mouth and esophagus of another turtle are probably Hyachelia tortugae (Tables 7 and 8). This specialized crustacean, first described from the Galapagos Islands, has also been recorded in Hawaii and is known only from sea turtles.

There was a noticeable paucity of barnacles on the turtles captured. None of the common turtle barnacle, Chelonibia testudinaria, was present, nor was the burrowing barnacle, Stephanolepas muricata. Even more surprising was the near absence of the harmless skin barnacle, Platylepas hexastylos. Only a few were found on two turtles and some of these were falling off and appeared to be dying. Platylepas commonly occurs in large numbers on the skin of Hawaiian green turtles.

Small neoplastic growths 1-3 cm in diameter were found on two male turtles captured. Five growths were present on one and two on the other. The sites of these tumors included the trailing edge of front flippers, corner of the mouth, edge of the eye, inguinal region, and top of the head. Except for the latter location, growths are occasionally seen at these same places in Hawaiian and other green turtle populations. Some of the tumors documented elsewhere have been much larger, and far more numerous on individual turtles, than the ones seen at Johnston. However, Cris Balubar reported that about 10 years ago he did see a turtle "covered with white growths." The etiology of tumors on sea turtles is presently unknown. Relevant background material on the subject can be found in Harshbarger (1977), Balazs (1980c), Glazebrook et al. (1981), Jacobson (1981), and the references contained therein.

Counts made of the major scales along the trailing edge of the front flippers, to a point perpendicular to the claw scale, revealed that 2 (9.5%) of the 21 turtles varied from the standard 6 left-6 right count (Table 5).

The number of postocular scales (scales posterior of the orbits) varied from the standard 4 left-4 right count in 4 (19%) of the turtles (Table 5).

Four other abnormalities were noted among the turtles captured. The tail of an adult female was curled tightly under the edge of the carapace and appeared to be paralyzed. There was no scarring to suggest an injury.

One turtle made an unusual "whistling" sound when breathing. The cause could not be determined. Another had a small extra scute along the midline of the plastron between the humeral scutes, and another had a slightly depressed area to the carapace in the region of the 2d central scute and 1st-2d right lateral scutes. There were no signs of an external injury.

Predation and Injuries

Evidence of injuries likely resulting from shark attack was seen on 3 of the 21 turtles captured. The injury on an adult male was the most pronounced: half of its tail was amputated and it had extensive, but mostly healed, lacerations of the right hind flipper. Two turtles had several deep cuts in their carapace. Some of these wounds, which were also mostly healed, could be seen near the painted numbers. Five other turtles had minor pieces missing from hind flippers, but this is common in green turtles. None of the turtles in Cris Balubar's photos showed signs of shark attack or other obvious injuries. The few probable shark-inflicted injuries seen at Johnston may not necessarily have happened there, since the adult turtles must periodically migrate elsewhere for breeding purposes.

Sea turtles are known to be prey for large sharks, especially the tiger shark, Galeocerdo cuvier. Captain Cameron was well aware of this food preference when he used turtles as bait to enhance his shark fishing at Johnston in 1892 (Farrell 1928). The graphic description by Benson (1953) of a shark swallowing a turtle whole at Johnston also attests to this fact. More recently, C. B. Cecrle, in litt. 1979 cited by Balazs (1982d), reported sharks feeding on a large turtle outside of the atoll.

Tiger sharks presently occur at the atoll, but they are not commonly seen nor frequently captured in recreational shark fishing. The most recent one caught was in August 1983 when a 4-m specimen was hooked in the ship channel at the western end of Sand Island. A 1-m whitetip reef shark, Triaenodon obseus, was used as bait. The stomach was not cut open, so the natural prey items are unknown.

The gray reef shark, Carcharhinus amblyrhynchos, often schools in abundance off the southwest corner of Johnston Island when kitchen garbage is dumped. Recreational fishermen fish for shark with baited hooks from shore here and at West and East Peninsulas. However, no reports were received of turtle parts ever being found in the stomach of gray reef sharks. Elsewhere this species is apparently not a regular predator of turtles, except possibly on hatchlings. One person interviewed stated that he had seen two turtles feeding on dead fish used as bait on a shark hook at West Peninsula.

Fishing for large tiger sharks used to be done with baited hooks set from markers along the main ship channel. This practice became prohibited, so personnel moored two large iron buoys 200-300 m offshore between West Peninsula and the southwest corner of the island. Both buoys are still present, but not often used for fishing since only small sharks (presumably gray reefs) have been caught there. During the diving surveys, only two sharks were seen, a gray reef at location M, and a whitetip at location L (Fig. 2). Large numbers of the former are said to enter the atoll for breeding purposes during the summer months.

The moray eel, Lycodontis javanicus (= Gymnothorax), occurs at Johnston Atoll where it is known to be an opportunistic predator of fish, octopus, and spiny lobsters (Brock 1972). This species is the largest moray eel in the Indo-Pacific; specimens seen at Johnston are estimated at up to 2.4 m long (Randall 1980). Lycodontis javanicus could conceivably prey on small immature green turtles, but there is no direct evidence showing this. However, a prey item as large (and unusual) as a 46.5 cm whitetip shark was found by Brock (1972) in the stomach of a 1.4 m moray eel. Eels live under ledges and in other coral recesses similar to where green turtles are typically believed to sleep. The eel's abundance and prey items have not been intensively studied along the south shore of Johnston Island. None was seen during any of the diving surveys. However, moray eels hide mostly in the reef during the daytime, and feed during twilight and at night.

Large groupers (Serranidae) occur at Johnston, but there is presently no evidence that they prey on turtles. In Hawaii, and elsewhere, whole immature turtles have occasionally been found in the stomachs of these fish. Benson (1953) describes the capture of a stunned "430 lb (195 kg) black sea bass" following an explosion to clear coral in the lagoon. The contents of the stomach were not mentioned. Sometime during 1970-71, a 27 kg grouper, Epinephelus sp., was caught at the southwest corner of Johnston Island near the garbage chute. The stomach was full of spiny lobsters (R. E. Brock, pers. commun., February 1984).

An unusual relatively minor injury was found on four of the turtles captured. This consisted of an ulcer on the dorsal neck surface over the supraoccipital bone of the skull. The exact cause is unknown, but could involve repeated abrasion against hard substrate, perhaps the roof of a coral recess where the turtles sleep.

Strandings

Information was obtained on strandings of four turtles. Three were described in interviews with resident personnel, and one by correspondence from the U.S. National Museum concerning the specimen mentioned in Amerson and Shelton (1976).

According to Cris Balubar, a large dead turtle "tangled in a Japanese fish net" washed up near East Peninsula several years ago. Also, at an unknown date a small turtle was found dead on the beach at Akau Island. No other information was available about these two incidents.

Phil Roseberry related that a few years ago he was told by Army personnel about a large dead turtle which washed in at Akau Island. He visited the site the next day, but the turtle was gone, presumably washed away by the next high tide.

Dr. Jack G. Frazier provided the following data on file for the specimen at the U.S. National Museum:

USNM 163581 (Catalogue entry)
Accession No. - 278016
Original No. - 11287
Name - Chelonia mydas/japonica
Locality - Sand Island, Johnston Atoll
Date collected - November 20, 1966
Received from - Smithsonian Institution Pacific Ocean Biological Survey Project
Collected by - --
When entered - September 14, 1967
Sex and No. of specimens - 1 head

Dr. Frazier also related that the head is approximately 10 cm wide and preserved in alcohol. It appears to have been collected fresh, and has a cut on the left side similar to what would result from a blow with a machete. This is the extent of information available. A 10-cm wide head would have come from a turtle about 75 cm SCL, hence of an immature size. Cris Balubar was unaware of this specimen, as were the other longtime residents interviewed. A probable scenario might be that a freshly dead turtle washed up at Sand Island from the adjacent ship channel. A short time later it was found by Smithsonian personnel, who used a machete or ax to sever the head for the museum's collection. One of these cuts may have accidently hit the side of the head. Other possible explanations might be that the gash resulted from a shark attack, or collision with a boat propeller. It seems unlikely that a live healthy turtle of this size would have been collected just for the head, unless the turtle was taken mainly for food or a trophy shell. By itself, and especially with no accompanying data, the head is of little taxonomic value, except to show the presence of Chelonia.

The U.S. National Museum's subspecies designation of japonica is the name sometimes applied to western Pacific green turtles. The type locality is Japan (Hirth 1971). Based on existing information, the use of this or any other trinomial for the Johnston population is not currently justified.

Basking

No evidence was found during the field study that green turtles bask ashore during the daytime, as they commonly do at Johnston's closest island neighbor, French Frigate Shoals in the Northwestern Hawaiian Islands (Whittow and Balazs 1982). Balazs (1978) indicated that the turtle collected at Sand Island in 1966 may have been basking (or nesting). However, this now seems unlikely in view of the information presented in the previous section.

Nitta (1982) stated that he received a report of turtles sometimes hauled out during the early morning on the coral-rubble and sand beach between the iron pilings and West Peninsula (Fig. 1). No turtles were found by Nitta (1982) when this site was visited at 0600 on July 9, 1982. Observers in the present study also surveyed the beach, which was 200 m long and accreted against the cement seawall that borders most of Johnston

Island. There were no marks in the beach suggestive of use by turtles. The site was visited on November 15 (2200), 16 (0500, and 2300) and 17 (0500), but no turtles were seen. Cris Balubar reported that the beach is unstable in that portions often wash away and return. He sometimes visits here early in the morning to look for baitfish, but has never seen a turtle ashore. Nevertheless, it is conceivable that turtles do occasionally come out at night to sleep along this shoreline when underwater sleeping sites become unacceptable due to storm surge or other factors. Such behavior is known at Necker Island and Pearl and Hermes Reef (Northwestern Hawaiian Islands), and on the Na Pali coast of Kauai, Hawaii.

An historic absence of basking by turtles at Johnston Atoll may have prompted the comment in 1859 by Brooke (MS.), quoted by Amerson and Shelton (1976), that "The reefs are covered with fish of various kinds. Mullet abound, but there are no turtles." Just 3 months earlier, in January 1859, Captain Brooke had visited French Frigate Shoals and Laysan Island, where he saw many turtles basking on the beach (Amerson 1971; Ely and Clapp 1973). These sights might easily have caused him to believe that land basking was common behavior for all sea turtles at remote Pacific islands. Seeing none along the shoreline at Johnston during his 2-day visit would naturally have come as a surprise, hence causing him to comment about no turtles being there. Since turtles were caught at Johnston 33 years later in 1892 by Captain Cameron (Farrell 1928), Brooke's (MS.) statement could not have been applicable to turtles in the water. It most likely meant that he expected to see turtles on the beach, and that no special search was made for them in the waters of the atoll. It should also be noted that when Captain Brooke arrived, 14 men were already living on Johnston Island, some since July 1858, building a wharf and railway for shipping guano (Amerson and Shelton 1976). Captain Cameron noted the abandoned remains of this facility in 1892 (Farrell 1928).

Reproduction

No historic records are known of turtles nesting at Johnston Atoll, although Amerson and Shelton (1976) speculate that perhaps they did in small numbers before habitation by man. Johnston Island was inhabited intermittently for guano removal starting in July 1858. Sand Island, however, seems to have remained uninhabited until the mid-1930's, when military construction began there.

The nesting season for green turtles in northern latitudes is from May through August. At French Frigate Shoals (lat. 23°45'N), the major nesting site for Hawaiian green turtles, the peak months are June and July. A similar season should exist at Johnston (lat. 16°45'N), if turtles nested there. The Tanager Expedition spent 10 days in July 1923 camped on uninhabited Johnston Island. According to Amerson and Shelton (1976), Wetmore (MS. a and b) "...recorded no turtles." However, from this statement it is unclear if Alexander Wetmore, leader of the expedition, actually noted an absence of turtles, or just made no mention of them in his field journal. The latter case applies for Wetmore (MS. b), but I have not seen Wetmore (MS. a). Nevertheless, while camped on Johnston Island, Wetmore (MS. B) tells of a nighttime walk along the beaches of "fine white coral sand." If turtles were seen coming ashore to nest in numbers, surely it would have been mentioned. This should also have been the case for any extensive nesting excavations seen in the vegetation zone during numerous daytime surveys. However, it is conjecture if the same would also apply for Sand Island. There were no overnight camps there, and only two daytime visits were made.

It should be noted that the Tanager Expedition had just come from French Frigate Shoals and other Northwestern Hawaiian Islands, where journal notes were in fact made about turtles basking, nesting, and being recently exploited (Amerson 1971). The expedition constituted the first discovery by scientific personnel of sea turtles actually basking. Consequently, most of the interest relating to turtles was focused on this behavioral aspect (Mellen 1925; Wetmore 1925).

The question of whether or not turtles nested at Sand or Johnston Island when the Tanager Expedition visited in 1923 can probably be answered conclusively from aerial photographs. A small seaplane made the first photographic flights over the atoll during the expedition on July 12 and 19 (Wetmore MS. b). These and other U.S. Navy aerial photos taken until the late 1930's should be of sufficient resolution to show nesting excavations, if such sites existed. The original photos are apparently on file in the U.S. National Archives (Amerson and Shelton 1976).

During his residency at Johnston Island since 1962, Cris Balubar only knows of one instance of a possible nesting, but couldn't recall the year. Turtle tracks and digging were seen at Sand Island, but there was no confirmation that eggs were laid. Cris Balubar also stated that he had never seen eggs inside turtles he had caught and cleaned. Upon further discussion, it was determined that only ova of a large and nearly mature size would have been noticed and remembered by him.

Several people interviewed, including Cris Balubar, said that they had seen turtles locked together copulating, sometimes for extended periods. Cris Balubar felt that this mating activity was more prevalent during September through November. Francisco Aguinaldo and Ed Mattson saw a copulating pair in July 1983 at the shoreline of the sand beach by the iron pilings. The turtles swam off quickly when approached. Previous occurrences of this sort may have been partly responsible for the report received by Nitta (1982) of turtles hauling out on this beach. Present accounts of turtles copulating at Johnston are supported by the fact that, in 1892, Captain Cameron tethered a few receptive females to attract and catch males intent on mating (Farrell 1928). The contradiction here is that, for the most part, green turtles are thought to mate only in waters adjacent to their nesting beach.

The lesions typically present on males and females following copulation were not seen on any of the turtles captured in this present study.

A survey of Sand Island's shoreline identified four sand beaches, all located at the eastern end which comprised the original portion of the island before enlargement. Each of these natural beaches offers access to the elevated interior where the soil is suitable for nesting. With the exception of one beach where there is a bright electrical light, Sand Island presently seems to be appropriate habitat for nesting, if turtles wanted to nest there. Even the beach by the iron pilings on Johnston Island has an elevated area of fine sand where nesting might successfully take place. In contrast, the man-made islands of Akau and Hikina are unsuitable, since the shorelines consist only of cement seawalls and coarse coral rubble, and the interiors are compacted aggregate from dredging.

Migrations

Since there presently is no nesting at Johnston Atoll, and possibly never was, the turtles must be periodically migrating elsewhere to reproduce. This would be consistent with the pattern found in most other green turtle populations, where round trip migrations take place between resident foraging areas and distant breeding grounds. Migrations of this nature are known to be made, even when what may appear to be acceptable nesting beaches are close by. Though not conclusively proven, the turtles are most likely returning to breed at their natal beaches.

A logical place where Johnston's turtles might go to nest would be French Frigate Shoals. This site is only 830 km to the north, and comprises the major rookery for green turtles migrating from islands throughout a 2,200 km expanse of the Hawaiian Archipelago. However, there are no tag recoveries to support the hypothesis of French Frigate Shoals actually being the breeding site for Johnston's turtles. Ample opportunities have existed for such a migratory pattern to be demonstrated. Over the past 20 years, more than 1,600 adults have been tagged at French Frigate Shoals, and about 200 others tagged elsewhere in the Northwestern Hawaiian Islands. None of these tagged turtles has been recovered in the Johnston population, neither in the present study, nor when turtle fishing was allowed at the atoll. Cris Balubar estimates he caught 60 turtles between 1967 and 1976, but found no tags. These same years were some of the most intensive for tagging turtles at French Frigate Shoals. Interestingly, during the years 1966-72, 860 Hawaiian monk seals, Monachus schauinslandi, were also tagged in the Northwestern Hawaiian Islands. Three of these have subsequently been reported at Johnston; one came from French Frigate Shoals, and two from Laysan Island (Schreiber and Kridler 1969; Johnson and Kridler 1983). Monk seals were apparently a conspicuous component of Johnston's fauna when Captain Cameron visited there in 1892 (Farrell 1928). In this century, however, very few seals are known to have migrated outside the Hawaiian Archipelago, and then only to Johnston Atoll. A migratory link between Johnston and French Frigate Shoals also exists for seabirds. Of 733 inter-island tag recoveries, 32% involved French Frigate Shoals (Amerson and Shelton 1976).

The isolated location of Johnston limits the number of other sites the resident turtles might go to nest. The Line Islands, starting with Kingman Reef 1,575 km to the southwest, is the next closest area to Johnston after French Frigate Shoals and the other Northwestern Hawaiian Islands. A low level of green turtle nesting occurs at the inhabited atolls of Fanning and Christmas in this island group. But none is known to occur at Kingman, nor the nearby atoll of Palmyra.

The closest island to the west of Johnston is uninhabited Bikar in the northern Marshall Islands. Bikar is located 2,220 km away and is considered a prominent nesting site for green turtles (Pritchard 1982). No tagging has been conducted at Bikar, so the resident foraging grounds for turtles nesting there are unknown. Presumably they include many of the Marshall Islands. Bikar is a traditional wildlife reserve owned by chiefs of a Marshallese clan who periodically visit to gather turtles, seabirds, and their eggs (Tobin 1952).

Canton and other islands of the Phoenix group are situated almost directly south of Johnston, below the Equator, at a closest distance of 2,160 km. Green turtles have been found to nest here, but again the areas where they migrate from are currently unknown (Balazs 1975).

The limited amount of tagging done in the Pacific has uncovered some impressive long distance migrations by turtles, each encompassing the boundaries of several island nations (Balazs 1982c). Turtles tagged at Johnston in the present study may very well yield similar results, and eventually pinpoint the nesting site.

From interviews, it was learned that three turtles had been marked at Johnston before the tagging done in this study. In 1971, Cris Balubar tagged a turtle (on the dorsal surface of a front flipper) with an aluminum plate embossed with his name, location (Johnston), weight of the turtle (130 lb (59.1 kg)), and date of release. The day and month could not be recalled. He also caught another turtle sometime in 1971 described as being "large and ugly," but apparently not diseased or injured. The carapace of this one was painted completely black before it was released. A second turtle was also marked with paint. This one weighed only about 14 kg and was hand captured by someone else close to shore at Hikina Island. The words "Happy New Year January 1981" were stenciled on the carapace with fluorescent paint. No recoveries have been reported for these three turtles.

Utilization

It is not possible to quantify the number of turtles taken at Johnston over the years, except for the estimate of 60 given by Cris Balubar for 1967-76. An estimate of 12-15 turtles harvested per year by "a long time resident" appears in Amerson and Shelton (1976).

All turtles caught at the atoll since military occupation in the 1930's can be assumed to have been taken for sport, trophy shells, and as a seafood delicacy along with fish and lobster. There is no evidence of commercial harvest during this period, although some shells were probably sold privately. In 1976 the refuge manager for the U.S. Fish and Wildlife Service (Palmer Sekora) prohibited all taking of turtles at Johnston. This measure was instituted to achieve consistency with the already protected status of sea turtles at other National Wildlife Refuges in the United States.

Cris Balubar's case history of turtle fishing is worth describing, since he is well known locally for this skill. He appears to be the only person over the past 22 years who regularly targeted turtles with a specific fishing technique. This viewpoint could, however, be biased due to Cris Balubar's long residency, and since he is still there to be interviewed. Other personnel fishing just for turtles may have come and gone over the years, leaving no verbal record of their activities. Turtle catching by others was probably only on an opportunistic basis while diving and spearfishing. For instance, some years ago Lee Gohr caught a 59-kg turtle while recreational diving between Sand and North Islands. Also, since turtle fishing has been illegal since 1976, it is unlikely any information would be volunteered about turtles taken thereafter. A secondhand report, believed to be reliable, was received that occasionally turtles are still taken for food when they are accidentally encountered by divers in the north of the atoll. In these instances, it was reported the divers discard the shell and flippers before returning to Johnston Island.

Cris Balubar's turtle fishing started in 1967 when he was asked to catch a turtle for one of the island's military officers. As it is now, most turtles were found along the south shore. West Peninsula was generally off limits for recreational purposes at that time. However, special permission for fishing was granted in this case. The technique successfully employed involved a fiber glass pole with a spinner reel and treble hook to cast out and snag the turtle while it was feeding. A lengthy period would then often be needed to reel it in. The turtle incurred very little physical injury during capture, since it was usually hooked only in a flipper. This fishing method is a modification of one sometimes used for turtles in Hawaii (Balazs 1980c). Cris Balubar subsequently caught turtles in this manner from a small boat off the south shore, as well as from the seawall. He estimates that 45 of the 60 turtles taken were by boat. According to Balubar, Johnston turtles taste much better than Hawaiian turtles. This difference could be due to the algal food sources utilized. A recent article in Hawaii Fishing News describes his snagging technique used to land a large yellowfin tuna from the seawall at Johnston (Balubar 1982).

The only firm evidence of turtles being exploited at Johnston before military settlement is Captain Cameron's mention of their use in 1892 for shark bait and food (Farrell 1928). Turtles, along with seals, were a preferred bait for shark fishing at that time. It is reasonable to assume that other commercial fishing expeditions stopping there would also have taken turtles, if they could be found. In 1918 an attempt was made to establish a fishing station at Johnston, but dissatisfied workers quickly terminated the plan. During the 1920's, at least two commercial fishing vessels visited the atoll. One was the Lanikai, a vessel known to take turtles from Pearl and Hermes Reef for markets in Honolulu (Thurston 1928; Amerson and Shelton 1976; Balazs 1980c). Brock et al. (1965) imply that at least one fishing boat from Honolulu regularly visited Johnston before World War II.

Guano mining outposts on remote Pacific islands, like the one started at Johnston in 1858, regularly used whatever marine resources were available for fresh food. Turtles were among those items eaten by guano diggers on Laysan Island. Presumably turtles were also eaten at other guano islands where they were present. Turtles were also eaten at the intermittent camps set up illegally by plume hunters in the Northwestern Hawaiian Islands. The remains of such a camp were found at Johnston in 1923 (Wetmore MS. b).

Environmental Perturbations

A number of man-made perturbations have historically taken place at Johnston that could have adversely affected turtles. Some of these impacts, like blasting to remove coral, almost certainly caused direct mortality. Others have possibly been more subtle, thus making them difficult to detect (Whittle et al. 1977). The highly modified environment at Johnston, and the various uncommon activities periodically conducted there, warrant the consideration of these perturbations. It is beyond the scope of this paper to give an in-depth evaluation and analyses of these factors. However, the information contained herein should provide some direction for possible future research of turtles at Johnston Atoll.

Initial blasting and dredging to clear coral and increase the size of Johnston and Sand Islands happened from 1939 to 1942. Woodbury (1946) describes the difficulties experienced in breaking up the coral, and the extraordinary amount of dynamiting required. Johnston Island was expanded from its original 19 ha to 85 ha, and 4-ha Sand Island was doubled in size. Major construction projects to further enlarge Johnston Island were completed in 1958 and 1964, resulting in the present land area of 253 ha. The man-made islands of Akau (10 ha) and Hikina (7 ha), with channels leading to them, were also finished in 1964 (U.S. Army Corps of Engineers 1983). The concussions from underwater explosions during these various projects would have stunned any turtle in the vicinity causing injury and death from direct impact or drowning. Such blasting, and the resulting dead fish, would also be an attractant to large sharks that could, in turn, easily have preyed on stunned turtles. The likelihood that this actually happened is supported by Benson's (1953) description of "...numerous huge sharks" being present during dynamiting, and one of them seen "...swallowing a sea turtle whole." Underwater explosions have also been set off occasionally in recent years. Moses Caballero mentioned the destruction of a live bomb found in the turning basin of the ship channel. It should be noted that some blasting also occurred in the lagoon waters of Johnston long before military activities. During Captain Cameron's 1892 visit, at least one marine harvest was made by driving fish close to shore and setting off "dynamite cartridges" (Farrell 1928: p. 406).

Several hydrogen bombs were successfully detonated at high altitude over Johnston in 1958 and 1962. Amerson and Shelton (1976) stated the following with respect to one of the environmental impacts:

> "During these nuclear tests, an elaborate water sprinkler system was installed on the original portion of Sand Island to protect the birds living there. In addition, other protective devices were used, including smoke pots placed upwind as a shade screen and aerial flares to divert the birds' attention from the flash of the blast itself."

Since the flash (and heat?) from these explosions was so intense at ground level, eye damage could presumably have resulted to any turtles on or near the surface at the time of detonation.

During 1962, three of the missiles carrying nuclear devices malfunctioned, exploded, and spread particles of radioactive material over the atoll and surrounding Pacific Ocean. One of these blasts was on the launch pad, significantly affecting a portion of Johnston Island (Anonymous 1962a, 1962b, 1962c). Decontamination efforts have been periodically carried out, including removal and dumping of debris and surface soil over deep water outside the atoll. As a result, some contaminated soil entered the nearshore waters of the island and certain areas of the island continue to be "off limits." The surface runoff of rainfall undoubtedly transports additional particles into the nearshore waters. The soil at the western end of Sand Island is also still contaminated (U.S. Army Corps of Engineers 1983). Benthic algae, including types which exist in the turtle foraging habitat along the south shore, concentrate certain radionuclides at rates higher than other plants and animals (Hines 1962: p. 145-151; Whittle et al. 1977). Hillestad et al. (1974) reported very low levels of gamma emitters in tissue from loggerhead turtles, Caretta caretta, in Georgia and South Carolina. The levels present in turtles from a contaminated area are apparently unknown.

During the early 1970's, various chemical weapons and herbicides were stored on Johnston Island. Also, canisters of dioxin were flown to the atoll in 1976 (Benson 1976). The herbicide was safely incinerated at sea in 1977 using a ship built for such purposes (Nelson 1977). However, leakage from these drums resulted in Herbicide Orange and dioxin contamination of soil at the northwest corner of the island. In 1973, various water, sediment, and marine biological samples were tested for dioxin and Herbicide Orange. A muscle and liver specimen from a green turtle of unknown size, taken between East and West Peninsulas, were included. A sample of Bryopsis, but not Caulerpa, from the same area was also analyzed. None of these four samples from 1973 (presumably measured on a dry matter basis) was found to have detectable levels of dioxin or Herbicide Orange (U.S. Army Corps of Engineers 1983: footnote in Table III-6, Appendix L).

Some leakage of nerve gas from deteriorating munitions containers has been reported (Borg 1982). As noted in a previous section, wash water from the decontamination procedure is discharged through the sewer outfall directly into the turtle foraging habitat. Storm drains may also receive some of this effluent.

A considerable amount of man-made debris was seen on the ocean bottom during diving surveys at locations G and U (Fig. 2). These were the only two offshore (>14 m) sites surveyed, so discarded items may exist over a much broader area off Johnston Island's south shore. The material seen consisted of 55-gal drums, a trailer, a Mike boat, and pieces of iron reinforcement bar. The drums were heavily rusted, but some appeared intact. The contents, if any, could not be determined through interviews with resident personnel.

Heavy metals are known to be discharged from desalination plants as the result of internal corrosion. Two types of discharge have been reported: one emitted when the plant is operating normally, the other produced during periodic cleaning and maintenance cycles (Chesher 1975).

High levels of copper are present in the normal effluent, and this element is believed to be the most toxic to marine organisms. When desalination plants shut down for maintenance, corroded copper-nickel surfaces dry and oxidize. With resumption of operation, copper contamination is 2-3 times higher than normal for a few hours. Higher levels of nickel and iron are also released. The discharge during this period is turbid and black (Chesher 1975). Few studies have attempted to measure heavy metal content in sea turtles and their eggs (Hillestad et al. 1974; Stoneburner et al. 1980; Witkowski and Frazier 1982). Furthermore, as emphasized by Witkowski and Frazier (1982) and Coston-Clements and Hoss (1983), it is difficult to determine the significance of such findings because little is known about baseline levels and physiological effects. Based on reports of copper levels discharged from a desalination plant (Chesher 1975), the facility at Johnston probably produces at present 1.3-2.6 kg of copper effluent per day under normal operation. Effluent from the plant apparently also serves to enrich, by some undetermined process, the existing radionuclide contamination in nearshore waters, thereby producing a localized "hot spot" (U.S. Army Corps of Engineers 1983: Appendix L, p. 5-6). Whether or not cooling water from other facilities besides desalination would do the same is unknown.

Petroleum spills can adversely affect turtles by external fouling, ingestion, and interference with olfactory perception and food supply (Coston-Clements and Hoss 1983). During the field study at Johnston, dried petroleum matter was found adhering to the seawall at the east corner of West Peninsula. It had likely gathered and washed up there from the funneling effect of prevailing winds and currents. The age of the material, and the length of time required for it to accumulate, could not be determined. Turtle foraging habitat around West Peninsula, and along much of the south shore, appears to be vulnerable to petroleum contamination due to its windage and proximity to the ship channel.

Artificial illumination on beaches is known to discourage adult turtles from nesting and disorient hatchlings crawling to the sea (Coston-Clements and Hoss 1983). However, almost no information exists on the effects of coastal lights on turtles foraging or sleeping at night in nearshore habitat. Nocturnal feeding is common behavior for green turtles in Hawaii (Balazs 1980c). However, at Johnston the catch rates from nets, and direct observations made from shore, suggest that foraging is mostly, if not entirely, during the daytime. Between West Peninsula and the island's southwest corner there are nine white lights of medium intensity set on posts 75-100 m inland. In addition, 23 dim yellow lights are located on the chemical storage bunkers facing the shoreline. None of these lights directly illuminate the nearshore waters, although they are clearly visible from offshore. At present, there are no lights on posts anywhere near the shoreline of West Peninsula itself.

Cholinesterase

Very low concentrations of organophosphorus compounds inhibit the activity of cholinesterase, an enzyme responsible for important physiological processes in the nervous system. Cholinesterase also occurs in serum and red blood cells. The inhibitory effect of organophosphorus compounds is the basis for their use as insecticides and certain chemical weapons. Cholinesterase inhibition can also be used to biochemically detect organophosphorus compounds in the environment or in an organism (Namba 1971; Lundin 1975).

At Johnston Island, red blood cell cholinesterase is measured in humans by the 17-Minute Manual Method. According to information supplied by Lucille Bodnar, who routinely performs this analysis at Johnston, the method is based on the principle that cholinesterase hydrolyzes acetylcholine bromide with the production of acetic acid. The change in pH is measured in a barbital-phosphate buffer when red blood cells are mixed with a known excess of acetylcholine bromide and allowed to hemolyze. The results are expressed in terms of the decrease in pH units during the 17-minute reaction period. The normal range for humans is 0.63-0.89 pH/h.

Cholinesterase values, using a 0.2 ml aliquot of red blood cells, were determined by this method for six adult and three immature turtles (Table 13). The validity of these results is unknown, since the analysis is designed for human blood. The method may be unsuitable for turtle blood due to the capacity of the buffer, size of aliquot used, or other factors. Verification is needed. In addition, the normal range of decrease in pH units for the green turtle is currently unknown. Given these analytical uncertainties and the small numbers sampled, Table 13 shows that cholinesterase for the nine turtles ranged from 0.13 to 0.34 pH/h. It is worth noting that the mean value for the three adult males (0.27 pH/h) was almost double the mean of the three adult females (0.14 pH/h). Also, the two immature females measured had levels similar to the adult males. Two of the nine turtles sampled were caught at net location 7, downwind of the sewer outfall. There is no indication from these few data that differences exist between sampling locations.

RECOMMENDATIONS

Management Measures

The information contained in this paper provides a basis for offering recommendations of management measures to help ensure the conservation of turtles at Johnston Atoll. These actions are:

1. A specific management zone for marine turtles should be established. 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 soundly manage the area 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.

2. 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 indicates that normal foraging behavior is easily disrupted. This may be the result of previous human harassment, including fishing efforts to hook them and regular encounters with small boats.

3. 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.

4. 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.

5. 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.

6. 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 turtles is, to a large extent, dependent upon a certain amount of future research being accomplished. Research on turtles at Johnston has long been neglected. 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 of 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 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 paper to indicate specific agency responsibility or priorities for support of this work.

1. 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.

2. Diving surveys with scuba should be made between West Peninsula and the southwest corner of Johnston Island to search for turtle sleeping areas. 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 before the large increase in personnel scheduled for the JACADS project.

3. 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 1 above. The normal range for green turtles should be determined from blood sampling currently underway in Hawaii.

4. 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.

5. 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 before large scale inhabitation by man.

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LITERATURE CITED

Amerson, A. B., Jr. 1971. The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Res. Bull. 150:1-383.

Amerson, A. B., Jr., and P. C. Shelton. 1976. The natural history of Johnston Atoll, central Pacific Ocean. Atoll Res. Bull. 192:1-479.

Anonymous. 1962a. Warhead detonation is averted. The Honolulu Advertiser, July 27, 1962.

1962b. Site repairs may take up to eight weeks. Honolulu Star-Bulletin, July 31, 1962, p. 1.

Anonymous. 1962c. Destroys Johnston N-shot. The Honolulu Advertiser, Oct. 16, 1962, p. 1-2.

Applied Eco-Tech Services, Inc. 1983. Johnston Atoll water quality and current study - a final report. Report submitted to U.S. Army Engineer District, Honolulu, 24 Aug. 1983, 100 p.

Balazs, G. H. 1975. Marine turtles in the Phoenix Islands. Atoll Res. Bull. 184:1-7.

1976. Green turtle migrations in the Hawaiian Archipelago. Biol. Conserv. 9:125-140.

1978. Terrestrial critical habitat for sea turtles under United States jurisdiction in the Pacific region. 'Elepaio 39(4):37-41.

1980a. Field methods for sampling the dietary components of green turtles, Chelonia mydas. Herpetol. Rev. 11(1):5-6.

1980b. A review of basic biological data on the green turtle in the Northwestern Hawaiian Islands. In R. W. Grigg and R. T. Pfund (editors), Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii, p. 42-54. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-4.

1980c. Synopsis of biological data on the green turtle in the Hawaiian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-7, 141 p.

1982a. Factors affecting the retention of metal tags on sea turtles. Mar. Turtle Newsl. 20:11-14.

1982b. Growth rates of immature green turtles in the Hawaiian Archipelago. In K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 117-125. Smithson. Inst. Press, Wash., D.C.

1982c. Sea turtles: A shared resource of the Pacific islands. South Pac. Comm. Fish. Newsl. 23:22-24.

1982d. Status of sea turtles in the central Pacific Ocean. In K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 243-252. Smithson. Inst. Press, Wash., D.C.

1983. Recovery records of adult green turtles observed or originally tagged at French Frigate Shoals, Northwestern Hawaiian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-36, 42 p.

Balubar, C. 1982. Biggest fish story--mail buoy. Hawaii Fish. News 7(10):8.

Benson, B. 1953. Johnston Island--it's not exactly paradise. Honolulu Star-Bulletin, Nov. 8, 1953, magazine section, p. 15.

1976. Air Force flies deadly dioxin canisters to Johnston Atoll. The Honolulu Advertiser, Dec. 9, 1976, A:14.

Bentley, T. B., and A. Dunbar-Cooper. 1980. A blood sampling technique for sea turtles. Final report for contract No. NA-80-GE-A-00082, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 14 p.

Borg, J. 1982. Nerve gas leaks seen under control. The Honolulu Advertiser, Nov. 4, 1982, A:5.

Brock, R. E. 1972. A contribution to the biology of *Gymnothorax javanicus* (Bleeker). M.S. Thesis, Univ. Hawaii, 121 p.

Brock, V. E., R. S. Jones, and P. Helfrich. 1965. An ecological reconnaissance of Johnston Island and the effects of dredging. Univ. Hawaii, Hawaii Mar. Lab., Tech. Rep. 5, 90 p.

Brock, V. E., W. Van Henkelem, and P. Helfrich. 1966. An ecological reconnaissance of Johnston Island and the effects of dredging. Second Annual Report. Univ. Hawaii, Hawaii Mar. Lab., Tech. Rep. 11, 56 p.

Brooke, J. M. MS. Journal of the *Fenimore Cooper* for 1859. [Unpublished manuscr.] G. M. Brooke, Jr., Lexington, Va.

Buggeln, R. G., and R. T. Tsuda. 1966. A preliminary marine algal flora from selected habitats on Johnston Atoll. Univ. Hawaii, Hawaii Inst. Mar. Biol., Tech. Rep. 9, 29 p.

1969. A record of benthic marine algae from Johnston Atoll. Atoll Res. Bull. 120:1-20.

Carr, A. 1972. Great reptiles, great enigmas. Audubon 74(2):24-35.

Chesher, R. H. 1975. Biological impact of a large-scale desalination plant at Key West, Florida. *In* E. J. Ferguson Wood and R. E. Johannes (editors), Tropical marine pollution, p. 99-153. Elsevier Oceanogr. Ser. 12.

Coston-Clements, L., and D. E. Hoss. 1983. Synopsis of data on the impact of habitat alteration on sea turtles around the southeastern United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-SEFC-117, 57 p.

Dawes, C. J., and R. H. Goddard. 1978. Chemical composition of the wound plug and entire plants for species of the coenocytic green alga, *Caulerpa*. J. Exp. Mar. Biol. Ecol. 35:259-263.

Ely, C. A., and R. B. Clapp. 1973. The natural history of Laysan Island, Northwestern Hawaiian Islands. Atoll Res. Bull. 171:1-361.

Farrell, A. (transcriber). 1928. John Cameron's odyssey. The MacMillan Co., 461 p.

Glazebrook, J. S., R. S. F. Campbell, and D. Blair. 1981. Pathological changes associated with cardiovascular trematodes (Digenea: Spirorchidae) in a green sea turtle _Chelonia mydas_ (L). J. Comp. Pathol. 91:361-368.

Harshbarger, J. C. 1977. Role of the registry of tumors in lower animals in the study of environmental carcinogenesis in aquatic animals. _In_ H. F. Kraybill, C. J. Dawe, J. C. Harshbarger, and R. J. Tardiff (editors), Aquatic pollutants and biologic effects with emphasis on neoplasia, p. 280-289. New York Acad. Sci., N.Y.

Hillestad, H. O., R. J. Reimold, R. R. Stickney, H. L. Windom, and J. H. Jenkins. 1974. Pesticides, heavy metals and radionuclide uptake in loggerhead sea turtles from South Carolina and Georgia. Herpetol. Rev. 5(3):75.

Hines, N. O. 1962. Proving ground. Univ. Washington Press, Seattle, 366 p.

Hirth, H. F. 1971. Synopsis of biological data on the green turtle _Chelonia mydas_ (Linnaeus) 1758). FAO Fish. Synop. 85, 1:1-8:19.

Ireland, L. C. 1979a. Homing behavior of immature green turtles (_Chelonia mydas_). Am. Zool. 19:952.

1979b. Homing behavior of juvenile green turtles, _Chelonia mydas_. _In_ C. J. Amlaner, Jr., and D. W. MacDonald (editors), A handbook of biotelemetry and radio tracking, p. 761-764. Pergamon Press, Oxford.

Jacobson, E. R. 1981. Virus associated neoplasms of reptiles. _In_ C. J. Dawe, J. C. Harshbarger, S. Kondo, T. Sugimura, and S. Takayama (editors), Phyletic approaches to cancer, p. 53-58. Jpn. Sci. Soc. Press, Tokyo.

Johnson, A. M., and E. Kridler. 1983. Interisland movement of Hawaiian monk seals. 'Elepaio 44(5):43-46.

Ludwig, G. M. 1982. Trip report: Johnston Atoll, September 12-17, 1981. U.S. Fish and Wildlife Service, Honolulu, 20 p.

Ludwig, G. M., S. Fefer, J. Maragos, and E. Nitta. 1982. JACADS project environmental survey at Johnston Atoll NWR July 8-11, 1982. Trip report. U.S. Fish Wildl. Serv., Honolulu, 21 p.

Lundin, S. J. 1975. The inhibition of cholinesterase activity by organophosphorus compounds as a means of an inspection procedure. _In_ The problem of chemical and biological warfare. Vol. VI. Technical aspects of early warning and verification, p. 177-183. Humanities Press, N.Y.

Meinesz, A. J. Jaubert, and M. Denizot. 1981. Distribution of the algae belonging to the genus Caulerpa in French Polynesia (atoll of Takapoto and island of Moorea). Proceedings of the Fourth International Coral Reef Symposium, Manila 2:431-437.

Mellen, I. M. 1925. Marine turtles sleep on Hawaiian sands. N.Y. Zool. Soc., Bull. 28:160-161.

Menzies, R. A., L. Kochinsky, J. M. Kerrigan. 1983. Techniques for muscle biopsy and blood sampling from sea turtles. Poster session presented at the Western Atlantic Turtle Symposium, July 17-22, 1983, San Jose, Costa Rica, 2 p.

Namba, T. 1971. Cholinesterase inhibition by organophosphorus compounds and its clinical effects. Bull. WHO 44:289-307.

Nelson, L. 1977. Herbicide burning to end this week. Honolulu Star-Bulletin, July 27, 1977, C:4.

Nitta, E. T. 1982. Johnston Atoll field trip report, July 1982. Southwest Region, Western Pacific Program Office, Natl. Mar. Fish. Serv., NOAA, Honolulu, 6 p.

Owens, D. W., and G. J. Ruiz. 1980. New methods of obtaining blood and cerebrospiral fluid (from marine turtles. Herpetologica 36:17-20.

Paul, V. J. 1983. Strategies of chemical defense in tropical marine algae of the order Caulerpales (Chlorophyta). (Abstract.) 64th Annual Meeting of the Western Society of Naturalists, Burnaby, British Columbia.

Paul, V. J., and W. Fenical. 1982. Toxic feeding deterrents from the tropical marine alga Caulerpa bikinensis (Chlorophyta). Tetrahedron Lett. 23, 48:5017-5020.

Pritchard, P. C. H. 1982. Marine turtles of the South Pacific. In K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 253-262. Smithson. Inst. Press, Wash., D.C.

Rainey, W. E. 1981. Guide to sea turtle visceral anatomy. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SEFC-82, 82 p.

Randall, J. E. 1980. A survey of ciguatera at Enewetak and Bikini, Marshall Islands, with notes on the systematics and food habits of ciguatoxic fishes. Fish. Bull., U.S. 78:201-249.

Russell, D. J., and B. A. Carlson. 1978. Edible-oil pollution on Fanning Island. Pac. Sci. 32:1-15.

Schreiber, R. W., and E. Kridler. 1969. Occurrence of an Hawaiian monk seal (Monachus schauinslandi) on Johnston Atoll, Pacific Ocean. J. Mammal. 50:841-842.

Stoneburner, D. L., M. N. Nicora, and E. R. Blood. 1980. Heavy metals in loggerhead sea turtle eggs (Caretta caretta). Evidence to support the hypothesis that demes exist in the western Atlantic population. J. Herpetol. 14:171-175.

Thurston, L. A. 1928. Features of Johnston Island. The Honolulu Advertiser, Aug. 5, 1928, p. 4, 11.

Tobin, J. E. 1952. Land tenure in the Marshall Islands. Atoll Res. Bull. 11:1-36.

U.S. Army Corps of Engineers. 1983. Johnston Atoll chemical agent disposal system (JACADS) - Final Environmental Impact Statement, 1 Nov. 1983. Pacific Ocean Division, Corps of Engineers, Ft. Shafter, Hawaii, 75 p. + Appendices A-M.

U.S. Fish and Wildlife Service. MS. Pacific Islands National Wildlife Refuges: Johnston Atoll NWR, Baker Island NWR, Howland Island NWR, Jarvis Island NWR. U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Votaw, H. C. 1943. Johnston Island. U.S. Naval Institute Proceedings, 69, 487:1176-1180.

Wetmore, A. 1925. Bird life among lava rock and coral sand. Natl. Geogr. Mag. 59:76-108.

MS. a. Field notes, 1923. [Unpublished manuscr.] Smithson. Inst., Wash. D.C.

MS. b. A scientific survey of Johnston Island, 1923, 25 p. [Unpublished manuscr. prepared in 1963.] [Page 5 missing from copy seen on file at the U.S. Fish and Wildlife Service, Honolulu.]

Whittle, K. J., R. Hardy, A. V. Holden, R. Johnson, and R. J. Pentreath. 1977. Occurrence and fate of organic and inorganic contaminants in marine animals. In H. F. Kraybill, C. J. Dawe, J. C. Harshbarger, and R. J. Tardiff (editors), Aquatic pollutants and biologic effects with emphasis on neoplasia, p. 47-79. New York Acad. Sci., N.Y.

Whittow, G. C., and G. H. Balazs. 1982. Basking behavior of the Hawaiian green turtle (Chelonia mydas). Pac. Sci. 36:129-139.

Witkowski, S. A., and J. G. Frazier. 1982. Heavy metals in sea turtles. Mar. Pollut. Bull. 13:254-255.

Woodbury, D. O. 1946. Builders for battle. E. P. Dutton and Co., N.Y., 415 p.

Table 1.--Results of turtle netting effort in meter-hours (MH).

Net location	Phase 1			Phase 2			Total		
	MH	MH per turtle	Number captured	MH	MH per turtle	Number captured	MH	MH per turtle	Number captured
1	4,460	1,115	4	1,975	1,975	1	6,435	1,287	5
2	509		0	4,206	526	8	4,715	589	8
3	1,085	362	3	3,513		0	4,598	1,533	3
4	567		0	--		--	567		0
5	1,026		0	--		--	1,026		0
6	216		0	--		--	216		0
7	--		--	2,748	550	5	2,748	550	5
8	--		--	280		0	280		0
9	--		--	400		0	400		0
10	--		--	340		0	340		0
11	--		--	949		0	949		0
12	--		--	820		0	820		0
13	--		--	153		0	153		0
14	--		--	340		0	340		0
15	--		--	420		0	420		0
16	--		--	420		0	420		0
17	--		--	189		0	189		0
Total	7,863	1,123	7	16,753	1,197	14	24,616	1,172	21

Table 2.--Daily turtle netting effort.

Date 1983	Net location	Number captured	Duration in hours	Length of net (m)	Netting effort (meter-hours)
<u>Phase 1</u>					
10/3-10/7	1	4	94.5	40	3,780
10/4-10/5	2		20	9	180
10/5-10/7	3	2	47	9	423
10/5-10/6	4		21	27	567
10/6-10/7	5		21	27	567
10/7-10/8	1		17	40	680
10/7-10/8	5		17	27	459
10/8-10/11	3	1	73.5	9	662
10/9-10/10	2		23.5	14	329
10/11	6		8	27	216
Subtotal		7			7,863
<u>Phase 2</u>					
11/4	3		10.5	40	420
11/4	2		10	27	270
11/5	2		10.5	40	420
11/5	1		8.5	40	340
11/5	3		6	27	162
11/6	2	2	9.5	27	257
11/6	3		9.5	40	380
11/6	7		7	40	280
11/6	8		7	40	280
11/7	7	1	10	40	400
11/7	9		10	40	400
11/7	2	1	8.5	27	230
11/7	3		8.5	40	340
11/8	2	1	9.5	27	257
11/8	3		9.5	40	380
11/8	7	2	8.5	40	340
11/8	10		8.5	40	340
11/9	3		10.5	40	420
11/9	11		10.5	40	420

Table 2.--Continued.

Date 1983	Net location	Number captured	Duration in hours	Length of net (m)	Netting effort (meter-hours)
11/9	2		9	27	243
11/9	1		9	40	360
11/10	1		9.5	40	380
11/10	2	2	9.5	40	380
11/10	3		8.5	46	391
11/10	11		8.5	40	340
11/11	2		10	40	400
11/11	7	2	10	40	400
11/11	12		10	40	400
11/11	3		10	18	180
11/11	1	1	5	27	135
11/12	2	1	10.5	18	189
11/12	3		10.5	40	420
11/12	7		10.5	40	420
11/12	12		10.5	40	420
11/12	2		8.5	77	230
11/13	1		8.5	40	340
11/13	2	1	8.5	27	230
11/13	7		8.5	40	340
11/13	13		8.5	18	153
11/13	14		8.5	40	340
11/14	1		10.5	40	420
11/14	2		10.5	40	420
11/14	11		10.5	18	189
11/14	7		10.5	27	284
11/14	15		10.5	40	420
11/15	2		10.5	40	420
11/15	3		10.5	40	420
11/15	7		10.5	27	284
11/15	16		10.5	40	420
11/15	17		10.5	18	189
11/16	2		6.5	40	260
Subtotal		14			16,753
Total		21			24,616

Table 3.--Tag numbers, capture sites, and straight carapace lengths of green turtles.

				Straight carapace length (cm)	
Tag No.[1]	Date 1983	Time of capture	Net location	Midline to posterior of postcentral	Midline to of notch
7451-55	10/4	0700	1	100.1	99.8
7485-89	11/6	1500	2	95.9	94.9
7565-69	11/13	1730	2	92.5	92.9
7461-65	10/5	1330	1	90.9	89.6
7490-94	11/7	1600	7	89.7	89.5
7500-04	11/8	1600	2	89.5	88.7
7512-16	11/10	0930	2	89.0	88.8
7468-72	10/6	1730	1	88.2	--
7456-60	10/4	1300	1	87.4	86.9
7560-64	11/12	1600	2	87.0	--
7473-75	10/7	1230	3	84.0	83.6
7521-25	11/11	1500	7	83.7	83.6
7517-20	11/10	1600	2	83.3	83.3
7495-99	11/7	1230	2	82.9	82.1
7555-59	11/11	1700	1	79.1	78.3
7476-80	10/11	1500	3	77.2	76.5
7509-11	11/8	1700	7	75.6	75.2
7505-08	11/8	1700	7	75.2	74.5
7551-54	11/11	1500	7	75.2	74.8
7481-84	11/6	1130	2	72.8	72.1
7466-67	10/5	1830	3	57.4	--

[1]Tag series used at Johnston Atoll--7451-7525 and 7551-7569.

Tag inscription reads: WRITE HIMB
UNIVERSITY
HAWAII, 96744

Table 4.--Body measurements and weights of green turtles.

Tag No.	Carapace length: Straight (cm)	Carapace length: Curved (cm)	Carapace width: Straight (cm)	Carapace width: Curved (cm)	Plastron length (cm)	Tail length (cm)	Head width (cm)	Weight (kg)
7451	100.1	107.8	83.2	105.5	81.1	25.6	13.5	--
7485	95.9	103.7	72.5	94.8	80.2	26.5	12.8	151.4
7565	92.5	96.7	72.1	96.0	79.3	26.4	12.6	141.8
7461	90.9	97.5	69.8	90.6	73.1	20.2	12.1	--
7590	89.7	94.5	71.6	88.5	67.5	[1]41.7	11.6	115.9
7500	89.5	96.0	68.8	85.5	72.4	25.2	11.9	--
7512	89.0	95.0	67.3	86.5	70.8	[1]54.6	12.3	114.1
7468	88.2	92.6	71.6	86.0	70.9	[1]44.0	12.1	--
7456	87.4	95.4	70.4	94.6	72.8	21.0	11.2	--
7560	87.0	92.6	67.4	85.3	70.6	21.2	12.0	108.6
7473	84.0	90.5	65.4	94.5	70.0	21.0	12.0	96.4
7521	83.7	92.2	62.2	80.0	67.2	[2] --	11.4	85.9
7517	83.3	87.2	64.6	82.0	68.2	[3] --	--	84.5
7495	82.9	89.2	65.4	80.6	68.3	18.2	11.3	87.7
7555	79.1	84.5	61.6	79.0	64.0	18.2	10.7	74.1
7476	77.2	84.5	59.6	82.0	61.2	14.5	10.2	67.7
7509	75.6	82.0	57.0	77.8	--	--	10.3	68.2
7505	75.2	81.5	57.8	75.5	60.4	17.0	9.9	65.0
7551	75.2	80.0	61.2	77.6	59.8	14.5	10.9	62.3
7481	72.8	79.1	58.1	76.2	59.3	12.5	9.7	63.6
7466	57.4	63.0	46.3	58.0	44.0	9.5	7.1	--

[1]Adult male.
[2]Short deformed tail--no indication of being a male.
[3]Adult male--tail partly amputated.

Table 5.--Front flipper measurements and scale counts of green turtles.

Tag No.	Straight carapace length (cm)	Flipper width[1]: Left	Flipper width[1]: Right	Flipper scales: Left	Flipper scales: Right	Postocular scales: Left	Postocular scales: Right
7451	100.1	14.1	14.4	7	6	3	4
7485	95.9	14.9	15.3	6	6	4	4
7565	92.5	14.0	14.3	6	6	4	4
7461	90.9	13.2	13.4	6	6	4	4
7490	89.7	13.6	13.5	6	6	4	4
7500	89.5	14.7	14.6	6	6	4	4
7512	89.0	15.4	15.0	6	6	4	4
7468	88.2	14.2	14.5	6	6	5	4
7456	87.4	12.4	12.6	5	5	4	4
7560	87.0	13.2	13.2	6	6	4	4
7473	84.0	13.4	13.2	6	6	4	4
7521	83.7	12.6	12.8	6	6	4	4
7517	83.3	14.7	14.6	6	6	4	4
7495	82.9	12.0	12.0	6	6	4	4
7555	79.1	13.1	13.1	6	6	5	4
7476	77.2	11.9	11.0	6	6	4	4
7509	75.6	12.4	12.0	6	6	4	5
7505	75.2	11.0	11.2	6	6	4	4
7551	75.2	12.0	11.2	6	6	4	4
7481	72.8	11.2	10.3	6	6	4	4
7466	57.4	--	--	6	6	4	4

[1]Straight line measurement taken from the anterior distal edge of the claw scale to the scale located directly across on the flipper's trailing edge (usually scale No. 6 counting proximal to distal along the trailing edge).

Table 6.--Sex determination of green turtles.

Tag No.	Straight carapace length (cm)	Tail length[1] (cm)	Testosterone level[2]	Sex
7451	100.1	25.6	--	Female
7485	95.9	26.5	≤11.1	Female
7565	92.5	26.4	--	Female
7461	90.9	20.2	--	Female
7490	89.7	41.7	11,248.6	Male
7500	89.5	25.2	≤11.1	Female
7512	89.0	54.6	561.6	Male
7468	88.2	44.0	--	Male
7456	87.4	21.0	--	Female
7560	87.0	21.1	13.3	Female
7473	84.0	21.0	--	Female
7521	83.7	[3] --	13.9	Female
7517	83.3	[4] --	2,324.9	Male
7495	82.9	18.2	13.7	Female
7555	79.1	18.2	418.7	Male
7476	77.2	14.5	--	--
7509	75.6	--	--	--
7505	75.2	17.0	≤11.1	Female
7551	75.2	14.5	--	--
7481	72.8	12.5	26.1	Female
7466	57.4	9.5	≤11.1	Female
Total				13 Females 5 males

[1]Straight line measurement from the posterior midline edge of the plastron to the tip of the extended tail.
[2]Testosterone level in the blood in picograms per milliliter (10^{-12}g/ml).
[3]Short deformed tail--no indication of being a male.
[4]Adult male--tail partly amputated.

Table 7.--Identification of stomach contents sampled from green turtles.

Tag No.	Straight carapace length (cm)	Sex	Capture site (net location)	Contents
7451	100.1	Female	1	*Oscillatoria* sp. (trace filaments)
7565	92.5	Female	2	*Bryopsis pennata* var. *secunda* *Oscillatoria* sp. Unidentified amphipod.[1] *Pyxidula* sp. (diatoms-trace)
7461	90.9	Female	1	*Zonaria* sp. (trace-filament)
7512	89.0	Male	2	*Caulerpa racemosa* var. *uvifera* *Climocosphenia* sp. (diatoms-trace) *Oscillatoria* sp. (trace-filament)
7473	84.0	Female	3	Unidentified fibers-trace
7495	82.9	Female	2	*Climacosphenia* sp. (diatom-trace) Unidentified filamentous bacteria
7476	77.2	--	3	*B. pennata* var. *secunda*
7466	57.4	Female	3	*B. pennata* var. *secunda* *Polysiphonia* sp. (fragment)

[1]Probably originated from the esophagus.

Table 8.--Identification of mouth and fecal contents sampled from green turtles.

Tag No.	Straight carapace length (cm)	Sex	Capture site (net location)	Contents
Mouth contents				
7485	95.9	Female	2	Caulerpa racemosa var. macrophysa Acrochaetium sp. (epiphytic on Caulerpa)
7565	92.5	Female	2	Bryopsis pennata Oscillatoria sp. filaments Pyxidicula sp. (diatoms) Unidentified amphipod
7560	87.0	Female	2	Bryopsis pennata var. secunda Pyxidicula sp. (diatoms)
7555	79.1	Male	1	Caulerpa racemosa var. macrophysa Unidentified filamentous bacteria Unidentified blue-green algae
7481	72.8	Female	2	Bryopsis pennata
Fecal contents				
7509	75.6	--[1]	7	Caulerpa racemosa var. uvifera (75%) Bryopsis pennata (25%)

[1]Not determined.

Table 9.--Algae collected during diving surveys with scuba.

Dive No.	Date 1983	Location	Algae collected
10	10/10	J	Bryopsis pennata var. secunda (Harvey) Collins and Harvey Caulerpa racemosa var. macrophysa (Kutzing) Taylor C. racemosa var. uvifera (Turner) Weber von Bosse C. serrulata (Förskal) J. Ag.
11	10/11	K	C. serrulata f. angusta (Weber von Bosse) Taylor C. serrulata (Förskal) J. Ag. Dictyota friabilis Setchell (epiphytic on Caulerpa)
13	11/4	M	Gelidium pusillum Ceraminium sp. (trace)
14	11/5	N	Caulerpa serrulata Avrainvillea lacerata Hydrocoleum lyngbyaceum Zonaria sp. Polysiphonia sp. (trace)

Table 10.--Percent nutrient composition of principal food sources used by green turtles.[1]

Algae	Dry matter	Crude protein[3]	Ether extract	Ash	Neutral detergent fiber[2]	Acid detergent fiber[2] Permanganic lignin	Acid detergent fiber[2] Cellulose
Bryopsis pennata var. *secunda* (from foraging site)	7.0	23.8	2.0	38.2	25.6	2.7	7.9
B. pennata var. *secunda* (detached)	7.1	25.7	2.6	33.8	27.8	3.3	11.3
Caulerpa racemosa var. *uvifera*	3.9	8.0	0.7	61.4	24.6	6.3	6.3
C. racemosa var. *macrophysa*	3.7	9.1	0.9	63.8	25.5	6.5	7.5

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

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

[3]Nitrogen x 6.25.

Table 11.--Mineral composition of principal food sources used by green turtles.[1]

Algae	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)
Bryopsis pennata var. *secunda* (foraging site)	2.00	0.27	0.94	1.06	11.10	110	8	19	57
B. pennata var. *secunda* (detached)	1.82	0.23	0.93	0.95	10.00	88	10	17	66
Caulerpa racemosa var. *uvifera*	2.45	0.10	1.07	0.41	19.36	90	9	9	76
C. racemosa var. *macrophysa*	0.87	0.10	1.28	0.31	22.00	2,558	11	29	81

[1]Dry matter basis. Ca = Calcium; P = Phosphorus; K = Potassium; Mg = Magnesium; Na = Sodium; Fe = Iron; Cu = Copper; Mn = Manganese; Zn = Zinc.

Table 12.--Identification of epizoites sampled from green turtles.

Tag No.	Sex	Straight carapace length (cm)	Epizoites
7485	Female	95.9	*Acrochaetium* sp. *Polysiphonia tsudana* *Lyngbya semiplena* Unidentified roundworms Unidentified amphipods Unidentified black "mites"
7565	Female	92.5	*Acrochaetium* sp. *Polysiphonia tsudana* *L. semiplena* *Sphacelaria tribuloides* *Urosopora* sp. *Pilinia* sp.[1] Unidentified foraminifera
7512	Male	89.0	*Acrochaetium* sp. *Polysiphonia tsudana* *L. semiplena* *Urospora* sp. *Pilinia* sp.[1] *Chadophora* sp. (trace) *Dermocarpa sphaerica* (epiphitic on *Chadophora* sp.)
7495	Female	82.9	Same as tag No. 7485
7481	Female	72.8	*Polysiphonia tsudana* *L. semiplena* *Urospora* sp. *Pilinia* sp.[1]

[1]Possibly *Pilinia rimosa* Kutzing, which may be a new record for the tropical Pacific.

Table 13.--Red blood cell cholinesterase values for nine green turtles.

Tag No.	Straight carapace length (cm)	Weight (kg)	Net location	Sex[1]	Cholinesterase[2]
7485	95.9	151.4	2	Female	0.15 0.16
7490	89.7	115.9	7	Male	0.27 0.27
7500	89.5	---	2	Female	0.13
7512	89.0	114.1	2	Male	0.23
7517	83.3	84.5	2	Male	0.29 0.30
7495	82.9	87.7	2	Female	0.14 0.13
7555	79.1	74.1	1	Male	0.32 0.34
7505	75.2	65.0	7	Female	0.26
7481	72.8	63.6	2	Female	0.28 0.31

[1]Based on testosterone level.
[2]Decrease in pH units (pH/h) using a 0.2 ml aliquot.

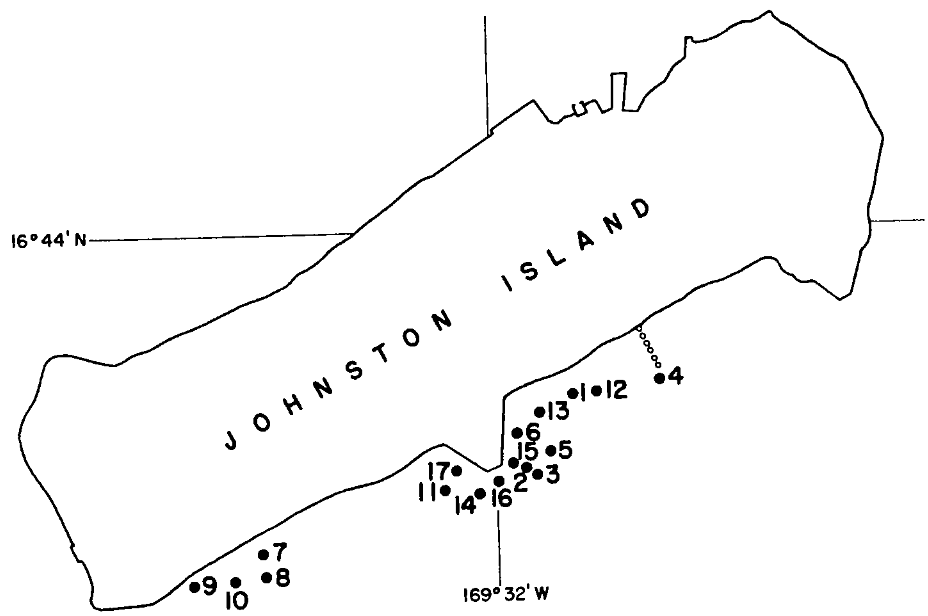

Figure 1.--Location of turtle nets.

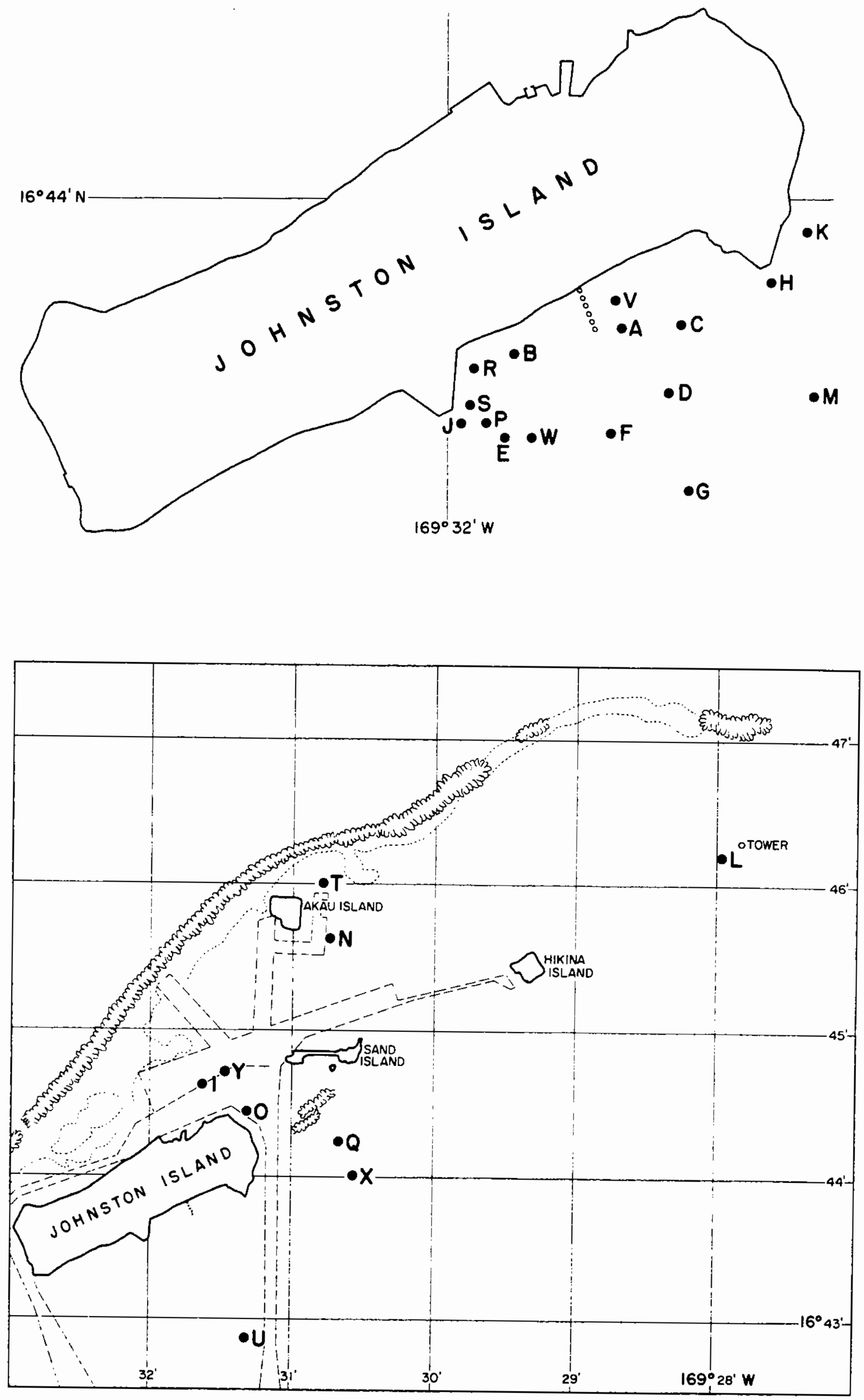

Figure 2.--Central location of 26 diving surveys with scuba. The bottom areas actually covered extend out in concentric circles from each location and overlap considerably for many dives.

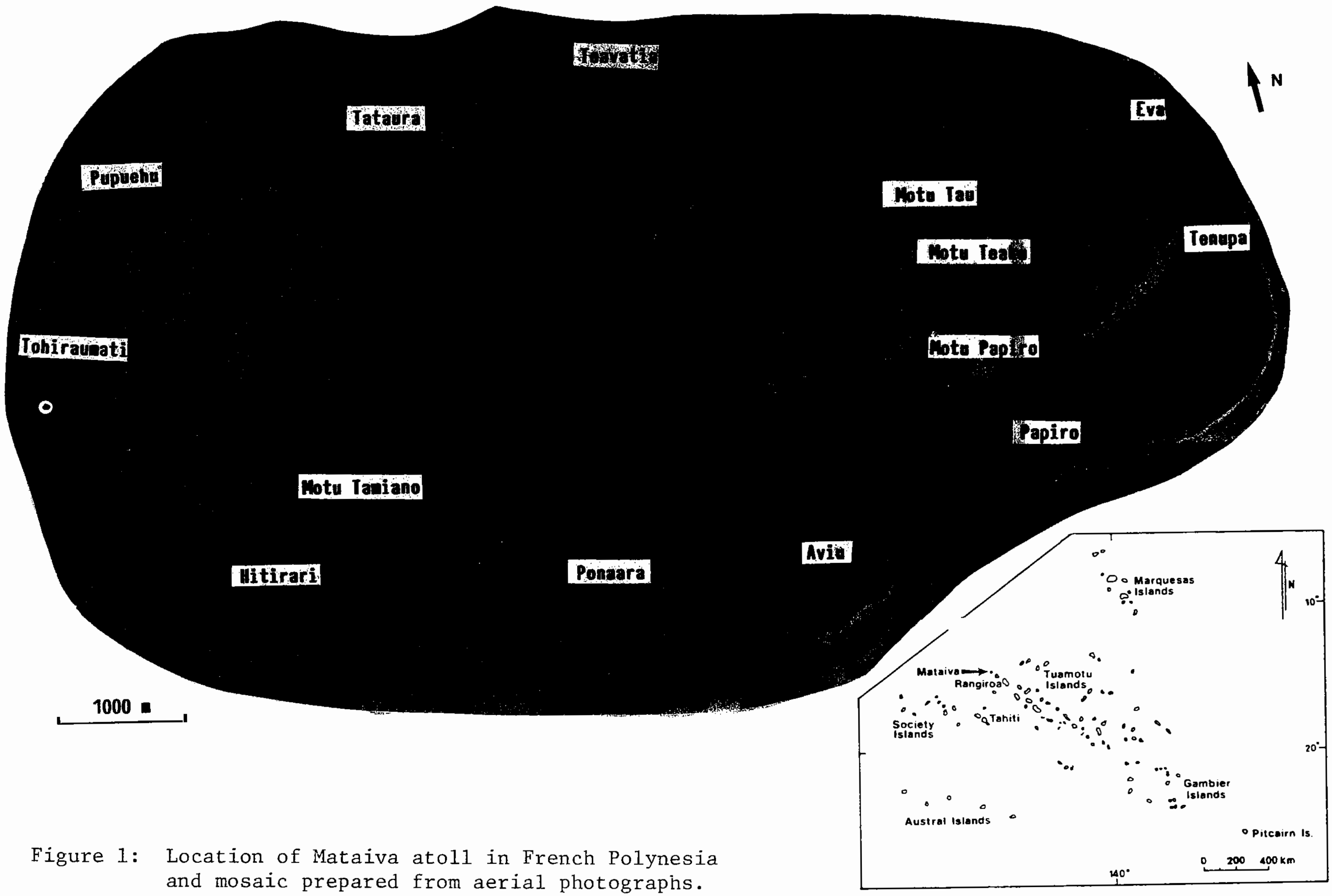

Figure 1: Location of Mataiva atoll in French Polynesia and mosaic prepared from aerial photographs.

In the pass and on the outer reef flats, the ichthyological fauna is much richer and made up of numerous species from the outside but which do not pass into the lagoon, such as triggler fishes (Balistoides undulatus, Pseudobalistes falvomarginatus, jacks (Caranx trifasciatus), emperors (Lethrinus mahsena), goatfishes (Mugil angeli, M. vaigiensis).

On the outer slopes, the fish population is dominated by the Acanthuridae family, mainly Naso and Acanthurus. Pomacentridae, Serranidae, Lutjanidae and Chaetodontidae are equally abundant. The specific richness is at its maximum between 10 and 20 m (70 species), whereas the maximum abundance is found between 3 and 10 m. The effect of the 1983 cyclones on the outer reefs, causing massive coral destruction, has brought about a slight decrease of the herbivorous populations, but, above all, a redistribution of certain species and a much higher density in the upper levels of 3 to 10 m.

CONCLUSIONS

Mataiva atoll has a singular morphology whose major characteristic is the partitioning of the lagoon into numerous pools. This is due to its peculiar geological history, during which several periods of uplift and subsidence occurred. During the periods of emergence, erosion processes resulted in the formation of a karstic relief, in the cavities of which phosphate deposits accumulated.

The present morphology, moulded onto the former one, has, as a consequence, created particular hydrological conditions in the lagoon: very high turbidity, considerable variations in water level, high nutrient concentrations.

The biological communities of the lagoon show the characteristics of a closed environment: few species are present, but some are very abundant. Mataiva stands out among atolls because of its high level of primary production, abundant zooplankton and a fairly poor, but very uneven distributed, benthic macrofauna. This latter, subject to strong variations in hydrological conditions, can suffer enormous mortality levels, affecting especially the corals. However, the evolution observed since 1981 seems to indicate that this is an accidental phenomenon and that the lagoon's biological communities retain the capability to survive and grow under difficult conditions.

Future research on Mataiva atoll must take into account the wide range of variation in the distribution and abundance of its lagoonal populations. This fact seems to be closely related to the hydrological environment and its long-term variations. Such research will mainly concern the hydrology, the primary producers and a quantitative evaluation of the benthic and ichthyological fauna.

Although Mataiva seems to be a very special atoll whose characteristics cannot be used as a model for the other Tuamotu atolls, it is a very interesting experimental field for some ecological studies, e.g. the relationship between live coral cover and reef fish populations. A fish survey, similar to those made in 1981 and 1983, is already planned for mid-1985, to follow the changes in the fish communities, as the corals recover from almost complete destruction in 1980.