

**ECOLOGICAL ASPECTS OF GREEN  
TURTLES AT NECKER ISLAND**

**A report based on an expedition to the Hawaiian  
Islands National Wildlife Refuge, Northwestern  
Hawaiian Archipelago**

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**October 1977**

**Unpublished Report**

CONTENTS

	<u>Pages</u>
INTRODUCTION .....	1
RESEARCH METHODS .....	3
FINDINGS	
Basking .....	4
Feeding .....	7
Growth and Migrations .....	10
Predation .....	11
Copulation .....	12
Archaeological Considerations .....	14
Management Considerations .....	16
REFERENCES .....	21
Figure 1. Hawaiian Archipelago .....	23
Figure 2. Necker Island .....	24
Figure 3. Pounds of Turtle Reported Captured in the Northwestern Chain, 1948-1959 .....	25
Table 1. Green Turtle Basking Activity at Necker .....	26
Table 2. Juvenile Green Turtles Captured at Necker .....	27

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## INTRODUCTION

With the exception of French Frigate Shoals, little definitive data presently exist on the ecology of green turtles (*Chelonia*) utilizing the Hawaiian Islands National Wildlife Refuge (Figure 1). Previous observations made principally during short-term visits have been summarized in issues of the *Atoll Research Bulletin* for French Frigate Shoals (Amerson, 1971), Gardner Pinnacles (Clapp, 1972), Laysan (Ely and Clapp, 1973), Pearl and Hermes Reef (Amerson *et al.*, 1974), Lisianski (Clapp and Wirtz, 1975), Nihoa (Clapp *et al.*, 1977) and Necker (Clapp and Kridler, 1977). The information presented by Amerson (1971) for French Frigate Shoals is in part erroneous, and corrections have been made in more recent reports based on my own research at this colonial breeding site (Balazs, 1974, 1976). No published reports have appeared for the refuge unit of Maro Reef, however the presence of turtles at this location has been established through recent sightings (Naftel, Giezentanner and Coleman, personal communications).

In order to gain baseline data on such factors as habitat requirements, growth rates, food sources, predation rates, reproduction, and migrations of turtles present within each refuge unit, a comprehensive research program has been undertaken with financial support from the State of Hawaii, the National Sea Grant Office (NOAA), and the National Geographic Society. Additionally, assistance in this work is being provided periodically by the Fish and Wildlife Service, the National Marine Fisheries Service, the U. S. Coast Guard, and the State Division of Fish and Game. Resulting information will be used to formulate long range management procedures for the total Hawaiian green turtle population.

Transportation is a serious constraint to conducting investigations at the isolated units of the Hawaiian Islands National Wildlife Refuge. Through the courtesy of Mr. Gary Naftel of the Easy Rider Corporation (Honolulu), I was able to obtain transportation to Necker Island on the R/V *Easy Rider* during the course of a 24 day voyage which extended from 15 August through 7 September 1977. This report covers the findings made during the study visit which encompassed seven consecutive days and nights on the island.

## RESEARCH METHODS

Necker (Figure 2) was visited between 0900 of 19 August and 0830 of 26 August. A preliminary one hour visit had been previously made on 22 June 1977, at which time I determined that considerable potential existed for conducting investigations at this location.

The two major research activities carried out were: 1) direct observations of basking, feeding and transiting turtles; and 2) capturing of juvenile turtles for body measurements, tagging and sampling of stomach contents. Observations were focused principally on the rock ledge and adjacent sheltered waters at the west end of Shark Bay. However, considerable time was also spent observing nearshore waters which are readily visible from Annexation, Flagpole, Summit, and Bowl Hills, Siever's Peak, and Northwest Cape. The capturing of juvenile turtles was accomplished with a large scoop net, and stomach contents were obtained with a flexible tube sampler which had been previously developed and tested successfully. Identification tags used were specially manufactured from Inconel 625, a highly corrosion resistant alloy of nickel and cadmium. Tags were affixed at a proximal location on the trailing edge of the turtles' front flippers.

## FINDINGS

Basking

Basking or emergence to land by turtles at Necker takes place exclusively on a rock ledge located at the west end of Shark Bay, immediately to the south of the low gap which separates Northwest Cape from the main part of the island. Most of this ledge is steep and in places completely perpendicular to the water. Only a small segment approximately 10 feet in length has a gradual enough slope to permit utilization by turtles. Formation of this small sloping segment is derived partially from a dike (vertical basalt stratum) that passes completely through the island's west end. If a dike did not intersect this particular ledge, it is unlikely that basking on Necker would occur. Only two other gradually sloping areas exist along the island's shoreline. These sites are also within Shark Bay, however both are more directly exposed to wave action and are littered with large water-worn rocks. In comparison, the site used for basking is sheltered considerably from the predominant Northeast waves by the presence of reef formations. The site is also composed of relatively smooth lava rock so that damage to the flexible plastron of a turtle would not result from repeated emergence. Habitat conditions of this small ledge segment are therefore unique, making basking possible in an otherwise unsuitable environment. Although basking occurs on a number of undisturbed coral sand beaches of the low islands in the Northwestern Hawaiian chain, it has not been observed and is probably not possible on any of the other volcanic rock islands (Nihoa, La Perouse Pinnacle at French Frigate Shoals, and Gardner Pinnacles).

Basking by marine turtles is presently an exceedingly rare form of behavior (Balazs, 1974) and Necker is very likely the only place in the world where it occurs on a rock ledge.

Most basking at Necker was found to take place between 2100 and 0800 (Table 1). This differs considerably from what I have recorded at French Frigate Shoals where the preferred basking time is 1100 to 1900 and emergence at night for purposes other than nesting has been observed but is uncommon. Although basking in freshwater turtles is not fully understood, the principal motivating factor is thought to be thermal control or heat gain (Boyer, 1965). The physiological ecology of basking in marine turtles has not been previously examined and this is presently the subject of a detailed two year investigation at French Frigate Shoals (Whittow and Balazs, 1977). The strategy of our research is to determine with sophisticated instrumentation what happens thermally to green turtles when they bask, thereby establishing a basis for accurately explaining why they bask. The finding at Necker of turtles emerging predominantly at night, in the absence of radiant heat, interjects a new and interesting aspect to this work. Numerous observations of basking turtles at French Frigate Shoals since 1973 have resulted in my tentative conclusion that several different reasons may exist for basking. This includes: 1) intentional heat gain; 2) escape by females from sexually aggressive males; 3) reduction of exposure to shark attack; and 4) a predilection to use an alternate resting site to the cave or other underwater habitat where turtles normally retreat for periods of quiescence. This latter reason may be applicable to the behavior exhibited at Necker in view of the fact that during the early morning hours of 25 and 26 August emergence appeared to be related to the setting of a nearly full moon. Green turtles are able to feed under low light conditions, therefore such

emergence may have represented the transition from active feeding to quiescence. Regardless of the principal motivating factor, thermal considerations would still come into play even with turtles emerged during darkness. The deep body temperature of adult marine turtles is known to be slightly above ambient seawater temperature due to a combination of metabolic heat and large body size (Hirth, 1962). Additional heat gain would probably occur in turtles that had been vigorously feeding for several hours. This heat should be retained for a longer period of time by a turtle in air than a turtle in water due to the far greater conductivity of the liquid medium. However, the effects of heat transfer brought about by convection from wind, by conduction from contact with rock, and by evaporation from seawater spray and rain would have to be taken into account before an accurate picture can be obtained.

All turtles basking at Necker were adults estimated to be 31 inches or more in straight carapace length. Both males and females were noted, but differentiation was not always feasible due to the possibilities of causing disturbance. A maximum of five turtles was present on the ledge at any one time. Like basking at other sites in the chain, individuals never emerged more than approximately four feet past the water's edge. Space limitations would therefore restrict the number of turtles that can be accommodated. Clapp and Kridler (1977) also list five basking turtles as the maximum number seen at one time at this location. Although I was unable to determine in each case if the same or different individuals were basking daily, two turtles with identifying marks seen on 19 August were not subsequently recorded. Observations of the number of adults feeding around the island suggest that considerable rotation would be possible.



Hawaiian monk seals, *Monachus schauinslandi*, are able to easily haul out at a number of locations at Necker and they regularly use the entire ledge (measuring approximately 100' by 50') associated with the turtle basking site. Turtles are therefore frequently in the immediate vicinity of seals in a manner similar to that which occurs at French Frigate Shoals. There is normally little interaction between the species other than an occasional seal lying in contact or partially on top of a turtle.

The intertidal crab, *Grapsus grapsus*, is also present on the ledge. On several occasions these crustaceans were observed directly on the backs of basking turtles and seals. It is probable that feeding was taking place on algae and associated organisms which grow on both species.

No tags were observed on the basking turtles, but close inspection was usually not carried out. Between 1966 and 1969 a total of nine basking turtles was tagged at Necker by personnel of the Fish and Wildlife Service. A turtle tagged in March 1967 was subsequently recovered in September 1967 at this same location (Clapp and Kridler, 1977). Tags in use at that time were made of Monel 400, an alloy of nickel and copper. During the course of my work at French Frigate Shoals, such tags were often found to have undergone severe corrosion in as short a time as two years. It is therefore likely that most, if not all, of the tags previously affixed to turtles at Necker have now been lost. Shortly before my departure on 26 August, tags were placed on three basking turtles (one male and two females). This was accomplished without the use of physical restraint and with a minimum of disturbance.

#### Feeding

The nearshore area of Shark Bay adjacent to the basking ledge is an important feeding site for both juvenile and adult turtles at Necker. Dense growths of

five principal kinds of benthic algae occur at this location, including *Caulerpa*, *Sargassum*, *Laurencia*, *Turbinaria* and *Asparagopsis*. Dissolved nutrients derived from the fecal matter of transiting seals, turtles and numerous seabirds undoubtedly help to stimulate this growth. Feeding activity in these waters occurred principally at sunrise and sunset for periods ranging from one to two hours. Such a schedule was believed to have been due to the lower tides which prevailed at sunrise and sunset during the greater portion of my visit. During periods of high tides and northeast winds, greater wave action and surge existed at this site due to the reduced protection afforded by the reef. Excessively turbulent water conditions therefore seemed to have been responsible for the absence of feeding. In support of this interpretation is the fact that at other less confined nearshore areas feeding was observed to take place at all times of the day. Additionally, during the almost complete calm which existed on 19 and 20 August, feeding activity near the basking ledge took place at all times of the day.

A maximum of five turtles (one adult, four juveniles) was seen feeding at one time near the basking ledge. Actual grazing on algal material took place well beneath the surface, either on the bottom or on the sides of rocks. During the calm weather of 20 August, timings were made of the respiration rates of an actively feeding juvenile estimated to be 21 inches in straight carapace length. Continuous observations made from 1029 to 1158 resulted in consecutive breath holds of 11, 14, 15, 14, 11 and 14 minutes. The average surface interval lasted 90 seconds, during which time from five to eight breaths were taken. This hyperventilation behavior was not exhibited by turtles feeding in rougher water. Instead, usually only one rapid breath was taken with a surface interval lasting three seconds or less.

The herbivorous reef fish, *Acanthurus sandvicensis* (manini) was regularly seen grazing on the carapace and flippers of turtles engaged in active feeding. A similar symbiotic relationship has also been recorded at French Frigate Shoals where a specific coral head near Whale-Skate Island serves as a "cleaning station" for the removal of ectoparasites from turtles.

Four juvenile turtles were captured while feeding (Table 2) and it was possible to obtain samples of stomach contents from three of these individuals (tag nos. 2380, 2384 and 2389). In all cases the sole alga present was *Caulerpa*. *Caulerpa* has also been recovered from a juvenile turtle at Midway, however samplings thus far made at French Frigate Shoals have yielded principally *Codium*, *Turbinaria* and *Lobophora*. During field studies at Kure in January 1977, juvenile turtles were observed ingesting *Codium* as well as the coelenterate *Physalia* (Portuguese man-of-war) which seasonally occurs in large numbers. It is therefore likely that the food sources used by a particular green turtle aggregation, such as at Necker, are dependent on availability as well as selection to meet nutritional requirements.

In addition to the intensively observed site adjacent to the basking ledge, both adults and juveniles were seen feeding at nearly all locations around the island's shoreline. Although a determination of the total number of turtles present is difficult to make, I tentatively estimated that at least 50 individuals (20 adults, 30 juveniles) were using the nearshore waters. This number would have to be increased considerably if significant rotation takes place with turtles that may be using offshore areas. Such rotation is a distinct possibility. Necker is situated on a bank having an area of 650 square miles with depths ranging from 48 to 108 feet. This is within the limits known to be used by green turtles for resident feeding pastures. Six

kinds of benthic algae, including *Codium*, have been collected from this bank during the course of fishing operations from the R/V *Easy Rider*. The area could therefore serve as important habitat to the turtle aggregation.

### Growth and Migrations

Continued periodic tagging of turtles at Necker will provide information on natural growth rates and migrations for this particular aggregation as a component part of the total population. Because work at Necker is presently only in the initial stage, it will be valuable to review my findings at other locations where studies have been in progress for longer periods.

As previously described (Balazs, 1974, 1976), the Hawaiian green turtle population is thought to be derived almost totally from the breeding colony which seasonally assembles at French Frigate Shoals from resident feeding pastures throughout the chain. This assemblage involved approximately 200 adult females each season. Dispersal of hatchlings from French Frigate Shoals results in aggregations of immature turtles at feeding pastures throughout the chain. In some cases, such as has been found at Necker, both adults and immature turtles are able to utilize the same feeding habitat. Although a general understanding has been achieved of the reproductive migrations undertaken by the adults, comparatively little is known about the developmental migrations and growth rates of the immature turtles. At the feeding pastures of French Frigate Shoals, 111 immature turtles have now been captured and tagged. Thirty five recoveries have thus far been made after intervals ranging from six months to two years. Results indicate very slow growth, averaging only  $\frac{3}{8}$  of an inch per year in straight carapace length. Similar growth rates have also been found at Midway, where an ongoing cooperative

research program with the Koral Kings Dive Club has resulted in the tagging of 212 turtles and 19 recoveries. Environmental conditions, particularly seawater temperature, can vary considerably between different locations in the 1,600 mile long Hawaiian chain. However, if the slow growth at French Frigate Shoals and Midway is indeed representative of most aggregations, the implications of age at sexual maturity and longevity in the population are substantial.

All of the recoveries of juvenile turtles tagged at French Frigate Shoals have been made at that same location. However, two long distance recoveries have been made of juveniles tagged at Midway. One of these occurred in Hilo Bay, Island of Hawaii after an interval of seven months, and the other at Wake Island (19°18'N, 166°36'E) after an interval of six months. Although no external injuries were present, this latter individual was reported to be in a weakened condition when tagged and it is likely that passive movement to Wake Island resulted from prevailing winds and currents.

### Predation

Shark research programs conducted around the major Hawaiian Islands and at French Frigate Shoals and Pearl and Hermes Reef have identified the tiger shark, *Galeocerdo cuvieri*, as a major predator of green turtles. Large adults as well as juveniles are susceptible to attack which results in mortality (Balazs, 1977). The only other documented marine predator of post-hatchling size turtles in Hawaii is a large and presumably rare grouper of the genus *Epinephalus* (Mench, 1974).

At Necker no direct evidence was found of mortality or injury to turtles resulting from shark predation. In comparison, it is not unusual to see such evidence at French Frigate Shoals in the form of lacerated or amputated flippers and deep cuts in the carapace. A small percentage of the seals at French Frigate Shoals also show unmistakable signs of attack, but similar wounds and scars were not observed on any of the seals at Necker. Although small schools of gray reef sharks (*Carcharhinus amblyrhynchos*) were seen in Shark Bay, no tiger or other large sharks were observed during the course of my visit. As a further comparison, at French Frigate Shoals it is not unusual to see tiger sharks in shallow water close to the islands. However, this occurrence is more common during June and July when young albatrosses are first learning to fly and expose themselves as easy prey on the water's surface.

The absence of evidence of shark predation during my visit suggests that this factor may not be as important at Necker as it presently appears to be for other Hawaiian turtle aggregations, particularly in the Northwestern chain. However, it would be valuable to sample the shark populations in both nearshore and offshore areas of Necker and analyze stomach contents. In addition to providing an indication of the numbers and kinds of sharks present, such research can yield information on distribution of turtles throughout the bank, predation rates by size categories, food sources utilized (from recovered turtle stomachs) and other important factors relevant to the Necker turtle aggregation. Similar information would be obtained simultaneously for the seals inhabiting the area.

#### Copulation

At 0715 on 24 August a copulating pair was observed at the surface in waters adjacent to the basking ledge. Although the entire area had been under surveillance since 0600, it is possible that these animals were locked together

out of view underwater for an unknown period prior to my initial observation. Copulation terminated after only four minutes, at which time a mutual separation seemed to take place. No rapid escape actions were carried out by the female, as have been seen in unreceptive individuals at French Frigate Shoals. After separation the female placed the ventral surfaces of her hind flippers together for a short period. This position has also been recorded in Australian female green turtles, both immediately after termination of copulation and after returning to the sea from nesting. Booth and Peters (1972) have tentatively interpreted such a behavioral pattern as a means of avoiding copulation. However, I believe that it could also be interpreted as a mechanism to inhibit the loss of sperm (after copulation) and underdeveloped eggs (after nesting).

The occurrence of copulation in waters adjacent to Necker is significant in view of the fact that egg laying is not possible on the island. Copulation has been thought to take place only off the nesting beaches, usually within a half mile off shore. Hirth (1971) has stated, "It is plausible that some mating takes place at the feeding grounds or at other areas away from the nesting beaches, although this has yet to be documented." My observations document such an occurrence, but it is conceivable that this was atypical behavior not resulting in actual insemination. It should be noted that in the spring of 1976, two turtles were seen from a distance locked together in West Cove at Necker Island (Naftel, personal communication). While this appears to be further evidence in support of copulation, it should be pointed out that I have recorded two males locked together in a "mating" position for a brief period during the non-breeding season at French Frigate Shoals.

A certain amount of caution will therefore have to be exercised in analyzing all such observations in order to determine what activity actually represents true copulation.

### Archaeological Considerations

At the time of Captain Cook's arrival in the major Hawaiian Islands in 1778 the native people were unaware of Necker's existence. The only island known to exist northwest of Kauai was Nihoa, and then only through legends. The discovery of Necker during historical times was made in 1786 by La Perouse who gave the island its present name. Evidence of prehistoric visitations or residence by Polynesian people clearly exists for the island. This includes 33 religious stone structures (maraes), 25 terraces, four platforms, 13 carved stone images, and an array of stone artifacts recovered from a single shelter cave. The origin of the Necker people and the circumstances that brought them to this small, isolated island are not positively known. It is thought, however, that the island's material culture may be representative of the culture which existed in the major Hawaiian Islands before 1300 A.D. (Emory, 1928).

The ecological relevance of this information is that no turtle parts, neither bones nor laminae, were discovered during the course of archaeological studies at Necker. However, in addition to turtle parts, items such as seal bones and opihi (limpet) shells which presently grow in abundance on the island were also noticeably absent in the excavations.

There can be little doubt that a marine turtle population of the genus *Chelonia* or its direct ancestors existed throughout the Hawaiian chain from a time long before the first human inhabitants. The volcanoes of the



Archipelago are known to become progressively younger from Northwest to Southeast, with Midway estimated to be 18 million years old and the Island of Hawaii less than 0.7 million years old. Although there is evidence of a minor eruption in recent times (Macdonald and Abbott, 1970), potassium-argon dating has estimated the Necker volcano to be 9.5 million years old (Dalrymple, *et al.*). In comparison, *Chelonia* type turtles existed from the beginning of the late Cretaceous, or about 100 million years ago (see Carr and Coleman, 1974). The absence of any turtle parts at Necker which would be indicative of use by humans for food or implements is therefore somewhat of an enigma. Although by no means abundant, in the major Hawaiian Islands recovered green turtle artifacts have included rib bone scrapers or spoons and ornaments of laminae. It should be noted, however, that the fishhooks and net spacers found in the major islands are fashioned from the thicker laminae (averaging 6 mm) of the hawksbill turtle, *Eretmochelys*. Except for a single and considerably doubtful report by Morrell (1841), there is no evidence that the hawksbill ever occurred in the Northwestern chain. Such fishhooks and spacers would therefore not be expected at Necker, unless they had been imported.

Two plausible explanations could be given for the absence of turtle parts on Necker. First, it is possible that the effects of long-term weathering deteriorated any material to a point of complete decomposition. The rate of such action would have been dependent upon the conditions of exposure, hence to some extent the specific location on the island. Furthermore, it is important to note that the bones of marine turtles are generally less dense than those of land turtles and mammals, and therefore should be more susceptible to deterioration. With respect to the laminae of green turtles

which have an average thickness of only two millimeters, such keratinized structures appear to be very resistant to the digestive processes of tiger sharks (Balazs, 1977). However, I have recovered laminae at French Frigate Shoals that were exposed to the sun for less than 24 years and already showed moderate amounts of flaking and cracking. The second explanation for the absence of turtle parts could be that all inedible bones and laminae were discarded into the sea, and artifacts as lightweight items of special value were removed by the last native inhabitants or visitors.

Emory (1928) has suggested that a stone enclosure associated with one of the Necker maraes may be a sacred refuse pit used for ceremonial feasts. In the Tuamotu Archipelago of Southeast Polynesia, particularly on the Islands of Napuka and Vahitahi, ceremonial feasts of the turtle were regularly carried out at the marae and the bones were deposited into such a pit (Emory, 1947). It would be possible to excavate the central portion of the enclosure at Necker without disturbing the stone walls. Such an undertaking could provide new and important historical information on the Necker turtle aggregation.

#### Management Considerations

The Hawaiian Islands National Wildlife Refuge, originally known as the Hawaiian Islands Reservation, was established in 1909 by an Executive Order of Theodore Roosevelt. As a unit of this sanctuary, Necker is administered by the Fish and Wildlife Service (Department of the Interior) with full legal protection afforded to its faunal, floral and geophysical components. However, the Necker unit encompasses only the emerged lands, with the

boundary being the mean lower-low water mark. Jurisdiction over waters extending from the shoreline out to three miles is held by the State of Hawaii. As in all State waters of the Northwestern chain, green turtles, as well as any hawksbills or leatherbacks (*Dermochelys*) which may occur, receive full legal protection under a Division of Fish and Game regulation (No. 36) adopted in 1974. Those waters between three and twelve miles are Federally controlled and any hawksbills or leatherbacks would also be protected in this area due to their Endangered classification under the Endangered Species Act of 1973. However, the green turtle is not presently designated under the act. This absence of legal protection for *Chelonia* apparently also applies to waters extending from 12 to 200 miles under the Fisheries Conservation and Management Act of 1976.

Based on observations made in 1923 and 1924, Emory (1928) stated that turtles "abound" at Necker. Although subjective, such an estimate of abundance is nevertheless noteworthy in view of the scarcity of early reports for this site. Rough seas and difficult landing conditions have to some extent undoubtedly served as a protective barrier to the exploitation and disturbance of turtles. At more hospitable locations in the Northwestern chain such as Laysan and French Frigate Shoals, large numbers of turtles were frequently taken during the late 1800's and early 1900's. At this latter location, nesting turtles have been removed as recently as 1959 (Strasburg, personal communication). Catch reports submitted to the State Division of Fish and Game for the Northwestern chain indicate that turtles have at times also been taken at Necker (Figure 3). It is unknown if these animals were captured while basking or taken directly from the sea. It should be noted that in some cases more turtles were actually taken than are reported for the areas shown

in Figure 3. For example, no reports appear for the estimated 200 turtles taken from French Frigate Shoals between 1946 and 1948 (personal communication to Amerson, 1971) or the nesting turtles removed in 1959. The actual number or pounds of turtles removed from Necker is therefore unknown.

While transiting Necker during the course of my observations of turtles, two intact bombs, numerous bomb craters (as evidenced by shrapnel) and the copper jacketed lead portions of bullets were found at several locations. In addition, during the short visit to Necker on 22 June, one intact and one partially exploded bomb were found underwater while diving in West Cove. The deposition of this ordnance by U. S. military aircraft is believed to have taken place principally during 1944 (Emory, personal communication). It is unknown what initial or long-term effects such activities may have imposed on the turtles or other wildlife. From the standpoint of altering unique habitat, it is fortunate that detonations did not occur on or near the turtle basking ledge. The bombing of Necker has not been previously recorded in the published literature or in available written reports. However, the adverse impact on archaeological structures was communicated to the Bernice P. Bishop Museum (Honolulu) in 1968 (Dalrymple, personal correspondence to E. H. Bryan, Jr.).

This historical information relating to the management and conservation of the Necker turtle aggregation has been presented in order to point out some of the past difficulties encountered. There are, however, factors with immediate management implications that should be considered.

A resurgent interest in commercial fisheries and other resource utilization of the Northwestern chain has developed in recent years. During the past two years in particular, several vessels have engaged in harvesting spiny lobsters

(*Panulirus*) and bottom fishes (*Pristipomoides* and *Etelis*) at the Necker Bank. The only anchorage in the area which affords even partial protection from rough seas is West Cove at Necker Island. This site has been regularly used by some vessels, with anchoring taking place within 500 feet of the island. Between May and July 1977 a permanent buoy existed in this area. Other vessels (i.e. R/V *Easy Rider*), when engaged in lobster fishing, have preferred to anchor in the vicinity of their traps, which is usually several miles from the island. The nearshore feeding habitat of West Cove regularly contains juvenile and adult turtles. The effects on these animals of vibrations from generator motors and high intensity lights of anchored vessels must be considered. Furthermore, such human proximity to relatively tame and palatable animals, both in the water and basking on the island, increases the possibilities of adverse activities occurring. A distinct hazard to humans also exists by anchoring in West Cove and other sites near the island. Detonation of an intact or even partially exploded bomb from contact with an anchor or other physical object would probably destroy a vessel (Naftel, personal communication).

Another important factor for consideration is the potential impact on turtles by professions of various disciplines who may be visiting Necker and other Northwestern areas in increasing numbers during the coming years. My principal concern at this time is for the continuation of the unique basking behavior. Disturbance to these animals which results in retreat to the water should not occur except under special circumstances relating to the collection of data of predetermined importance. Also, any recovery of tag numbers or tagging of basking turtles should not involve turning the animals over on their backs. In addition to imposing stress which could decrease the incidence

of basking, such activity on the rock ledge at Necker has a high probability of physically damaging an animal's carapace and limbs.

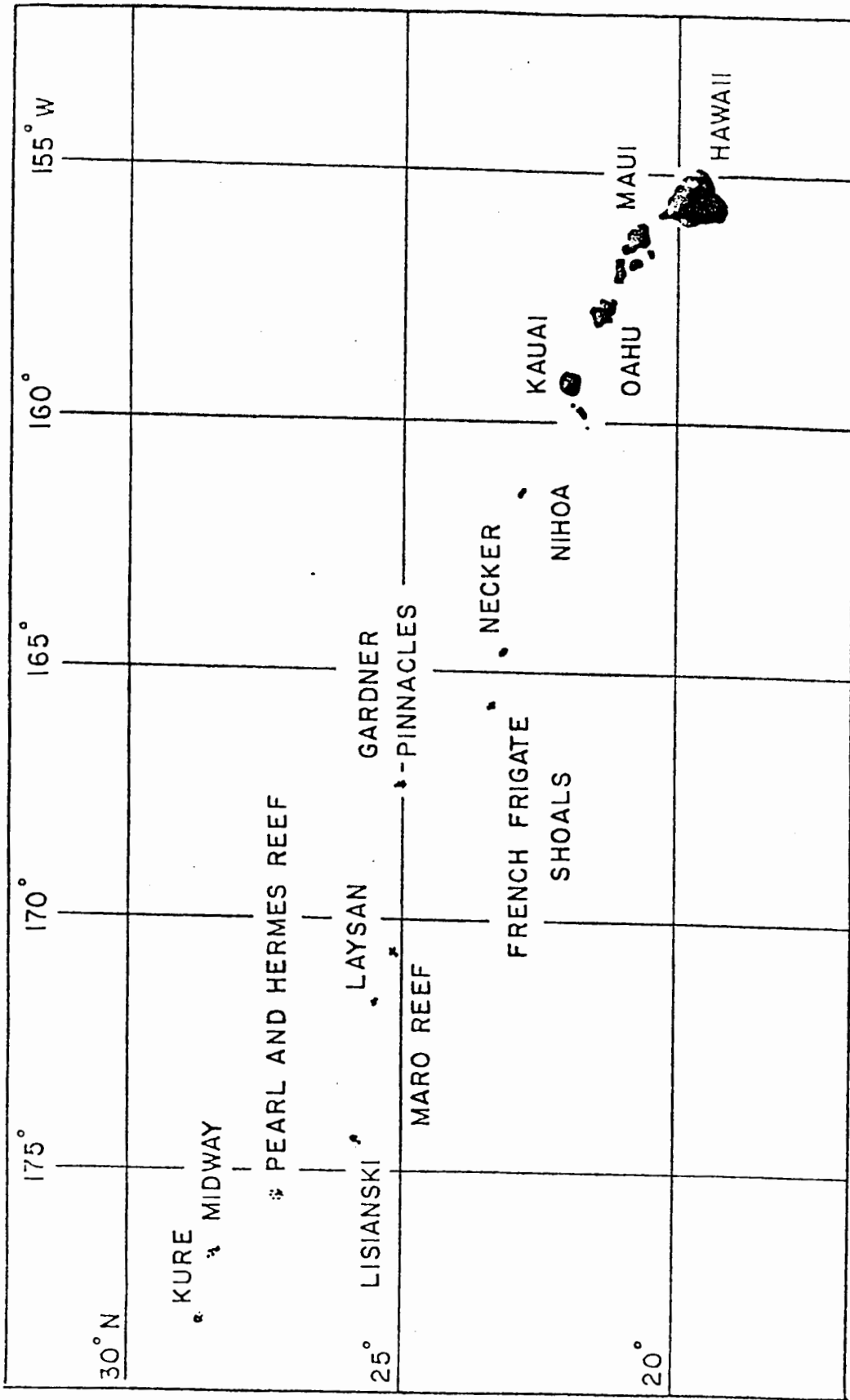
The last factor to be identified for consideration relates to the air space over Necker and other units of the Hawaiian Islands National Wildlife Refuge. On 9 August 1977 a helicopter was observed over Laysan Island at an altitude of approximately 50 feet (Johnson and Johnson, personal communication). This was presumably part of training exercises from a ship in the area. Low level helicopters create substantial noise and wind with an accompanying high velocity movement of loose substrate. Considerable disturbance to basking turtles, as well as seals with pups and nesting seabirds, would therefore be expected to result. It should be noted that helicopter activity in the Northwestern chain appears to have become more common starting in the early 1960's. In 1961 and 1962 helicopters were used in conjunction with base camps for military personnel on Necker as well as Nihoa and Gardner Pinnacles (Clapp, 1972; Clapp and Kridler, 1977; Clapp, *et al.*, 1977). Also during the 1960's the use of helicopters was initiated as a means of transportation between Midway and the Coast Guard Loran Station at Kure Atoll. At one point, the Fish and Wildlife Service favored helicopter use in conjunction with military maneuvers as a means of travel to the various units of the Refuge (see Hawaiian Islands National Wildlife Refuge brochure, April 1970). The present incidence of low level overflights is unknown, and a thorough examination of the subject appears warranted.

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## HAWAIIAN ARCHIPELAGO NORTH PACIFIC OCEAN

Figure 1. The eight units of the Hawaiian Islands National Wildlife Refuge include Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, and Pearl and Hermes Reef. Kure is a wildlife refuge under the jurisdiction of the State of Hawaii and Midway is an overseas territory administered by the U. S. Navy.

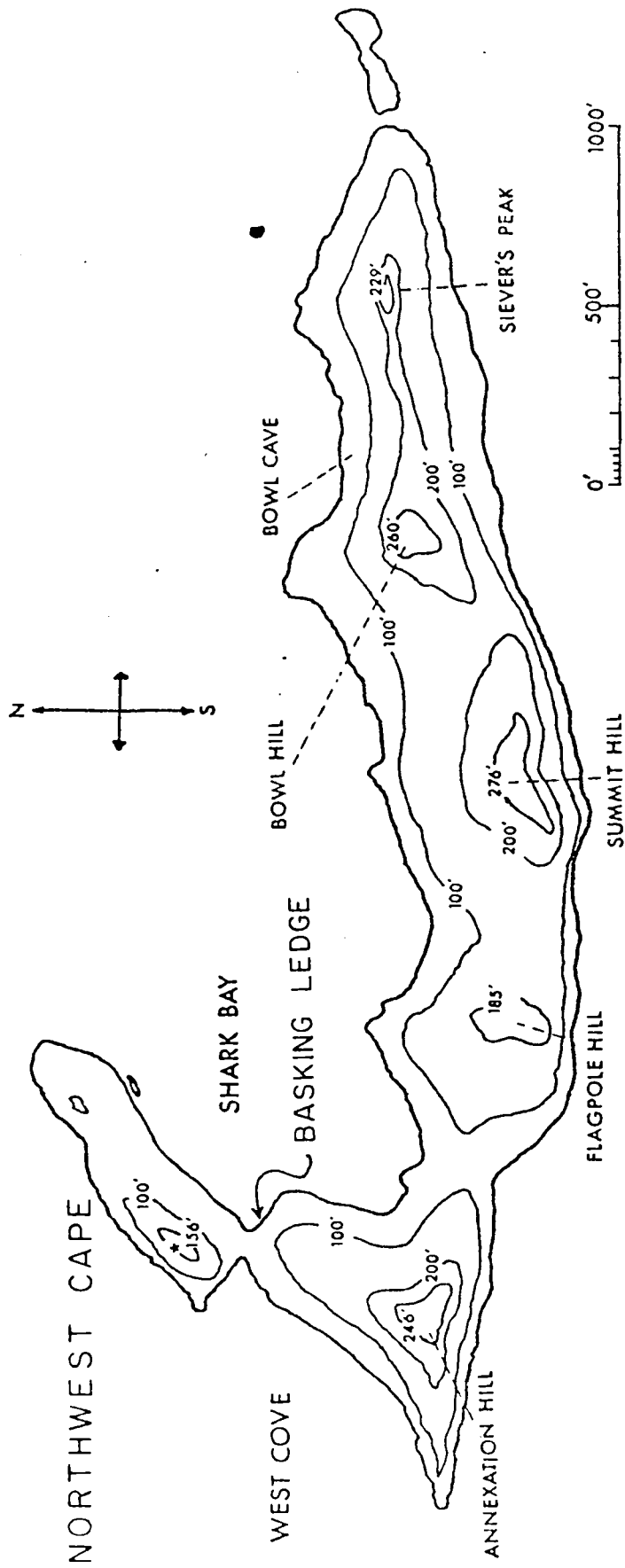


Figure 2. Necker Island ( $23^{\circ}35'N$ ,  $164^{\circ}42'W$ ) has an area of 41 acres and consists of sparsely vegetated volcanic rock. It is located 155 miles from Nihoa and 75 miles from the colonial Hawaiian green turtle breeding site of French Frigate Shoals.

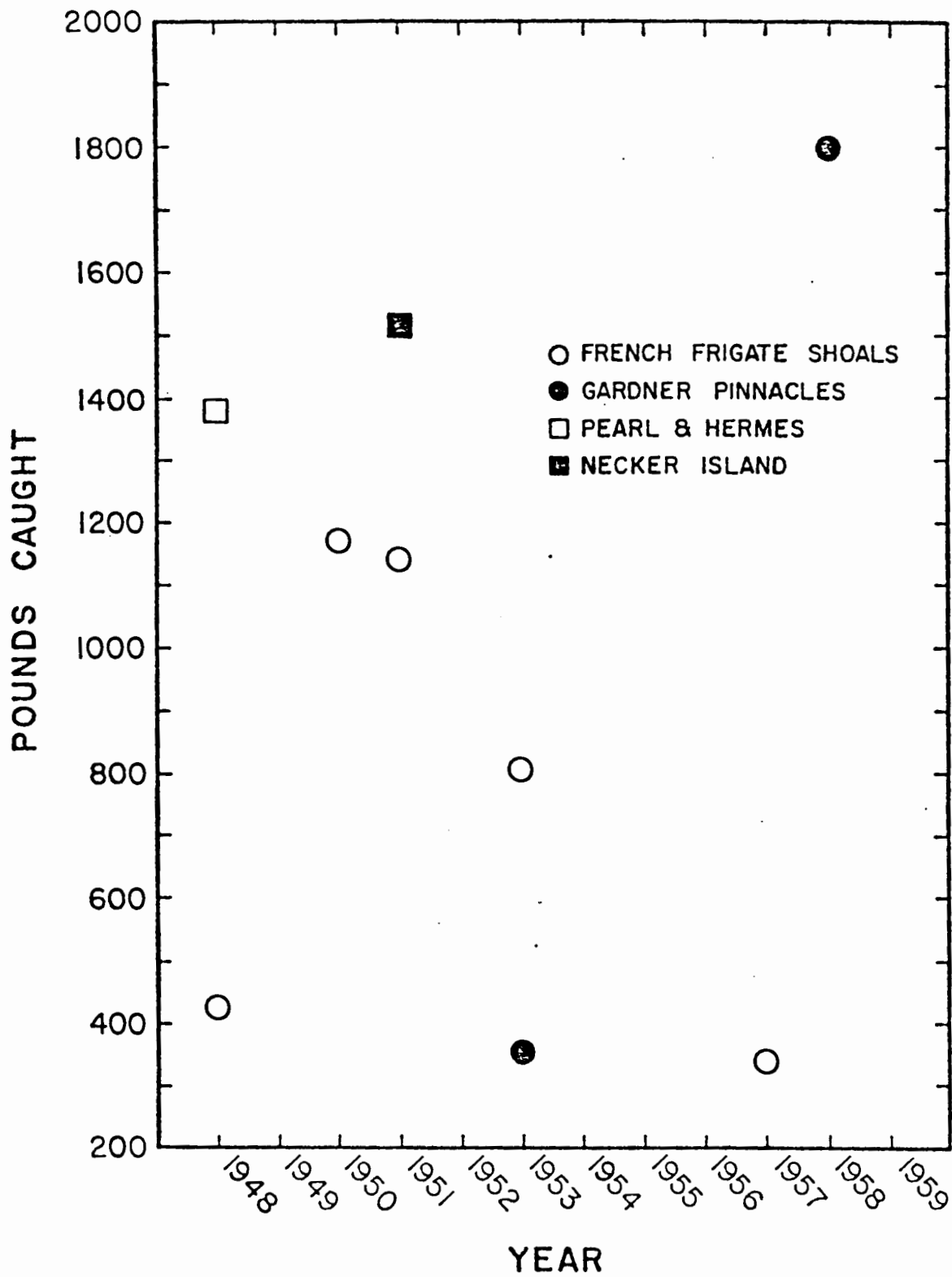


Figure 3. Pounds of turtle reported captured in the Northwestern chain, 1948-1959 (data provided by the State Division of Fish and Game).

Table 1. Green Turtle Basking Activity at Necker Island

Dates	No. Turtles	Approximate Times Ashore	Hours - Minutes	
			Total	Exposed to Radiant Heat*
19 August 1977	4	<0900-1215	>3-15	>3-15
20	1	0800-0900	1-0	1-0
20-21	1	2100-<0600	<9-0	0
21-22	4	2215-0645	8-30	0-10
21-22	1	2215-0800	9-45	1-25
22	1	0815-1245	4-30	4-30
22	1	2115-2130	0-15	0
23	1	0030-0615	5-45	0
23	2	0030-0715	6-45	0-40
23-24	2	2130-0745	10-15	1-10
25	3	0300-0615	3-15	0
25	1	0300-0800	5-0	1-35
26	3	0315->0730	>4-15	>1-05

\* sunrise - 0635

sunset - 1925

seawater temperature - 27°C

Table 2. Juvenile Green Turtles Captured at Necker Island

Date	Tag. No.	Straight Carapace		Curved Carapace		Plastron		Curved/Straight	
		Length	Width	Length	Width	Length	Width	Length	Width Ratio*
21 August 1977	2380	16-5/8"	14-1/4"	17-5/8"	16-3/4"	13-1/2"	28 lbs	1.18	
22 August 1977	2382	17-3/16"	14-1/4"	18-1/2"	17"	13-3/4"	30 lbs	1.19	
23 August 1977	2384	17-1/8"	14-3/8"	18-1/4"	16-3/4"	14-1/8"	28 lbs	1.17	
24 August 1977	2389	19"	15-1/8"	20-1/2"	18-1/4"	14-5/8"	37 lbs	1.21	

\* an indicator of body thickness