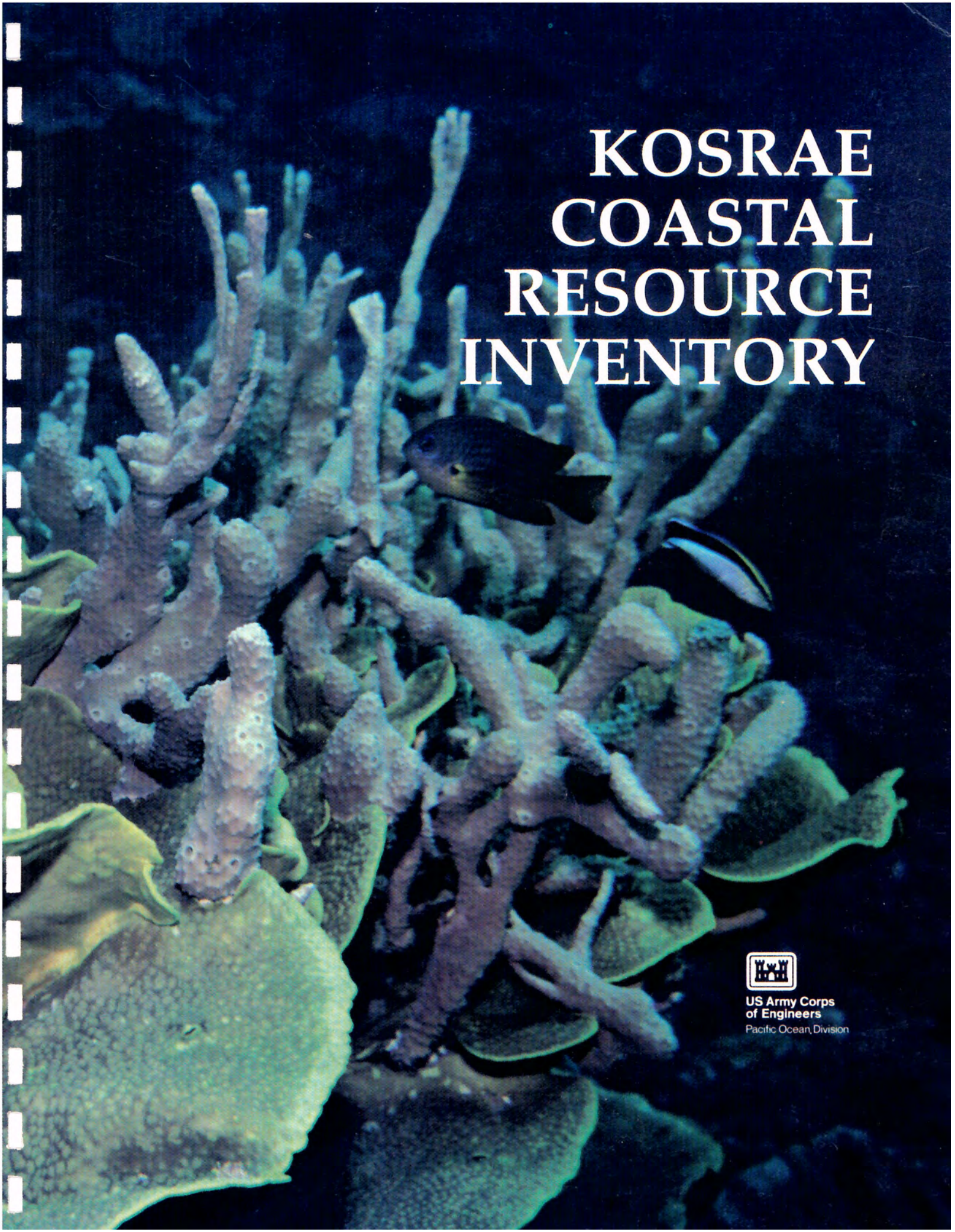
KOSRAE COASTAL RESOURCE INVENTORY



US Army Corps
of Engineers
Pacific Ocean Division

KOSRAE
COASTAL RESOURCE INVENTORY

Prepared

by

Environmental Resources Section
U. S. Army Engineer District, Honolulu

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INTRODUCTION

The Kosrae Coastal Resource Inventory (KCRI) was prepared by the U.S. Army Corps of Engineers, Pacific Ocean Division. It is the companion volume to the Kosrae Coastal Resource Atlas.

The Corps' coastal resource inventory program has been under the direction of Dr. James E. Maragos of the Corps since its initiation in 1978. Portions of this narrative report were written by Dr. Maragos (physiography, corals, impacts on coral reefs); Dr. Ross Cordy, State of Hawaii Department of Land and Natural Resources (summaries of archaeological and historical resources, and list of specific sites in Appendix E); and Peter Galloway, U.S. Army Corps of Engineers (remaining sections). Some portions of the report are based on the field notes and summaries prepared by Mike Gawel, chief of the FSM Marine Resources Division; Carlos Cianchini, Peace Corps volunteer at the Kosrae Marine Resources Division; and Mike Molina, FSM fisheries biologist. Maragos, Galloway, and Cianchini participated in most of the field survey. Gawel and Molina participated in some portions of the field work, while Mike White, chief of the Kosrae Marine Resources Division; Jack Sigrah; and Teddy John, Kosrae State Historic Preservation Officer, each participated in one day of field work.

The purpose of the Kosrae Coastal Resource Inventory (KCRI) is to describe the natural resources of ecological, recreational, subsistence, cultural, and commercial importance. The information presented is potentially useful to users of coastal resources, as well as to government officials with responsibilities or interest in coastal resources management, land use planning and resort development, fisheries management and wildlife conservation, water quality management, recreation, historic preservation and other forms of coastal resources development. This narrative report is designed to be used in conjunction with the atlas. Together, the report and atlas are intended to describe and analyze supporting baseline data which can be used to identify valuable resources so that future development can be planned so as to minimize or avoid adverse impacts on these resources.

Sources cited in this report are referenced throughout the text by numbers appearing in brackets [ ] and are listed in the REFERENCES CITED section at the end of the report.

KCRI begins with a summary for the whole of Kosrae, followed by five narrative sections corresponding to the five geographic (map) sections of the atlas (Figure 1, page 6). Each of these sections contains its own summary, followed by discussions of grouped KCRI station results for various subsections of the coast. Information presented at each level includes: GENERAL DESCRIPTION, PHYSIOGRAPHY, FLORA, CORALS, OTHER INVERTEBRATES, FISHES, OTHER VERTEBRATES, ARCHAEOLOGICAL AND HISTORICAL RESOURCES, RESOURCE USE, AND WATER QUALITY. Brief explanations of the information presented under each heading are given below. A discussion of human impacts on Kosrae's reefs is included in the overall summary.

GENERAL DESCRIPTION

Under this heading, a very brief, general introduction is given, including notable natural or manmade features and locations of the recognized human population areas.

PHYSIOGRAPHY

Under this heading are included descriptions of the physical features of the terrestrial and marine environments, from the mountains to the ocean slopes of the coral reefs. Major emphasis is on the marine environment.

FLORA

Under this heading, information is presented on plants seen during the KCRI field survey. Only the larger and more conspicuous algae are noted; small or cryptic forms generally are not. The general occurrences of seagrass beds, mangrove forests, and swamp forests are briefly described, based primarily on the aerial photograph interpretation mapped in the Kosrae Coastal Resource Atlas (described in atlas introduction). Terrestrial vegetation is not included except for incidental observations made at some shoreline areas.

CORALS

Information on corals seen during the KCRI field survey is presented under this heading. Included here are the "reef" or stony corals (order Scleractinia), black corals (order Antipatharia), blue corals (order Coenothecalia), sea fans (order Gorgonacea), soft corals (order Alcyonacea), and some members of the class Hydrozoa such as fire corals (Milleporina, Stylasterina, etc.). Other members of the phylum Cnidaria, such as sea anemones, are included under OTHER INVERTEBRATES. Emphasis is on describing large and common corals which contribute the most to overall coral cover.

OTHER INVERTEBRATES

Under this heading, information is presented on invertebrate animals, other than corals, which were found at KCRI stations during the field survey. The conspicuous macroinvertebrates, particularly the crustaceans, echinoderms and mollusks, are described, while small or cryptic invertebrates generally are not. Some information obtained from local resource users during interviews is also included, particularly information concerning invertebrates harvested from areas not included in the KCRI field survey (swamp forests, mangrove forests, inland waterways, interiors of coastal strands).

FISHES

Under this heading, summary information is presented on the fishes seen at KCRI stations during the field survey. Survey emphasis was on the fishes of importance for food. Conspicuous species such as schooling

grazers (parrot fishes, surgeon fishes) and carnivores (jacks, snappers) were recorded; cryptic, nocturnal and other small or inconspicuous species were generally not.

OTHER VERTEBRATES

Information on reptiles, birds, and marine mammals is included under this heading, including the incidental observations made during the KCRI field survey and some observations reported by local fishermen during interviews.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Under this heading, known archaeological and historical resources found in coastal areas are summarized.

RESOURCE USE

Under this heading, information is presented on the current utilization of resources, based primarily on data gathered during interviews with local resource users. Information obtained from the interviews was used to map resource use in the Kosrae Coastal Resource Atlas; additional information on resource items and resource use problems obtained from interview participants is presented in the RESOURCE USE summaries for each of the five map sections.

WATER QUALITY

Information regarding the quality of marine waters is presented under this heading. The current classification of waters (under the TTPI Marine and Fresh Water Quality Standard Regulations [73]) in each of the five map sections is summarized and significant natural or manmade discharges affecting water quality are identified. General observations of water quality and oceanographic conditions made during the KCRI field survey are noted at individual area descriptions.

METHODS

KCRI relied upon three primary sources of information: (1) aerial photography, (2) a field survey, and (3) interviews with local resource users and officials. To a much lesser extent, it relied upon literature reviews.

AERIAL PHOTOGRAPHY

Aerial photographs of the Kosrae coastal areas taken in 1985 were obtained from Perry and Associates, Guam and are described in the Introduction section of the Kosrae Coastal Resource Atlas. The photographs provided information for the atlas and this narrative report regarding the distributions of physical reef features, seagrass beds, and mangrove and swamp forests.

FIELD SURVEY

A 3-week field survey (referred to in the text as the KCRI survey) was conducted during May and July-August, 1986. Physical and biological resources of the reef system were surveyed by a field team at 52 stations (indicated on the atlas maps) which were chosen so as to obtain a fairly even geographic distribution and sampling of Kosrae's reefs. Swamp forests, mangrove forests, inland waterways, and interiors of coastal strands were not included in the survey. Although much of the survey was performed with snorkeling equipment, SCUBA gear was used to examine many deeper slopes, ocean reefs, and the sides of the reef passes. The amount of time spent at each KCRI station was determined by the relative complexity of the reef environment, water quality, weather and sea conditions, and safety considerations.

The survey was qualitative in nature. Each team member was assigned responsibility for specific organism groups or features and, using clipboards and waterproof species checklists (or blank forms), recorded information on the relative abundances of algae, corals, other invertebrates, or fishes. In general, only the larger, more conspicuous species were recorded, as they could be consistently observed without difficulty. Small, cryptic or nocturnal species were generally only incidentally observed and are therefore underrepresented in the survey results. The relative abundances of algae and corals were recorded at each station as follows: rare (observed only once at the station); occasional (present more than once but only within a single zone); common (conspicuous in only one or a few zones, or locally substantial in a single zone); abundant (conspicuous in most zones or dominant within a single zone); dominant (25 percent or more of total cover, or conspicuous in all zones). For non-coral invertebrates and for fishes, abundances were reported based on the numbers of individuals seen at each station, as follows: rare (1); occasional (2-4); common (5-14); abundant (15 or more).

Sketches were made to record reef physiography, substrate types, and estimated live coral cover. Additional notes were made by all team members on water quality, outstanding features, and incidental observations of vertebrates other than fish. Photographs were taken and specimens of some difficult or unknown organisms were collected for later identification.

Identifications of organisms were made by KCRI team members to the taxonomic level judged to be appropriate in each case, using the following references: wetland plants [65]; algae [41]; corals [78-84]; echinoderms [35, 46, 59, 60, 64, 67, 70]; mollusks [8-10, 29, 32, 36, 37, 58, 60]; crustaceans [50, 69]; fishes [4, 47, 53, 54, 61, 63]. Consulted references which became available subsequent to the field work included Reid's 1986 revision of mangrove-associated Indo-Pacific littorinid snails [56] and Randall's 1987 changes in the names of some Indo-Pacific surgeon fishes [55]. The few incidental bird observations were checked with some existing references [33, 34] and a recent Pacific reference work [51]. Identifications were based on external morphology; they should be regarded as tentative and not used as records for taxonomic purposes.

The team members and their areas of concentration were: Rooston Abraham, fishes and invertebrates; Carlos Cianchini, fishes; Peter Galloway, algae and non-coral invertebrates; Mike Gawel, algae and invertebrates; James Maragos, reef physiography and corals; Mike Molina, fishes; and Mike White, fishes.

INTERVIEWS

Preliminary information on use of Kosrae's coastal resources was gathered by the KCRI field survey team during an informal interview held with the staff of the Kosrae Marine Resources Division. Subsequently, additional detailed information on the use of Kosrae's reef resources was gathered during a series of meetings held at each of five communities: Lelu, Utwe, Malem, Walung, and Tafunsak. Chief magistrates were asked to request fishermen or other knowledgeable resource users to attend the meetings. Announcements were made via radio through a local radio station. At each of the five meetings, participants were presented with an explanation (in Kosraean, by a Kosraean-speaking member of the Marine Resources Division) of the purpose of the meeting and were shown a copy of the marine resource atlas previously prepared for Pohnpei [42]. Care was taken to stress that the information desired was to be used in planning for the wise use of Kosrae's reef resources. Participants were then asked, again with the translation assistance of a Kosraean-speaking member of the Marine Resources staff, to indicate on a map the locations of various types of reef resources used in their area. Participants were also asked to identify any problems concerning the resources, e.g., whether the various resources were increasing, staying the same, or declining. Information was obtained on locations and possible causes of reef degradation, ocean access problems, and other resource-related information.

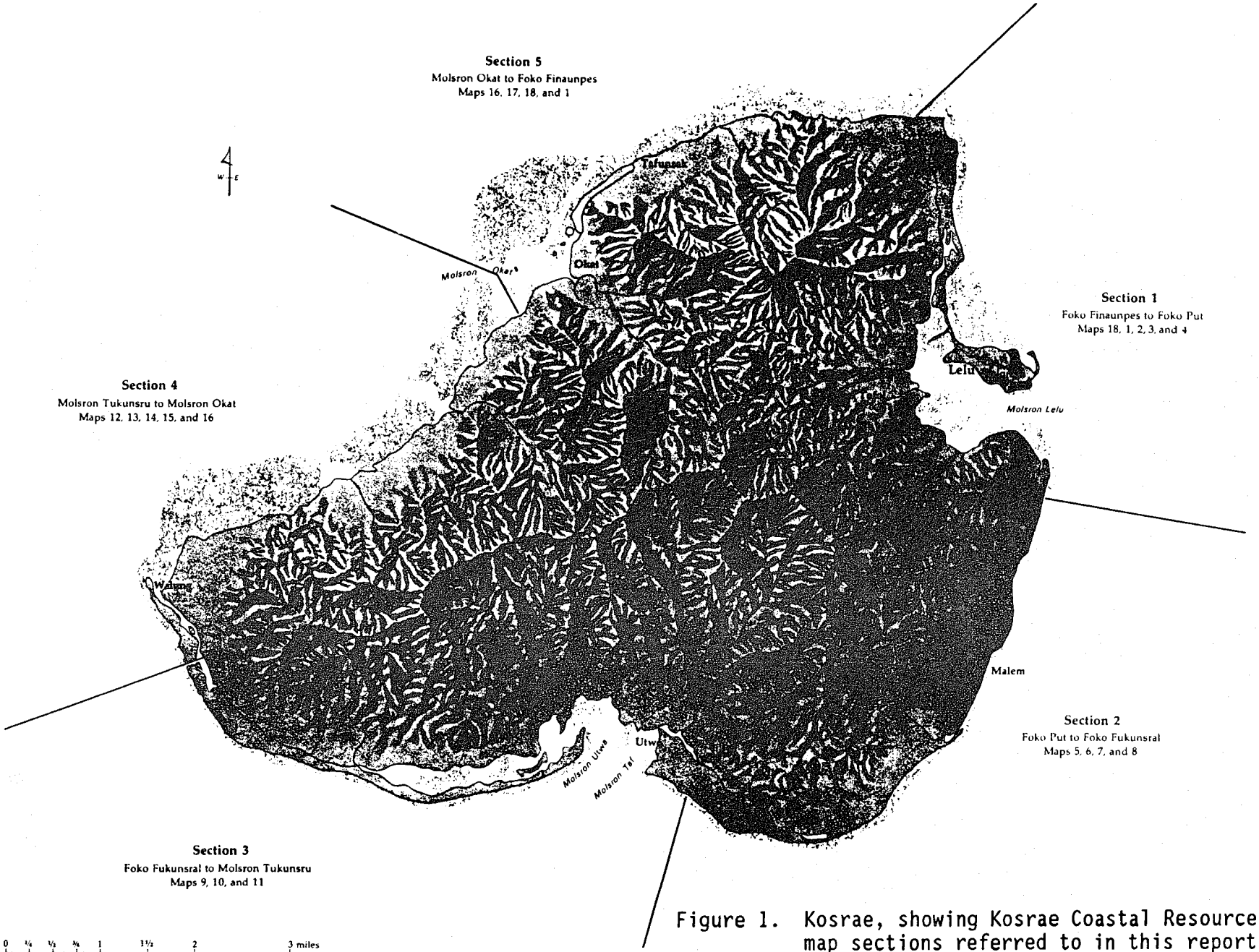


Figure 1. Kosrae, showing Kosrae Coastal Resource Atlas map sections referred to in this report. Figure adapted from the atlas.

OVERALL SUMMARY

GENERAL DESCRIPTION

Kosrae Island (Figure 1) is a high, volcanic island in the Caroline Islands, situated a little over 5 degrees north of the Equator. It has a total area of about 112 square kilometers (42 square miles) [76, 85]. The climate is invariably warm and moist: average monthly coastal temperatures vary only about 0.5 degrees Centigrade about the annual mean of 27.4 degrees; average annual rainfall at the Kosrae weather station in Lelu is 5 meters; and relative humidity is high, 80 to 90 percent [38, 76].

The steep, mountainous interior of the island is covered with lush tropical vegetation supported by the abundant rainfall (which is somewhat greater than on the coast). Subsistence farming is actively practiced, the main subsistence crops being bananas, breadfruit, citrus fruit, coconuts, and taro. Some cash crops (primarily copra) are also grown. Pigs are common livestock. Food resources are actively obtained from the coastal forest and the coral reefs beyond. The local economy is also supported by fishing, handicrafts, tourism, and government jobs [38].

A coastal road circles the eastern two-thirds of the island, built largely on the coastal strand at the seaward edge of the mangrove forest, and connects the largest four human communities of Tafunsak, Lelu, Malem and Utwe. The road was extended through the mangrove forest in 1982 to provide vehicular access to the new airport and harbor facilities built on the reef flat at Okat during 1980-1985. Actions were being taken during 1987-1988 to extend the circumferential road past Utwe towards the fishing village of Walung.

The human population of Kosrae, which in 1980 census figures was about 5500, primarily inhabits the relatively narrow coastal strands, isolated from the basaltic uplands by mangrove or swamp forest. Most of the island inhabitants are clustered within the villages, the largest of which is Lelu with nearly half of the island's population. Other large villages are Malem, Utwe and Tafunsak. A small village is situated at Walung. New population centers or villages are expected to develop at Tofol and possibly at Okat.

PHYSIOGRAPHY

Kosrae is a high triangular island with an area of approximately 112 square kilometers (42 square miles) and of volcanic origin, probably consisting entirely of oceanic basalt. There is evidence of carbonate rock or raised reefs above an elevation of 3 meters on the slopes of the high island. The original volcano(es) of Kosrae have become deeply weathered over geological time and form an irregular mountainous region in its center with deeply incised valleys and four high peaks with heights from 465 to

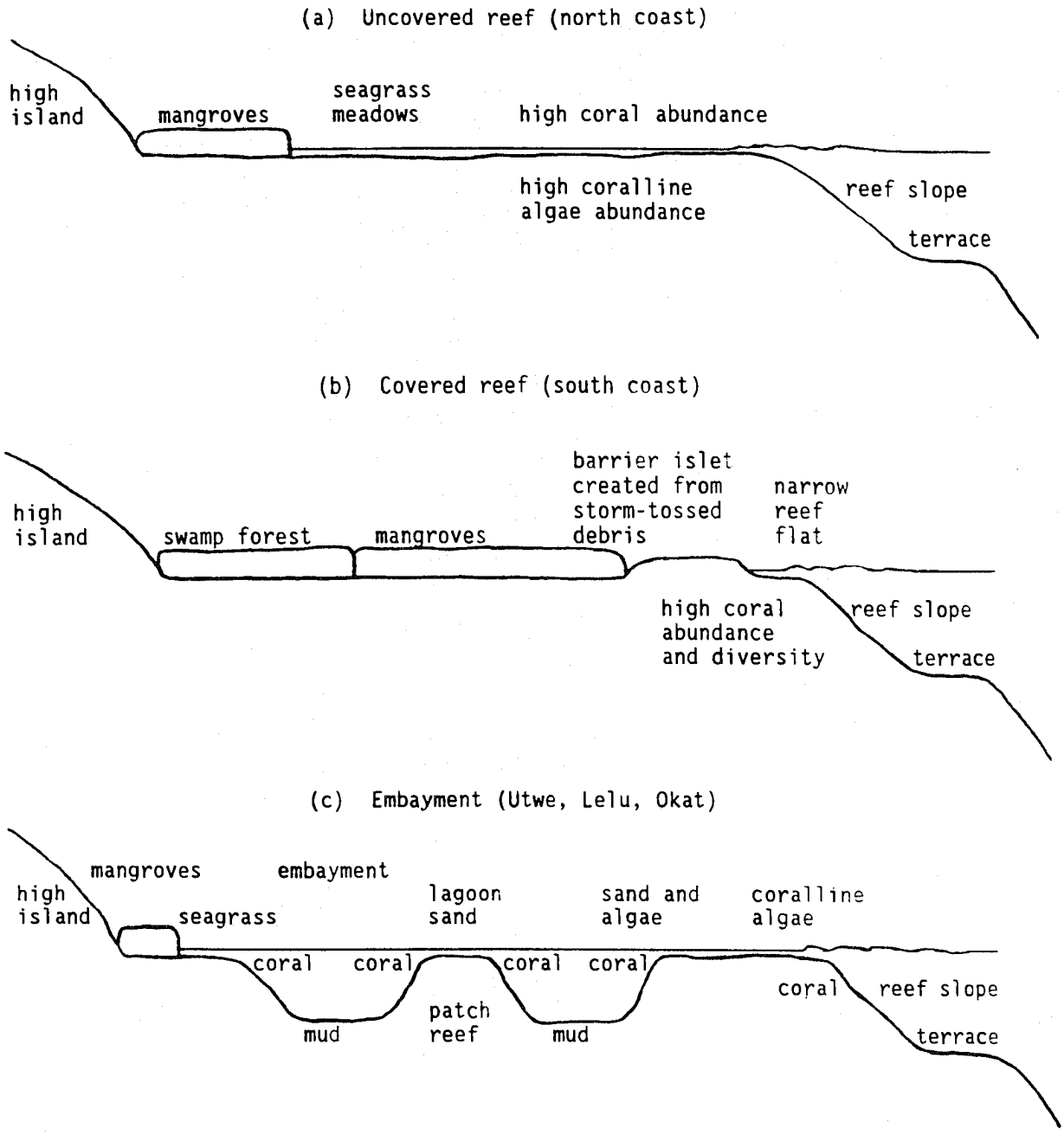


Figure 2. Diagrammatic representations of "typical" cross sections through the Kosrae reef system, showing terminology of features as used in this report. Three diagrams are presented, including: (a) a typical fringing reef not covered by forests, (b) a typical covered fringing reef platform, and (c) a very wide reef system with embayments and rudimentary lagoons.

629 meters above sea level [76]. Steep ridges radiate outward and downward from the center towards the gently sloping foot slopes, hills, alluvial fans and coastal plains. Around much of the island there are continuous mangrove swamp forests and seaward coastal strands [38]. The island is surrounded by a broad shallow carbonate platform much of which is now covered by freshwater swamps, mangrove forests and low coral land and beach strand.

The carbonate platform is probably of recent coral reef origin and extends 2 to 5 kilometers (1 to 3 miles) out from the island's volcanic "shoreline" boundary. Along the southern half of Kosrae the inner sections of the reef platform rests near sea level and is covered with saturated soil conditions and large tracts of freshwater swamp forests. Closer to the sea, the vegetation cover is replaced with mangrove forests and surface brackish water conditions. The coastal strand and coral lands generally occur seaward of the mangroves although in some locations small mangrove stands extend out from the open seaward shoreline. This same inshore to offshore pattern (volcanic "shoreline", freshwater swamp, mangrove forest, strand/coral land, and open seaward shoreline) is repeated along the other coasts of the island except that freshwater swamps tend to be less developed while mangrove forests are better developed. The mangrove forest occupies the outermost portion of the shoreline, on the reef flat in many areas, reaching widths of over 0.6 km along the northwest coast, in Tafunsak (Section 5). Beyond the mangrove fringe, terrigenous sediments are an important component of some nearshore areas, but usually the inner open reef flats are dominated by calcareous sand and rubble deposits which support seagrass beds of variable density and width. The middle to seaward portion of the open reef platform is frequently covered by coral rubble shingle tracts, and some large blocks. On windward (north and east facing reefs), the outer edge or margin of the reef platform is covered by a solid reef pavement which gives way to a gradually sloping spur-and-groove formation in the surf zone where robust corals and coralline algae are abundant. Steep reef slopes and terraces with very luxuriant coral growth and high coral diversity extend beyond the spur and groove formation. On leeward facing reefs the spur-and-groove formations are less developed or absent altogether, and a coral-rich reef slope descends abruptly beyond the outer edge of the reef flat.

Rudimentary lagoon or embayments bisect the reef platform at three places: Lelu Harbor off the east coast, Port Lottin or Utwe Harbor off the south coast, and Okat Harbor off the north coast.

The floors of the embayments are deep, 20-30 m or more, and are covered with fine muds and silts. Deep passes cut through the reef at the entrance to the embayments, and are flanked by steep, talus slopes with variable coral cover. The inner slopes of the embayment and passes show lower coral cover but are dominated by lagoon or quiet water species. The outer reef passes have high coral abundance and diversity dominated by open water species. Recently coral abundance has declined in the embayments due to recent coastal construction. Dredging, filling and causeway construction in Lelu harbor has blocked circulation and has caused coral declines on inner reefs and nearby deep reef holes. More recent small boat channel

dredging and filling for the jet airfield and deep draft dock at Okat have caused considerable declines to reef flat and embayment slope communities. Ongoing dredging and the recent opening of a channel through the reef at Port Lottin have caused siltation and declines in coral abundance.

The reef platform surrounding Kosrae has probably undergone substantial change and growth since the recession of the last ice age (approximately 8,000 years ago). Sea level rose approximately 90-100 m during the period of transition between the glacial and interglacial period. As sea level rose and water temperatures became warmer, the reefs surrounding the island continued to grow upwards, keeping pace with sea level rise. The distances between the outer edge of the reef platform and volcanic shorelines also increased due to a combination of reef extension and inner shoreline recession. When the reef platform became sufficiently wide, the inner shoreline areas became calm water environments facilitating the establishment and growth of mangroves. As mangroves continued to grow out on the reef platforms, the inner shoreline areas became less and less saline due to reduced mixing. In turn this facilitated the establishment of the freshwater coastal swamps. The coastal strand and coral lands were probably formed from sand rubble and debris thrown up on the reefs during large storms. A slightly higher (2 m) sea level stand about 4,000 years ago may also have resulted in reef growth above present sea level. As sea level receded to its present state, any reefs formed during the higher stand would have emerged; in turn these could have served as the elevated platforms for existing strand and coral land.

Considerable reef material has now been deposited on the reef platform along the entire southwestern to southeastern facing reefs, almost all the way out to the outer edge of the reef flat. Hence very little uncovered reef flat remains along these coastlines, with wave action breaking very close to the coral and strand shoreline. The concentration of coral rubble, sand, and other reef deposits along the southern half of the islands reefs suggest that wave action from tropical storms, including typhoons may have played an important role in depositing this material up on the reef platform from the offshore slopes and terraces. The high abundance and diversity of reef corals along these slopes provide an ever ready source of new material for coral island building. Infrequent storms would generate sufficient wave action to dislodge or break off coral fragments and transport them up the slope and onto the reef flats.

The formation of "barrier" coral islands and beach strand along the outer edge of the reef platform would further restrict the movement and mixing of marine waters within the inland portions of the reef platform, hastening the transition from mangrove to freshwater swamps. Diagrammatic, cross-sectional representations for three types of coastline profiles (uncovered reef platform, covered reef platform and embayment) are shown in Figure 2.

FLORA

The wetland vegetation of Kosrae is described in the 1978 inventory of wetland vegetation in the Caroline Islands by Stemmerman and Proby [58], which includes a review of the literature on the vegetation of Micronesia and an annotated bibliography. Maxwell [48] presents a vegetation description of the native upland forests of Kosrae based on habitat types, relating it to the earlier work of T. Hasakawa, which he cites; the "upland forests" of Maxwell include Terminalia-dominated fresh-water swamp forests (see below).

The Kosrae Coastal Resource Atlas included general mapping of swamp forests, mangrove forests and seagrass beds (from interpretation of aerial photographs; see atlas introduction) and is the primary basis for the present report. A detailed vegetation map of Kosrae (excluding seagrass beds) at a map scale of 1:20,000 was published in 1987 by the U.S. Department of Agriculture (Forest Service) [85]; this map was based on black and white photos taken in 1976, but was supplemented with ground sampling which provided estimates of changes in areas of the various cover types. The 1987 Forest Service report adjusts the estimated total area of Kosrae's forests (upland, swamp, mangrove and dwarf) downward from 8,009 hectares (19,790 acres) to 7,066 hectares (17,460 acres), with concomitant upward adjustment in the total area of other cover types (secondary vegetation, agroforest, and "non-forest").

The "upland forests" of Maxwell [48] are outside of the scope of the present report, with the exception of the Terminalia carolinensis dominated fresh-water swamp forests ("peat forests" of Hosokawa; "lowland high canopy swamp forest" of Stemmerman and Proby) which occur in the lowland portions of some stream valleys. Stemmerman and Proby [65] cite Hosokawa's 1971 strong recommendation that examples of this type of forest be preserved; these authors identified one small area (less than 10 hectares) of such forest off of the Yewok Road in Malem Municipality (map symbol near bottom of Kosrae Coastal Resource Atlas Map 5) and noted that, based on 1976 aerial photographs, the most extensive Terminalia swamp forest, previously studied by Hosokawa but not visited during their study, appeared to be in the Yela River valley. Maxwell suggests the preservation of a portion of the relatively undisturbed T. carolinensis stands in the Okat and Yela stream valleys in Tafunsak Municipality (the Yela Terminalia forest shows partially at the right (east) margin of Kosrae Coastal Resource Atlas Map 15; the Okat forest (not shown) would be at the right margin of Map 16).

Mangrove forest and lowland swamp forest occupy relatively large areas between the basaltic uplands and seaward strand areas of Kosrae. Mangrove forest is most extensive along the south and northwest coasts of the main island, while lowland swamp forest occurs primarily along the southeast coast. Stemermann and Proby [65] point out that Kosrae differs from the other Caroline Islands in that much of the mangrove forest occurs behind a protective coastal strand, which, in the absence of a barrier reef, is essential for the protection of the mangroves from wave action. Stemmerman and Proby observed that the only significant area of mangroves that is not behind a coastal strand is on the northwest shore between Tafunsak and the

Mot River (corresponding to portions of Kosrae Coastal Resource Atlas Sections 4 and 5). Stemmerman and Proby also observed that mangrove forests on the northwest coast include some of the tallest Sonneratia trees in the Caroline Islands, with abundant epiphytes, and recommended that the area be considered a candidate for protection if a natural reserve system were ever initiated.

Swamp forests and mangrove forests are important sediment traps which moderate the effects of excess storm runoff on the reef system. Swamp forests have been modified in some areas by development of agroforestry (e.g., coconut and breadfruit plantings), cutting of timber, and construction of human habitations. Mangroves have been cut at some locations to create boat channels and have been cleared and filled at other places for roads. The importance of mangrove forest as habitat for mangrove crabs at Pohnpei is discussed by Perrine [50], and Stemmerman and Proby [65] point out that these crabs are common in mangrove channels throughout the Caroline Islands. Coconut crabs (Birgus latro) and land crabs (Cardisoma sp.) are found in some swamp forest areas. Mangrove forests provide roosting areas for fruit bats (Pteropus sp.) and, on the seaward margins, for seabirds [65, 85].

Seagrass beds are mapped in the Kosrae Coastal Resource Atlas. Seagrass beds extend out over large areas of fringing reef flats along the north and west coasts of the main island, and on the broad reef flat just north of Lelu Island. In areas with narrower reef flats, the seagrass beds (if present) are correspondingly narrower. Seagrasses also occur in shallow areas in inland waterways, the most extensive such area being at Lulu Nefalil in Utwe. Like the mangroves, seagrasses act as traps for terrigenous silt and sediments. The seagrass beds are important habitat for some invertebrate animals and fishes. Tsuda, Fosberg, and Sachet [74] list three seagrass species for Kosrae, Cymodocea rotundata, Enhalus acoroides and Thalassia hemprichii. In their 1979 report on a baseline environmental survey conducted at Okat prior to construction of the new airfield, Eldredge et al. [30] list the same three species. The TTPI Office of Planning and Statistics land use guide [72] lists an additional species, Halodule uninervis. For the purposes of the KCRI survey, seagrass species were not differentiated.

Lists of marine algae occuring at Okat are included in the 1979 survey report of Eldredge et al. [30] (for Okat, but useful for Kosrae in general) and in the Office of Planning and Statistics 1979 land use guide [72]. Only conspicuous macroalgae were recorded during the KCRI field survey; these are listed by station number in Appendix A. Occurrence of the most common algae observed during the KCRI survey is summarized very briefly in the following paragraph.

Algae of the genera Caulerpa, Padina, and Halimeda are generally common on areas of sand-veneered reef pavement not subjected to heavy scouring action. These (and other less conspicuous) algae occur within seagrass beds and are fairly common, but irregularly distributed, on patch reefs. The margins and slopes of reef holes and patch reefs are typically dominated by living corals, but these areas also support locally abundant coralline

algae and patches of Halimeda sp. at some sites. The fringing reef crests at some locations have dense beds of brown algae belonging to the genera Sargassum and Turbinaria. The shallow portion (depth generally less than 3 m) of the fringing reef slope normally has abundant crustose coralline algae. The shallow slope typically also has patches of sand-producing green algae belonging to the genus Halimeda, which contribute calcareous material to the sediments of the reef slope.

CORALS

There have been only two published studies of corals from Kosrae, one by Kvammen (1973, in FAA, 1977 [31]), as part of the U.S. federal planning for the Okat Airfield and Dock project, and the other by Eldredge et al. (1979) [30], also at Okat. The earlier survey was very cursory, included no quantitative surveys, and included numerous spelling and taxonomic assignment errors. The latter survey (Eldredge et al., 1979) involved 17 transects in the Okat region and additional reconnaissance surveys by Mitchell Chernin with specimen identifications checked by Richard Randall. This latter study reported 105 species and 40 genera and subgenera of stony corals and 13 species and 8 genera of soft corals from the Okat area. Although these are sizable numbers for any given reef tract, they do not compare to the results of island-wide studies of coral accomplished at nearby Pohnpei and Truk (see Devaney et al., 1974 [29]; U.S. Army Corps of Engineers, 1986 [77]; and the Yap Islands proper [44]. Hence until the present inventory, the coral fauna of Kosrae had not been adequately characterized.

The Kosrae Coastal Resources Inventory involved approximately 50 coral stations around the island, including all major coral habitats. Although quantitative surveys or transects were not conducted, species lists and relative abundances of each species was reported and is summarized in Appendix B. The surveys of reef and other stony corals were accomplished primarily by James E. Maragos with Peter Galloway and Michael Gawel providing information for a few stations. Primarily Gawel accomplished the soft coral surveys with Maragos recording information on black corals (Antipatharians) and soft zoanthid corals (Zoantharians). The results of 1986 Kosrae field inventory yielded 64 genera and subgenera and 146 species of stony corals. The complete tabulations for the soft corals are not available. Combining the lists from Eldredge with those of the present survey indicates that 181 species and 67 genera and subgenera of stony corals and 13 species and 8 genera of soft corals have now been reported from Kosrae. All but 3 of the 40 genera reported by Eldredge et al. (1979) were reported again during the 1980 survey. However, 35 of the 105 species reported earlier were not recorded during the later survey. Coral taxonomy at the species level is still confusing, and there is difficulty in comparing earlier lists to those of later reports which have benefited from the taxonomic advances of Charles Veron and co-workers at the Australian Institute of Marine Science. Applying the revisions and reassignments by Veron and Pichon (1976, 1979, 1982) [79-81], Veron et al. (1977) [82], Veron and Wallace (1984) [83] and Veron (1987) [78] indicates that at least 9 of the species reported by Eldredge et al. (1979) are now considered

junior synonyms of other reported species.

Hence the total list from Kosrae now includes about 172 stony coral species and 13 soft coral species belonging to 67 genera and subgenera and 8 genera respectively. Although these numbers are more impressive than earlier reports from Kosrae, they are similar to comparably sampled atolls in the Marshall Islands (Kwajalein) and to comparably sampled islands in the Eastern Carolines (Pohnpei, Truk). They are slightly lower than the numbers from well sampled atolls in the Marshalls (Enewetak, Bikini), and much lower than the numbers from comparably sampled islands in the Western Carolines (Yap, Palau).

Kosrae's isolated position in the Eastern Carolines and its relatively small size may explain the lower numbers of coral species and genera observed to date. Nonetheless coral abundance is extremely high in several preferred habitats, especially coral and reef development on the ocean reef slopes. Corals achieve high abundance and diversity along outer ocean facing reef slopes around the island and the upper slopes of the reef slope and reef margin or edge. Leeward reefs are also zones of high coral abundance and diversity. Good coral development is also reported on the outer slopes of the passes, embayments and deep reef holes away from pollution sources. The fewest species and lowest abundance of corals are found on the shallow reef flats where temperature and salinity extremes, low tide exposures, and competition from benthic algae and seagrasses contorls coral development. Coral development is low within portions of embayments recently stressed by dredging, filling, and water pollution.

Two natural factors have recently served to reduce coral development at Kosrae: predation by the crown-of-thorns starfish (Acanthaster) and recent damage from tropical storm waves. Typhoon Lola achieved gale force and near hurricane-force winds at Kosrae during May 1986 causing major coral damage to southern facing reefs to depths of 10-15 m. Coral growth forms particularly hard hit by the waves were staghorn, ramose, foliaceous, tabulate, and vasiform species. The crown-of-thorns starfish predation was particularly noticeable along the ocean-facing reef slopes of the northeast sector, especially in water depths less than 10 m on flatter terraces.

OTHER INVERTEBRATES

The most conspicuous part of Kosrae's macroinvertebrate fauna is dominated by crustaceans, mollusks, and echinoderms. The 1979 report of Eldredge et al. [30], which provides species lists and distribution information for invertebrates found at Okat during a baseline marine environmental survey, is a useful guide for Kosrae in general; many of the invertebrates listed in the 1979 report, which was conducted prior to the construction of the new reef airfield and dock facilities, also occur elsewhere at Kosrae. A list of the invertebrates observed during the KCRI field survey is presented in Appendix B. Some highlights of invertebrate distribution follow below; they are based on observations of marine environments made during the KCRI survey and on information obtained from interviewed residents (for the inland mangrove, swamp forest, seagrass and

waterway areas, which were not surveyed).

Land crabs (Cardisoma sp.) are commonly seen at night on the circumferential road; these crabs are captured in swamp forest areas and probably inhabit most coastal areas where vegetation and suitable burrow sites exist. During interviews with local resource users, at least one informant stated that some land crabs can be found higher up, in the mountains, and that these crabs may be a different species. Coconut crabs (Birgus latro) are caught in swamp forest and in strand areas associated with mangroves. Coconut crabs move back and forth between beach strand and adjacent forest areas and are sometimes captured while crossing the coastal roads at night; during the KCRI survey, one adult crab was observed walking on the road at night near Malem. The mangrove forest and the brackish-water channels lacing it are habitat for the highly valued mangrove crab, Scylla serrata, which occupies mangrove channels throughout the Caroline Islands [65] and has been studied in detail at Pohnpei by Perrine [50].

Inland waterway areas with seagrass beds and mangrove forest, not visited during the KCRI survey, are known to be habitat for various invertebrates. At only one known site in the Utwe inland waterway of Lulu Nefalil (Atlas Map 10, center), a particularly popular species of clam is collected, known locally as popol; this clam has been tentatively identified from a partial (one valve) shell specimen as a member of the family Unguliniidae, possibly Diplodonta semiasperatoides, by Ms. Reggie Kawamoto of the B. P. Bishop Museum, Honolulu (personal communication).

Where mangroves occupy open reef flats (e.g., in inner Lelu Harbor), the snail Littoraria scabra is usually present on mangrove prop roots, stems, and lower leaves. Where manmade or natural sandy or rocky beaches occur, other shoreline snails are frequently found: L. coccinea occurs on trunks of living or dead coconut trees or other trees, while Nerita plicata is commonly found on shoreline rocks. N. albicilla may be seen occasionally on beach rocks at the water line.

The clam Asaphis violescens was found to be locally common at some rocky shoreline areas and in areas with Sonneratia roots. Hermit crabs were observed to be ubiquitous in shoreline areas and in the rubble/shingle zone of reef crests; these crabs are therefore not mentioned at each section and subsection of this report.

The solid substrate generally found along the edges and upper slopes of patch reefs and reef holes supports some sessile, filter-feeding invertebrates, such as featherduster worms and oysters. On the shallow reef flats of lagoon and patch reefs, the typically patchy distribution of sand, rubble, reef rock, microatolls, and living soft and hard corals provides habitat for diverse communities of echinoderms (e.g., spiny sea urchins), mollusks (including octopi), and crustaceans (including spiny lobsters, Panulirus sp.).

On reef flats, various invertebrates are generally found, including the most abundant sea cucumber species observed during the KCRI survey, Holothuria atra (the only other sea cucumber seen frequently during the

survey was Actinopyga mauritiana, noted below). During the KCRI survey, no specimens were observed of the single species of sea cucumber species which is collected in nearshore reef flat areas for food (subsequently identified tentatively from a single small specimen brought for inspection as Stichopus variegatus). Cones and cowries are generally common on sand and rubble overlying reef pavement. Octopi occupy holes in the reef pavement and rubble. Toward the reef crest and beyond, larger gastropods such as Turbo argyrostomus and Trochus niloticus may be found. Cowries, sea cucumbers, crabs and a diverse assortment of other invertebrates typically occur under coral shingle near the reef crest. In the surf zone and seaward spur-and-groove zones of exposed reefs, the sea cucumber Actinopyga mauritiana adheres tightly to the reef pavement, and spiny lobsters (Panulirus sp.) may be seen in cracks and holes.

On the hard substrate of reef fronts, especially in spur-and-groove zones, byssally-attached giant clams (Tridacna sp.) occur in modest numbers. Since more than one species of living Tridacna may have been observed during the KCRI survey, the name Tridacna sp., or just Tridacna, is used where appropriate in this report. No living specimens or shell remains of the bysally-unattached (free-living) giant clam Hippopus hippopus were found during the KCRI survey. Piled shell remains of harvested Tridacna were found at some KCRI stations (noted in individual section descriptions). Shells of the world's largest species of giant clam, Tridacna gigas, are sometimes exposed during dredging activities in Kosrae's coastal areas. At present, this species is not known to occur at Kosrae [1, 84]. T. gigas now receives some international protection under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (50 CFR 23). Stocking of Kosrae's reefs with hatchery-reared giant clams has been cited as a possible means to restore wild populations [1].

Down the reef slopes, occasional specimens of Trochus niloticus, Turbo sp., and the coral-eating crown-of-thorns starfish Acanthaster planci are usually the most conspicuous macroinvertebrates. Some Acanthaster feeding activity was noticeable at Station 33, and both feeding activity and considerable reef damage were observed at Station 36. Since Kosrae was not included in the 1969 Pacific Acanthaster Survey [11], there are apparently no data with which to compare the pattern of present activity with that which existed during the widespread Pacific outbreak.

FISHES

Fishes recorded during the KCRI field survey are listed by station in Appendix D. Emphasis was on recording readily observable species (see METHODS). The KCRI survey recorded a (minimum) total of 252 fish species, representing 41 families (Appendix D). A detailed listing, including Kosraean names, of fishes which have been observed and collected in Kosrae is available at the FSM Marine Resources Division. More than 250 species of fishes are known to be consumed by humans as food in Kosrae.

Species associated with mangroves include mullets, rabbit fishes, cardinal fishes, slipmouths, mangrove snappers and monodactylids. Inshore habitats of unconsolidated substrates support goat fishes and mullets; burrow-dwelling eels and gobies; and certain wrasses, rabbit fishes and parrot fishes associated with seagrasses.

Large schools of grazing surgeon fishes, rabbit fishes, rudder fishes and parrot fishes move from the terrace and reef front zones to the reef crest, and sometimes the reef flat, with rising tides. Large predatory jacks, snappers, emperors and sharks range these same zones. Species of most other familiar families are less errant and are found in healthy abundances except where dredging impacts appear to have damaged fished stocks at Utwe and Okat Harbors.

OTHER VERTEBRATES

Green sea turtles (Chelonia mydas) and hawksbill turtles (Eretmochelys imbricata) are regular inhabitants of the reef system of Kosrae. The green sea turtle is listed by the United States as a threatened species, and the hawksbill turtle as an endangered species (50 CFR 17.11). Only four observations of sea turtles (species undetermined) were made during the KCRI field survey, and all of these occurred at one location (Station 28) in Molsron Okat, Utwe. There are presently no known sea turtle nesting sites at Kosrae; the only historical nesting site known to the fishermen interviewed was at Foko Pe in Utwe. All seagrass beds are potential turtle feeding grounds.

One sea snake was observed during the KCRI survey. A yellow-and-black banded individual was observed moving slowly across the inshore reef flat (water depth approximately 15 cm) in East Tafunsak (Station 37).

Monitor lizards (Varanus indicus [72]), although not observed during the KCRI inventory, are said by fishermen to eat coconut crabs (Birgus latro), land crabs (Cardisoma sp.) and mangrove crabs (Scylla serrata). Fishermen interviewed at Malem stated that the lizards were introduced into Kosrae in 1936 by the Japanese, who apparently brought six of them to Malem (and possibly other areas of Kosrae) and let them go; the lizards are described as green in color and are said to grow to about 1 m in length.

Recent checklists of the birds of Micronesia (with separate listings for Kosrae) are provided in the 1985 report by Pyle and Engbring [52] and in the tropical Pacific field guide by Pratt et al. [51]. Ten species of seasonally migratory shorebirds were observed during 43 counts conducted at Kosrae during 1981-1982 by Hayes [34]. Birds were only incidentally noted during the KCRI survey. Resident Pacific reef herons (Egretta sacra) were commonly seen in most shallow coastal areas, and tattlers (Heteroscelus sp.) were observed on the revetment of the new reef runway (Station 3). Several individuals of one forest bird species, the cardinal honeyeater (Myzomela cardinalis), were seen flying to trees on the small reef islets off of Lelu Island (Station 11).

Fruit bats (Pteropus sp.) occur in Kosrae [68]. The 1979 notes on the status and natural history of Micronesian bats by Brunner and Pratt [7] did not include Kosrae, but these authors described the demand for fruit bats as a food delicacy on other Pacific islands and concluded that protection might be necessary to prevent the depletion of fruit bats througout Micronesia. Fruit bats are reported to roost in mangrove areas [65].

Small groups of unidentified cetaceans (dolphins or porpoises) were occasionally observed outside the reef during the KCRI survey, especially along the southern shore of the main island.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Kosrae's historic sites have been extensively studied only since 1979 under a multi-year archaeological research program [2, 3, 5, 6, 17-27, 40, 66, 75]. Previously, little was known of local prehistory, since Kosrae is one of the rare Pacific islands where oral histories dating back into prehistory are extremely limited -- a result of severe depopulation, conversion, and culture change which occurred in the mid to late 1800s.

The common historic sites on Kosrae are permanent dwelling sites. These are small enclosures, rectangular alignments, pavings and platforms which are remnants of house foundations. Sometimes these are found within a large walled enclosure, a house compound wall. The sites are usually scattered or clustered in small groups. Complexes of 10-20 house compounds are less common. And one enormous permanent dwelling site is present -- the ruins of Lelu, a site that covers 40 hectares and once contained over 100 house compounds. Lelu is one of the truly impressive historic sites in Micronesia, indeed in the Pacific. Some of its dwelling compounds have 5 m high walls, with the wall material including massive columnar basalt and round basalt stones weighing several tons. Additionally, a canal system is present within the site and numerous paved streets. Lelu is strikingly similar to Nan Madol on Pohnpei, but very different also.

Few of Kosrae's historic sites are actually on the reef flats. However, because Kosraeans were fishermen as well as farmers, many permanent dwelling sites are on dry land immediately adjacent to reef or embayment waters or adjacent to channels through the mangroves with access to reef or embayment waters. Such sites are commonly found on the strand islets along the reef edge or along the outer margins of the mangroves; the bulk of the sites, however, are on the edge of the coastal plain. There are many cases of artificial landfill, in which stone foundations were extended out into the mangrove swamp or off strand islets. Lelu is the classic case of artificial landfill, with much of that site having been built over the shallow reef flats. And there are cases in which alluvial and/or sand islets within the mangroves have been stabilized and used for permanent dwellings. Much of the latter locations were used late in prehistory.

Other than landfill and stabilized islets for permanent dwellings relatively few historic sites have been identified on the reef flat. Stone

foundations of fishtraps are reported in historical documents on shallow reefs, but not in great numbers.

These historic sites reflect a 2,000-2,500 year period of human occupation on Kosrae. Current ideas see Kosrae settled by Nuclear Micronesian speakers, a subgroup of Austronesian, whose initial origins lie in eastern Melanesia. Linguistic reconstructions show they were farmers and fishermen, with their crops including breadfruit, bananas, taro, coconuts, sugar cane and yams. The time of Kosrae's initial settlement is uncertain. Recent analyses of swamp cores suggest man-induced burning between B.C. 500-A.D. 0. This conforms with linguistic expectations. So far, the earliest archaeological site dated is at Wiya (Ko-D15-1) on the sandy Tafunsak coast, A.D. 95 $\pm$ 70. It is expected that the early settlements would have been on sandy shores with nearby freshwater swamps, thereby enabling easy access to marine and agricultural zones.

By the A.D. 600s, sites were widely scattered, indicating population spread throughout much of the island. And by the A.D. 900s-1200s, it appears that nearly all land units had been settled and that population had spread well up into the valleys on the island.

It is suggested that a number of small competing polities existed on the island prior to the A.D. 900s-1200s. By the A.D. 1200s-1400s, Kosrae's polities seem to have become fewer in number and larger in area, each with a ruler and a level of chiefs over internal land units. Ca. A.D. 1400, the Lelu polity seems to have defeated the others in war and unified the island, leading to the formation of one of the more complex, hierarchical polities in Micronesia. Oral histories note this success in war; and the massive, walled compounds of Lelu were constructed in the A.D. 1400s. From the A.D. 1400s-1700s, traditions and archaeology indicate that Kosrae remained unified. Reconstructions of social ranking suggest a ruler, high chiefs, and low chiefs were present at this time.

Archaeology documents rapid population growth in the A.D. 1400s-1600s, with estimates of 7,500-10,000 people present just prior to European Contact [27]. In the 1790s a typhoon hit the island, and according to oral histories massive starvation resulted. Overall population dropped, perhaps to 3,000-6,000 [57].

In 1824, a French exploring expedition under Captain Duperrey arrived on Kosrae, initiating European Contact and the advent of written records on the island. Whalers followed, with the whaling peak in the 1840s-1850s; and Kosrae became one of the major leisure ports of the Pacific at this time. With the whalers came diseases and new material goods, and the missionaries, Congregationalists of the American Board of Commissioners for Foreign Missions (A.B.C.F.M.) based in Boston and Hawaii. The 1850s-1880s, thus, were a period of massive change on Kosrae. Population plummetted to ca. 200-300. The traditional religion and political system disappeared, and outlying settlements were abandoned and became replaced by nucleated villages around churches. Not long afterwards, Kosrae came under foreign control -- first under Spain, then Germany and Japan, and last under the United States.

Information on specific archaeological sites, listed by Kosrae Coastal Resource Atlas map number, is provided at Appendix E.

RESOURCE USE

The resources of Kosrae's coastal environments are used in a variety of ways. The swamp and mangrove forests which together surround much of Kosrae Island are still largely intact, but are broken at places by developments. On the northwest side of Kosrae, at Okat, the mangrove forest has been cleared for the access road to Kosrae's new airfield (with reef runway) and commercial marine port. Various causeways, channels, landfills, and dredge sites have or are being constructed (or planned) through mangrove forest or on the open reef flats, including the causeway connecting Lelu Island to the main island. On Lelu Island are situated the ruins of prehistoric Lelu, which was constructed with access channels to the ocean. The swamp and mangrove forests are harvested in certain areas for production of local lumber and handicraft material. The mangrove crab (Scylla serrata), known locally as powa, is widely distributed around Kosrae and is hunted for food through the mangrove forest and in the brackish-water channels lacing the forest; the mangrove crab fishery at another of the Caroline Islands, Pohnpei, is described in detail by Perrine [50]. Some swamp forest, mangrove forest and beach strand areas hold populations of the coconut crab or aie (Birgus latro), which is highly regarded as food and is occasionally picked up on the coastal road at night. Land crabs (Cardisoma sp.) occur sporadically in vegetated coastal areas and are occasionally collected for food. At some shoreline areas, beach sand is collected by hand.

In inshore and nearshore mangrove and seagrass areas, bivalves are harvested for food, including relatively common clams, punak (Asaphis violescens, Anadara antiquata, and possibly other species) and "rare" clams, tuk (Periglypta puerpera, and possibly other species). A species of round clam known as popol (tentatively identified; see overall summary section) is very popular and is known to occur at only one known inland mangrove waterway locality in Utwe (Atlas Map 11).

On the nearshore reef flats, one species of sea cucumber, wurur (Stichopus variegatus) is collected and the internal organs are eaten; of the sea cucumbers (wah) at Kosrae, this is apparently the only species eaten. Sea anemones (lut) are collected and boiled with coconut milk. Nerite snails, kufahl (Nerita polita), are collected from nearshore rocky areas and some reef flat rubble zones; this species is the only nerite identified as eaten (no littorines identified as eaten). Other reef flat (and reef front) species of snails which are collected for food include Turbo argyrostoma (kaweng), Strombus gibberulus (wahl), and Lambis lambis (fulma).

The extensive seagrass beds on the reef flat provide feeding areas for sea turtles at high tide. Green sea turtles, but not hawksbill turtles, may still be taken for subsistence by residents under U.S. law (50 CFR 17.42); the green sea turtle is listed by the U.S. as a threatened species,

and the hawksbill turtle as an endangered species (50 CFR 17.11).

On Kosrae's reefs, gill netting, throw netting, spearfishing, poisoning with leaves (op sra) or other parts of toxic plants (Derris spp.), and other methods are used to harvest a wide variety of reef fishes; the most important food fishes and the areas they are harvested from are identified by symbols on the atlas maps. Certain reef areas, particularly reef holes, tend to attract some valued species such as rabbit fish, and these places are of particular importance to reef fishermen. In addition to the bony fishes, small moray eels (Echidna nebulosa and/or Gymnothorax pictus) are very popular and are caught on shallow reef flats. Hammerhead sharks (paiko hammer) are caught with hook and line in harbors and reef passes.

Giant clams, netula/natula (Tridacna sp. and possibly Hippopus hippopus) are harvested from the reef front and slope; stocking of Kosrae's reefs with hatchery-reared clams has been cited as a possible way to restore depleted natural populations [1]. Spiny lobsters (Panulirus sp.) are taken at night. The large gastropod mollusk Trochus niloticus is collected for the meat and shell from the outer reef flats and shallow ocean slopes; a portion of the reef area between Molsron Yela and Molsron Okat has been designated as a reserve area to protect this species (not marked on atlas map) [1].

In addition to possible food resources, certain reef flats, e.g., on the south side of Lelu Harbor (Station 9) offer recreational and educational potential because of their easy access and high biological diversity.

Because of the generally clear water, abundant coral growth, and large standing crops of large food fishes (especially snappers, jacks, groupers, and parrot fishes) found there, the reef passes offer much recreational diving potential. The reef passes and the reef ocean slope are bottom-fished for snappers and groupers. Further offshore, yellowfin tuna and barracuda are caught by trolling.

Information on resource use obtained from interview participants (see Methods) has been placed on the Kosrae Coastal Resouce Atlas maps, using symbols for the various resources. In the RESOURCE USE summary for each of the five map sections, additional information provided by interview participants about particular resources and resource problems is summarized.

Problems affecting resource use which were identified by interview participants at five villages of Kosrae include: the use and misuse of the roots and leaves of fish poison plants, op (Derris spp.); the blockage of water flow and fish movements due to the construction of causeways, revetments, etc.; and, in some areas, a general increase in fishing pressure (probably facilitated by the absence of social restrictions on fishing in any area desired). The possible role of the crown-of-thorns starfish (Acanthaster planci) in affecting coral reefs and fisheries was noted, as was the possible significance of introduced monitor lizards (Varanus indicus) eating coconut crabs and mangrove crabs. Specific notes

are at the 5 section summaries.

WATER QUALITY

Marine water quality at Kosrae ranges from pristine to moderately polluted. Even in pristine areas, natural factors such as fresh water discharge and deposition of terrigenous sediments may affect nearshore coral reefs, but the effects are normally moderated by the presence of swamp or mangrove forest, which traps the sediments and slows the release of high peak flows of fresh water runoff which occur following heavy rains. The seagrass beds which cover large areas of the fringing reefs also trap organic matter and fine sediment and help keep these materials from smothering the living coral polyps of the coral reefs, which are limited in the speed at which they can shed particulates. Some pristine nearshore reef flat areas have very clear water. While water quality at fringing reefs is subject to terrestrial influences, especially near the mouths of streams or rivers, the lagoon and patch reefs visited during the KCRI survey consistently exhibited fairly clear water, except near dredge sites. Waters of the ocean slopes usually are clear and therefore have high potential recreational value.

Nearly all water quality degradation at Kosrae occurs at nearshore fringing reef areas or within embayments. In rural areas, marine water degradation has been caused directly by the use of over-water toilets and pig-pens, and indirectly by animal wastes carried by surface runoff into streams and hence to the sea [71]. In agricultural areas, pesticides can also reach marine waters by surface runoff. Local dredging or filling activities, especially those involving removal of swamp or mangrove forest, have the potential to strongly affect local marine water quality.

Marine water quality at Kosrae has previously been most affected near the urban center of Lelu, where a variety of residential and industrial sources have affected the inshore waters. However, as future developments occur around the island (e.g., dredging and filling to support the circumferential road), water quality effects can be expected to become more apparent elsewhere.

Recent water quality surveys have been conducted at Okat by the University of Hawaii [12] and at several Kosrae sites by the University of Guam [13, 14, 15, 16]. Earlier surveys were accomplished by the Trust Territory of the Pacific Islands [62, 71].

Marine waters at Kosrae are classified for use under the Marine and Fresh Water Quality Standard Regulations [73] as AA (most protected), A (intermediate protection), or B (harbor or other use). Full definitions from the regulations are reproduced as Appendix F of this report.

HUMAN IMPACTS ON KOSRAE'S REEFS

Human activities have recently resulted in major damage to Kosrae's coral communities including filling on Okat's reef flats to create land for the jet airfield; dredging and sedimentation at various sites in Okat to obtain fill for the airfield and dock; dredging and filling at the Okat dock; dredging and stockpiling in inner Lelu Harbor; more recent dredging in inner Utwe harbor; and causeway construction to connect Lelu island to the main island of Tofol. Although culverts were placed in the causeway, they were insufficient in maintaining circulation within inner Lelu harbor, and one culvert was subsequently blocked in 1974 during construction of the Lelu airfield. The airfield land is now used by marine resources and fisheries offices. The ongoing circumferential road project has generated the need for fill material for use in roadbed construction. This material is obtained from reefs at selected "borrow" sites. Dredging at Utwe involved breaking through an inner reef to gain access to the stockpile site. In the process fine silts and muds previously held back by the reef washed through the new channel, burying the famous Bully Hayes shipwreck (Leonora) and adjacent reefs. Many corals have been stressed, and water clarity and reef fish levels have declined dramatically.

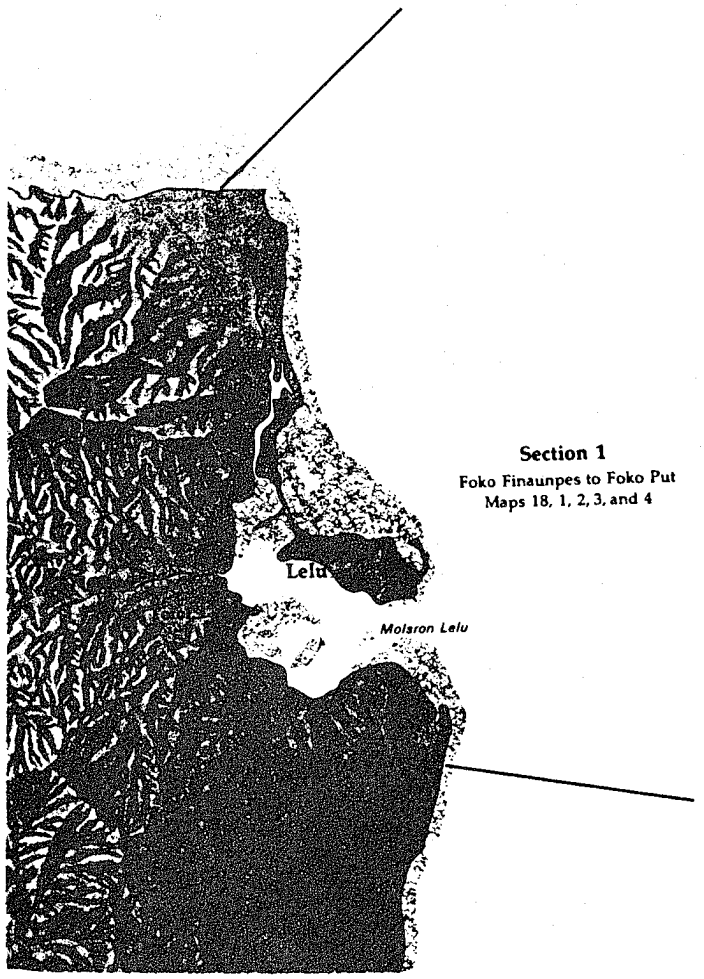
Fishermen in three major villages (Tafunsak, Lelu, and Utwe) have expressed concerns about the reef damage and related decline of reef fisheries, and a fourth village (Walung) is concerned about the future social and ecological impacts of extension of the circumferential road to Walung. The coastal areas near Walung are the only completely undamaged and pristine reef areas still left on Kosrae, and offer great reef fishery and tourism potential. The government of Kosrae must act wisely in the design of future coastal construction projects especially the ongoing circumferential road and future small marinas projects at Okat, Lelu, and Utwe. Consideration should also be given to establishing additional culverts in the Lelu causeway to improve the chances for coral reef recovery and to properly site and design the opening and closing of reef borrow sites. Environmental regulations to control coastal construction projects and planning for state and National Park development is needed. There is considerable at stake to the Kosraeans. Although the island of Kosrae is still large relative to its population size, the reefs and associated fisheries have declined dramatically during only the last decade. With so few reefs to begin with the Kosraeans must make wise choices for the island to attract tourism and ocean recreation. Restoration of other reefs for aquaculture, cultural preservation, reef fisheries, and recreational uses are also possible and important options. Subsistence fishery resources must also be protected for the future welfare of the Kosraean villagers.

MAP SECTION 1 (LELU)

SUMMARY

GENERAL DESCRIPTION

The central coastal region of this northeastern municipality of Kosrae is dominated by Lelu Harbor and the adjacent basaltic island of Lelu with its village of Lelu, the most populous village of Kosrae. The Lelu stone ruins, a noted archaeological site, are also located on Lelu Island. The Lelu causeway and an abandoned reef airstrip occupy the extensive reef flat to the north of Lelu Island. In both the northern and southern portions of this municipality, the coastal road follows the barrier formation at the seaward side of the mangrove forest.



PHYSIOGRAPHY

Both reef and volcanic rock formations occur along the coast of Section 1. The most prominent coastal volcanic formation is Lelu Island which is approximately 0.6 km (1 mile) long and 0.5 km (0.3 mile) wide. Its highest elevation is Finol Poro at about 110 m (360 feet). The eastern half of Lelu Island is hilly and steep and habitations are confined to the narrow coastal fringe. The western half of the island is flatter and supports the great majority of the population. Lelu Island is a remnant volcanic sea stack, the only one on Kosrae that was naturally separated from the main island. The Lelu causeway was hand built in the early 20th century and consists primarily of stacked coral shingle walls and fill of coral sand, rubble, and shingle, covered by the compacted coral roadway. Before the causeway was constructed, Lelu Island was not connected to the Kosrae mainland.

The reef formations of Section 1 include 7 km (4 miles) of eastern facing fringing reefs exposed to windward open sea conditions; the large eastern facing embayment of Lelu Harbor; 3 deep reef holes in the fringing reefs adjacent to the causeway; and 2 patch reefs in the southern portion of Lelu Harbor. The fringing reef flats are narrow along the northern part of Section 1, between Sroanef and Finaunpes. South of Sroanef, to the east of the causeway, the fringing reef broadens to the most extensive on Kosrae, achieving a width of 1 km (0.6 mile) near the reef hole at Yenasr. Wide fringing reef flats occur along the southern headland of Lelu Harbor at Foko Puk and become progressively more narrow to the south and southern boundary of Section 1.

Large mangrove swamps up to 0.8 km (0.5 mile) wide and 1.2 km (0.8 mile) long occur inland of the coastal strand and roadway within the northern portion of Section 1, between Finaunpes and Putukte. Large open waterways including Mutunnenea occur within the southern half of this large mangrove swamp. A second large mangrove swamp occurs further south within the innermost (western) fringe of Lelu Harbor near Tofol. South of Lelu Harbor and Foko Puk the mangrove swamp progressively narrows.

Freshwater coastal swamp forests are not well developed in Section 1 except at Infal Kaa within Lelu Harbor, landward of the fuel pier, and south of the volcanic headland south of Lelu Harbor at Ten Wak. The coastal swamp forests occur between the landward volcanic "shoreline" and the narrow seaward fringe of mangroves.

Seagrass beds development corresponds to the width of the fringing reefs in Section 1. Where the reefs are wide, the seagrass beds are wider and more developed, especially between Sroanef-Yenasr and the reef flat north of Lelu Island. Seagrass beds are small and patchy in Lelu Harbor, confined to the larger fringing reef flats. Wide seagrass beds occur along the headland at Foko Puk, south of Lelu Harbor and become progressively more narrow at the south boundary of Section 1.

Living coral communities are best developed on the outer ocean-facing fringing reef slopes and are less developed within the slopes of Lelu

Harbor and the reef holes and least developed on the shallow reef flats. Well developed spur-and-groove formations occur along the outer margins of the reefs within the surf zone.

Lelu Harbor is the largest of the three major embayments in Kosrae. Lelu Island forms the prominent northern headland of the entrance to the harbor. The harbor channel entrance (Molsron Lelu) exits in an easterly direction. The southern promontory to the harbor includes the headlands of Muntunlik and Ten Wak and constitutes the easternmost point of Kosrae Island. The floor of the harbor is deep, mostly in excess of 20-30 m, and is blanketed with fine silts and muds. The deeper reef slopes of the harbor are dominated by talus slopes of coral rubble, with live coral more conspicuous on the steep mid-level and upper portions of the walls. Sand, some live coral, and rubble dominate the top of the reef flats fringing the harbor. Lelu Harbor measures 3 km (2 miles) long by 2 km (1 mile) wide in its longest dimensions.

FLORA

A large mangrove forest occurs inland of the coastal strand and roadway within the northern portion of Section 1, extending southward from Finaunpes, narrowing at Putukte and ending at Finpukal. Another large mangrove forest borders the western edge of inner Lelu Harbor. Along the southern edge of Lelu Harbor, there are smaller areas of mangrove forest intermixed with areas of swamp forest. South of the harbor, mangrove forest gives way to the very extensive swamp forest which extends southward through much of Malem municipality.

As shown in Atlas Maps 1-4, the extent of seagrass beds in Section 1 appears to correspond to the width of the fringing reef platform. Seagrass beds were observed to be relatively narrow in the northern portion of Section 1, very extensive on the broad reef flat seaward of the Lelu causeway and along the northern side of Lelu Island, relatively rare or sparse on the reef flats within Lelu Harbor (possibly due to effects of the Lelu causeway; see Lelu Causeway and Lelu Harbor area descriptions which follow), and extensive on the broad reef flat just south of the Lelu Harbor entrance. During the KCRI survey, reef flat algae were observed to be highly variable in distribution, except on the reef crests, which nearly all had well developed beds of Turbinaria and Sargassum (with some plants over 50 cm tall at Stations 17 and 12). Halimeda and crustose coralline algae were common to abundant on the reef slope at most offshore stations.

CORALS

Corals achieve very high abundance and diversity along all of the outer ocean-facing reef slopes of Section 1, especially below the spur-and-groove formations between depths of 5-20 m. The outer walls of the entrance channel to Lelu Harbor also achieve high coral abundance and diversity. The coral biota of the ocean reef slopes is characterized by species adapted to moderate to heavy wave action and pristine, transparent waters.

The coral development in the large outermost reef hole at Yenasr is high, but coral communities are stressed and poorly developed in the smaller 2 reef holes adjacent to the causeway and near the proposed small boat marina in Lelu Harbor. These coral communities as well as others along the slopes of Lelu Harbor have been subjected to major reductions in circulation and increases in sedimentation attributed to dredging, filling causeway construction, and perhaps sewage discharges. The coral biota in the harbor is for the most part characterized by species adapted to high sediments and protected conditions.

The reef flats in Section 1 are shallow and do not support good development of living coral communities except along the outer reef margins. The floor of Lelu Harbor contains no coral development due to silt accumulation except for colonies which have established on the ship and airplane wrecks in the harbor with hard surfaces elevated above the bottom.

OTHER INVERTEBRATES

As revealed by the mapped resource use data in the Kosrae Coastal Resource Atlas, the mangrove forest areas inland of the coastal strands of the northern portion of Section 1, and smaller mangrove areas bordering Lelu Harbor, are inhabited by the mangrove crab (Scylla serrata). Coconut crabs (Birgus latro) are found in beach strand areas associated with the large northern mangrove forest and with the relatively much smaller area of mangrove forest at Foko Puk. Land crabs (Cardisoma sp.) are found in the swamp forest areas south of Mosron Lelu. Known habitats of additional invertebrates collected by residents are also revealed by the resource use symbols on the atlas maps. Highlights of invertebrate observations at KCRI stations in Lelu follow.

During the KCRI survey, rock crabs (Grapsus sp.) and intertidal snails were observed to be common along shoreline areas in Section 1. The snail Littoraria coccinea was usually found on tree trunks or on rocks, while Nerita plicata was found frequently on shoreline rocks.

A wide variety of invertebrates were commonly observed on the reef flats, including various gastropod mollusks (especially cowries, cones, turbans, trochus) and echinoderms (especially the sea cucumber Holothuria atra, which was common to abundant over much of the reef flats, and brittlestars). Along the margins of the large reef holes seaward of the Lelu causeway (Station 12), numerous invertebrate species were observed; these included featherduster worms, Christmastree worms, and various species of sea cucumbers.

Reef shingle near the reef crest, exposed at low tide, was occupied by some intertidal neritid snails. Common invertebrates living near the reef crest included gastropod mollusks (Trochus spp., Turbo argyrostomus) and sea cucumbers (Actinopyga mauritiana). The reef flat at Station 9 was particularly rich in readily observed invertebrates, including polychaete worms and various crabs; because of its richness and relatively easy

access, this reef flat would be suitable for teaching reef ecology.

Giant clams (Tridacna sp.) were occasionally observed in the spur-and-groove zone of the reefs in this section. Down the reef slopes, yellow sponges were generally common.

FISHES

Fishes recorded in Section 1 during the KCRI field survey are listed by station in Appendix D. Survey emphasis was on recording conspicuous species utilized for food. At least 122 fish species, representing 34 families, were recorded in Section 1.

Fishes recorded as common or abundant at one or more areas within Lelu Harbor (Stations 46, 47, 48, 49, 51, 52) included surgeon fishes (Acanthurus blochii, Ctenochaetus binotatus), jacks (Caranx melampygus), butterfly fishes (Chaetodon spp., Heniochus varius), gobies (Acentrogobius ornatus), sweetlips (Plectorhynchus pictus), rudder fish (Kyphosus sp.), wrasses (Halichoeres hortulanus, Thalassoma hardwickei), snappers (Lutjanus spp.), goat fish (Parupeneus cyclostomus), angel fish (Pygoplites diacanthus), damsel fish (Chromis ternatensis), groupers (Cephalopholis analis), rabbit fish (Siganus fuscescens), and moorish idols (Zanclus cornutus).

Fishes recorded as common or abundant at one or more of the inshore areas at the entrance, or outside, of Lelu Harbor (Stations 16, 17, 12, 10, 11, 9) included surgeon fishes (Acanthurus spp., Ctenochaetus striatus), trigger fish (Rhinecanthus aculeatus), blennies (Amblygobius albimaculatus), jacks (Caranx melampygus), butterfly fishes (Chaetodon sp., Heniochus chrysostomus), squirrel fishes (Neoniphon sp., Myripristis sp.), various wrasses, emperors (Lethrinus harak), snappers (Lutjanus fulviflamma), mullet (Liza vaigiensis), various damsel fishes, and parrot fish (Scarus spp.).

Fishes recorded as common or abundant at one or more of the offshore (reef slope) areas outside of Lelu Harbor (Stations 13, 14, 15, 1, 2) included various surgeon fishes (Acanthurus spp., Ctenochaetus striatus, Naso lituratus), trigger fishes (Balistapus undulatus), fusiliers (Caesio sp., Paracaesio sp.,), jacks (Caranx sp.), butterfly fishes (Chaetodon sp., Megaprotodon trifascialis), squirrel fish (Myripristis sp.), rudder fish (Kyphosus sp.), wrasses (Halichoeres spp.), snappers (Aphareus furcatus, Lutjanus spp., Macolor niger), goat fish (Parupeneus multifasciatus), threadfin (Scolopsis cancellatus), sweepers (Pempheris oualensis), various damsel fishes, parrot fish (Scarus spp.), groupers (Cephalopholis argus), and moorish idols (Zanclus cornutus).

OTHER VERTEBRATES

Vertebrates other than fishes were recorded only incidentally during the KCRI field survey. Several Pacific reef herons (Egretta sacra) were

observed on the reef flat on the east side of Lelu Island (Stations 10-11). A local informant stated that these birds nest on the reef islets (KCRI Station 11). Several cardinal honeyeaters (Myzomela cardinalis) were observed flying from Lelu Island toward the trees of the reef islets (Station 11). Any of the other vertebrates discussed in the overall summary section of this report may occur in Lelu Municipality.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

This section of Kosrae, encompassing the Lelu Harbor area, has long been dominated by one historic site -- Lelu, the ruling center of old Kosrae. Lelu was the center of the Kosraean world. This site includes Lelu Island and the small islets of Yenasr, Yenyen and Pisin. Detailed historical and archaeological work on the Leluh Ruins has taken place since 1979 [5, 17, 18, 20-24], and major parts of the site have been preserved as the Lelu Ruins Historical Park, under the management of the Kosrae State Division of Culture and History.

Population estimates suggest ca. 1,500 people lived in Lelu at the end of prehistory. The ruler and all the high chiefs dwelled here, as well as some low chiefs and a large commoner population. Over 100 walled compounds were present in Lelu, some with massive basalt walls similar to Nan Madol on Pohnpei. Access to compounds was by paved streets, canals, lagoonal waters or harbor waters. Most compounds were dwelling areas, but there were also two mortuary compounds with royal tombs and a number of sacred places where important ceremonies associated with Kosrae's major deities took place. Yenasr islet was a sacred place where final rites were given to the bones of rulers before they were dropped into the adjacent hole in the reef.

Interestingly, most of Lelu is artificial landfill -- stone foundations built out over the reef flat. Much of the flat land on Lelu, most of Yenyen and all of Pisin and Yenasr are landfills. These landfill activities seem to have begun in the A.D. 1200s; they continued into the 1700s, and continue today. The massive walls of Lelu date back to the A.D. 1400s.

Besides this site, fishtraps once abounded on the reef flat near Yenasr and Yenyen.

Mainland settlements around Lelu Harbor were located behind the mangroves and swampy coastal flats in such areas as Innem and Tofol [19, 26, 40] or on the beach in areas directly across from Lelu.

The details of prehistoric and early historic exploitation of reef resources in this area are unknown. However, laboratory analyses of the extensive faunal material from excavations in Lelu are almost complete and soon will be reported.

RESOURCE USE

The reef flat on the south side of Lelu Harbor (Station 9) offers recreational and educational potential because of its easy access and high biological diversity.

A meeting was held on 28 July 1986 with resource users at Lelu. Information obtained was used to map resource use in Section 1 of the Kosrae Coastal Resource Atlas. Additional information obtained from participating resource users is summarized below.

Notes on resource items

According to fishermen interviewed, the most important reef fishes for food are mullet, rabbit fish, rudder fish, squirrel fish, jacks, snappers, groupers, goat fish, surgeon fish, parrot fish, and big-eye scad. Hammerhead sharks (and other shark species) and moray eels are also eaten.

Freshwater shrimp are found in the streams, but "only the Filipinos" get them.

Of the sea cucumbers (wah), they eat only one kind, wurur; a small specimen was subsequently provided by a member of the Kosrae Marine Resources Division and tentatively identified as Stichopus variegatus.

Only a few people eat "rock crabs" (grapsids).

Coconut crabs are "found in Lelu ruins but no one wants to go there to get them." Participants stated that these crabs occur in other places where there are Pandanus and bananas.

Regarding land crabs: "can find some way up in the mountains -- may be a different species."

At high tide, sea turtles are found up on the reef flat south of Lelu Island. There is no known turtle nesting in the Lelu area. The people catch turtles by spearing, netting, or grabbing by hand. When asked about species, participants said they don't eat hawksbill turtles (i.e., only green turtles). One time a leatherback turtle was caught on a beach and made people sick when they ate it.

Resource use problems

While discussing gill netting near the old airstrip (at the end furthest from the causeway), the interviewed fishermen commented that "fishing isn't as good as before" because the water is now too deep and flow is constricted by the end of the airstrip. A fisherman who once caught 3000 herring in one day prior to construction of the old airstrip said that this can no longer be done because of the airstrip. Off the northeast end of the old runway there was previously a group of corals, but they were affected by the strong current following airstrip construction.

The suggestion was offered that perhaps the end could be taken off the old airstrip to reduce the water flow (current) around the airstrip. Some live corals are said to still be found to the south of the airstrip, probably due to the presence of culverts.

When asked about the culverts of the Lelu causeway, the fishermen indicated they thought that unblocking the central culvert, or adding additional openings near Marine Resources, may help the fisheries (there are four culverts still open in the causeway, two on each side of Marine Resources, but the largest, central one is blocked). The causeway was built by hand in 1949. Rocks were brought from the reef flat by raft for the project.

When asked about silt, sand, and seagrasses on the reef flats of the inner part of Lelu Harbor, the fishermen indicated that Yelpong reef flat fishing has been affected by the creation of the causeway, but that the next reef (Wenosr) has not. Yelpong reef flat now has no apparent seagrasses; the sand is still there but has silt on it some of the time. Migrations of fish (all species, but mainly rabbit fish and mullet) have been blocked by the causeway.

The people from Lelu are not restricted to Lelu for fishing, but can go anywhere on the island (no social restriction). Road development now makes this easier.

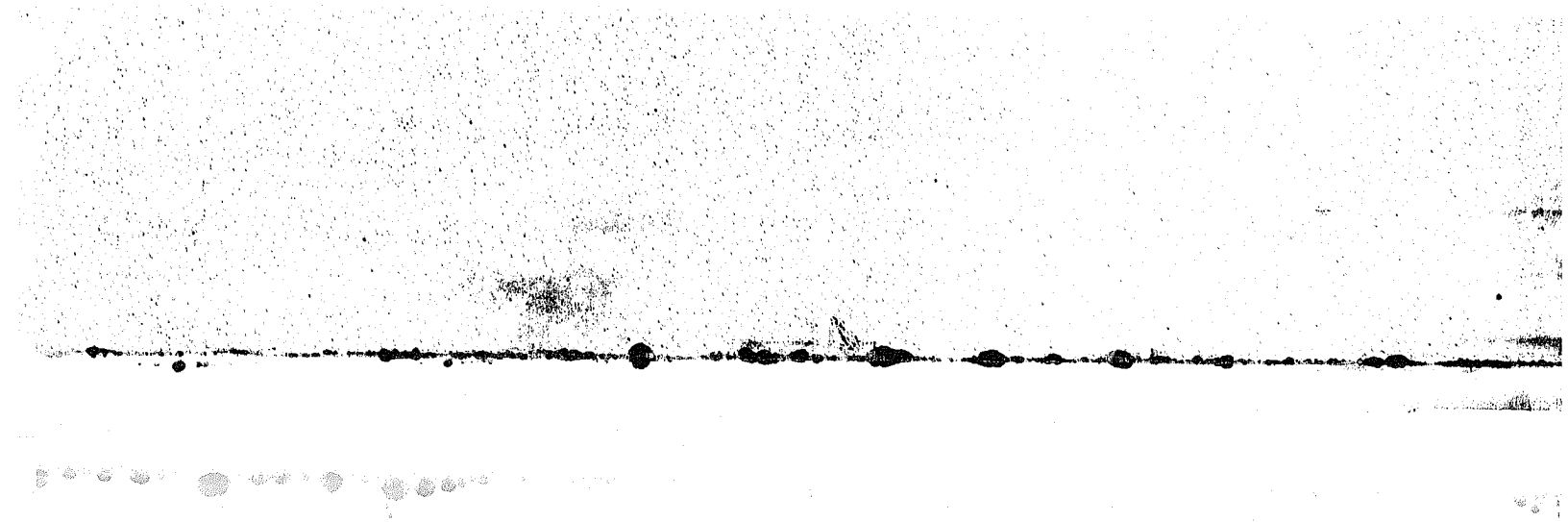
"New fishing gear" and "overfishing" have affected fisheries.

WATER QUALITY

The marine waters of this section are classified AA, except that the area adjacent to Lelu causeway is Class A and Lelu Harbor is Class B [73]. For class definitions, see Appendix F.

Point and non-point sources affecting water quality in 1979 [71] included dredging at the Finpukal (Lelu) causeway, discharges from the old hospital at Metais, a few over-water benjos on the bay of Lelu, natural discharges from 5 year-around streams which feed into Lelu Harbor, pesticide runoff from agriculture, oil contamination from the Lelu dock area, and some refuse dumping and over-water benjos discharging into the channel exiting the Lelu ruins.

Observations of reef conditions and water quality made during the KCRI survey tend to support the idea that water quality in the Lelu area, especially in inner Lelu Harbor, has been affected by the presence of the Lelu causeway. At least partially restoring water circulation (by such measures as reopening the existing, blocked culvert in the central area of the causeway) may benefit water quality, and thus the biota, in the inner harbor area. Better water clarity conditions were observed in the less developed portions of Lelu Municipality lying to the north and south of the harbor area.



(especially Caulerpa racemosa) formed a carpet on the hard reef pavement. Algae of the genera Padina, Halimeda and Turbinaria were scattered over this more seaward reef flat, into the beginning of the surf zone. Toward the reef crest, Jania sp. and Valonia sp. were occasionally to commonly seen. Sargassum sp. was abundant on the reef crest. Beyond the Sargassum, crustose coralline algae were common.

On the reef slope (KCRI Station 13), crustose coralline algae dominated hard surfaces not covered by corals. Halimeda sp. was common in depressions and at the bases of corals.

CORALS

Coral development on the reef flat (Station 16) is controlled by shallow depth, heavy wave action, and perhaps the constant movement of shingle and rubble. Average live coral coverage was less than 1 percent on the reef flat as a whole although coverage increased to 5-10 percent near the outer margin in the surf zone. Only 7 coral species were reported on the reef flat. Beginning inshore and moving offshore these species were Porites (Synaraea) rus, Acropora spp., A. digitifera, Pocillopora damicornis, Porites cylindrica, Goniastrea retiformis, and Porites lutea. Living broken fragments of the fire coral Millepora platyphylla were also noted.

In contrast coral development was luxuriant seaward of the surf zone (Station 13). Coral coverage achieves 40-50 percent in shallow water below the spur-and-groove zone and gradually increases to 75-80 percent at a depth of 15 m. A total of 28 living coral species were observed with the most important being large heads of the brain coral Platygra daedalea, foliaceous mats of Galaxea fascicularis, vasiform or table-coral species (Acropora irregularis, A. cytherea, A. hyacinthus), and the brain coral Favia stelligera. Other common species included Goniastrea retiformis, Fungia spp., staghorn species of Acropora, Leptoria phrygia, Porites (S.) rus, Lobophyllia hemprichii, Porites cylindrica, Pocillopora verrucosa, Montipora foliosa, and the fire coral Millepora platyphylla. The soft coral Lobophytum sp. was also common.

OTHER INVERTEBRATES

Intertidal snails (Littoraria coccinea and Nerita plicata) and unidentified grapsid crabs were common on shoreline rocks.

The sandy nearshore portion of the reef flat was found to be inhabited by burrowing gastropods (Terebra crenulata) and by numerous hermit crabs which occupied various small gastropod shells. The nearshore area was strewn with occasional shells of several bivalves, especially Asaphis violescens and Quidnipagus palatum. The sea cucumber Holothuria atra was common to abundant across most of the reef flat.

The abundant shingle and rocks of the broad pavement area concealed numerous mollusks. Abundant cowries (especially Cypraea moneta and C. annulus) and a common mitre (Strigatella paupercula) were found under shingle all the way to the reef crest. Two species of intertidal snails, Nerita albicilla and N. polita, were occasionally to commonly found on shingle. Several juvenile Trochus niloticus and one living Tridacna sp. were seen near the reef crest.

On the reef slope (KCRI Station 13), the sea cucumber Bohadschia argus was found. Yellow sponges were reported as common.

FISHES

On the reef flat (Station 16), the most common fishes observed were surgeon fish (Acanthurus triostegus), wrasses (Halichoeres hortulanus and H. sp.), damsel fishes (Chrysiptera leucopoma and Pomacentrus pavo), and parrot fish (Scarus sp.).

On the reef slope (Station 13), at depths to 15 m (50 feet), the most common fishes recorded included surgeon fishes (esp. Acanthurus blochii, Ctenochaetus striatus, Naso lituratus), trigger fishes (esp. Balistapus undulatus), fusiliers (unidentified), butterfly fishes (Chaetodon sp., Heniochus sp.), squirrel fish (Myripristis sp.), wrasses (esp. Halichoeres marginatus), snappers (esp. Aphareus furcatus, Lutjanus fulvus, Macolor niger), goat fish (Parupeneus multifasciatus), sweepers (Pempheris oualensis), damsel fishes (Chromis sp., Pomacentrus pavo), parrot fish (Scarus sp.), groupers (Cephalopholis argus), and moorish idols (Zanclus cornutus).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Foko Fin Nanpes area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 1 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

WATER QUALITY

At the time of the KCRI survey, nearshore waters (Station 16) were very turbid, but horizontal visibility improved greatly, to about 9 m (30 feet), at a distance of approximately 30 m (100 feet) from the shoreline. Horizontal visibility offshore (Station 13) was also excellent, approaching 30 m.

PUKUSRIK (PUKUSRUK)
(Stations 17, 14)
(Atlas Map 2)

PHYSIOGRAPHY

Although the reef platform off Pukusrik is about 1 km wide as measured from the volcanic shoreline, most of it is covered by a large mangrove swamp landward of the coastal road and strand. An inland waterway (Inya Insrefusr) traverses the middle of mangroves, meandering along a north-south axis.

The road is situated on the coastal strand. The beach consists mostly of coral rubble, and shingle with some fine sand at the base of the beach slope. The presence of dead coconut tree trunks suggests episodes of prior shoreline erosion along this stretch of coast. However, no erosional scarps were present during the mid-1986 survey.

The open reef flat is narrow, approximately 120 m wide, and faces due east into the prevailing tradewinds and tradewind generated surf. The surface of the reef is covered with a narrow band of seagrasses inshore and a thin veneer of carbonate sand and turf algae on hard reef pavement along the middle section. The outer reef flat is a hard reef pavement with some loose scattered coral rock and shingle. The outer edge of the reef flat is covered with fleshy macroscopic algae (Sargassum).

Considerable dead coral shingle and rubble covered the upper slopes of the reef within the area of maximum wave action. Carlos Cianchini indicates a large storm passed over this section in December 1985 and may have caused the shoreline erosion and accumulations of dead coral on the outer reef slope. Live coral coverage was about 25 percent. Further downslope coral coverage increased to 75-80 percent at a depth of 18 m where the reef transitions from a gradual to steep slope. Spur-and-groove formations are well developed between depths of 0-4 m on the upper, ocean-facing reef slope. Below 4 m there are meandering extensions of the grooves or channels into the deeper zone of high live coral development.

FLORA

Coconut trees, some uprooted, occupied the beach berm, and a large mass of coral shingle occupied the nearshore area at Station 17. Seaward of the

shingle, only small patches of seagrasses were observed on the sand-veneered reef pavement. The green alga Caulerpa serrulata was seen occasionally on the inner reef flat, while C. racemosa was common further offshore. Seaward of the point where wave action became noticeable, algae of the genera Turbinaria and Halimeda were common, and Padina sp. was occasionally seen. Caulerpa and Halimeda formed a mat which was denser toward the zone of breaking waves. Turbinaria also exhibited increasing seaward density. A moderately dense stand (estimated 60 percent bottom cover) of tall (0.5 m) Sargassum was encountered near the reef crest. Valonia sp. was common at the outer edge of the reef. Numerous drifting fragments of the large red alga Halymenia durvillaei were also observed at the outer edge of the reef.

Offshore, beyond a depth of 6 m (KCRI Station 14), Halimeda sp. was observed to be common in depressions.

CORALS

Corals are poorly developed on the reef flat due to its shallow nature and scouring action from breaking waves and suspended sediments. Only 9 species of stony corals were reported with small table corals (Acropora digitifera), encrusting corals (Porites (S.) rus), fingercoral (Porites cylindrica) and head coral (Porites lutea) the most common. As a whole, coral coverage on the reef flat was less than 1 percent but increased to 5-10 percent near the outer edge and breaker zone.

In contrast, overall coral coverage on the reef slope averaged over 50 percent, increasing with depth. At least 42 species were reported during a half-hour survey, a fairly high number. The greater diversity and abundance of corals on the slope reflects more favorable conditions there compared to the reef flat. Abundant species included the brain corals Goniastrea retiformis, Platygyia spp., Favia stelligera, and Favia spp.; the staghorn corals Acropora spp.; and the table coral Acropora hyacinthus and other Acropora species. Other common stony corals included Fungia spp., Porites spp., Montipora spp., Hydnophora spp., Porites (Synaraea) rus, Psammocora nierstraszi, Coscinaraea columna, Echinopora lamellosa, Turbinaria stellulata, Echinophyllia aspera, Mycedium elephantotus, Goniopora spp., Millepora platyphylla, Leptoria phrygia, and Pocillopora verrucosa. The soft coral Palythoa was common at depths of about 6 m.

OTHER INVERTEBRATES

Intertidal snails (Littoraria coccinea) were observed on coconut tree trunks at the beach. Inshore, ophiuroids (brittlestars) were abundant under shingle. The sea cucumber Holothuria atra was common over much of the reef flat. The few gastropod mollusks seen included occasional Vasum turbinellus (occupying holes in the reef pavement) and cowries (Cypraea moneta and C. annulus, clinging to the undersides of reef rocks). No bivalve mollusk shells were seen.

On the reef slope, beyond a depth of 6 m (KCRI Station 14), a hermit crab in a Trochus shell was noted. Yellow sponges were recorded as common.

FISHES

The most abundant fishes observed on the reef flat (Station 17) included surgeon fish (Acanthurus triostegus), wrasses (Halichoeres hortulanus, H. sp.), and various damsel fishes (esp. Chrysiptera leucopoma, Pomacentrus pavo).

On the reef slope (Station 14), the most abundant groups recorded included surgeon fishes (esp. Ctenochaetus striatus, Naso lituratus), trigger fishes (esp. Balistapus undulatus), rudder fish (Kyphosus sp.), wrasses (esp. Halichoeres sp.), snappers (esp. Aphareus furcatus, Lutjanus fulvus, Macolor niger), goat fishes (esp. Parupeneus multifasciatus), sweepers (Pempheris oualensis), damsel fishes (esp. Plectroglyphidodon dickii), and parrot fishes (esp. Scarus sp.).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Pukusrik area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 1 summary). The region of Pukusrik (Map 2) is unsurveyed.

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

WATER QUALITY

During the KCRI survey, noticeable silt and turbidity were present close to the shoreline; the water was noticeably cooler and clearer approximately 30 m from the shoreline. Offshore (Station 14), horizontal visibility increased from approximately 12-15 m (40-50 feet) at a depth of 9 m (30 feet) to in excess of 24 m (80 feet) at a depth of 15 m (50 feet). Inshore silt may have been residual from a major storm which occurred in December 1985.

LELU CAUSEWAY
(Stations 12, 15)
(Atlas Map 3)

PHYSIOGRAPHY

This area of the reef includes the fringing reef off the north side of Lelu Island, extending west to the seaward side of the causeway. The landward side of the causeway includes a continuation of the inshore reef flat, a small island, a narrow seagrass fringe, and a narrow mangrove fringe abutting the high volcanic shoreline. An inland waterway (Inya Mutunnenea) meanders through the mangrove fringe, and in March 1988, a new bridge was being constructed over it to accomodate both boat traffic in the waterway and vehicular traffic on the road and causeway.

Seaward of the causeway is found one of the largest seagrass meadows on Kosrae with a maximum width of over 400 m. The seagrass beds extend along the entire north coast of Lelu Island, the east (ocean) side of the Lelu causeway, and continue as a narrower band up the coast to the north. Beyond the seagrasses the broad reef flat is dominated by sand and fleshy algal cover. The fringing reef flat achieves a maximum width of 1 km when measured oceanward from the causeway and is among the largest on Kosrae.

Two deep reef holes punctuate the seaward side of the causeway and another is found on the landward side near the proposed small boat marina. The largest reef hole (near Yenasr) is located 300 m off the seaward side of the causeway and measures 400 m long and 100 m wide and at least 15 m deep. The upper lip and slopes of this reef hole are dominated by live coral cover and show overhangs and caves. The bottoms of all reef holes are covered with sediment. Live coral coverage in the other two smaller and shallower holes is less due to stress from reduced circulation and increased sedimentation from causeway construction and other recent dredging and filling. Instead the slopes are covered with sand or dead coral rubble.

Coral and fleshy algal coverage increases towards the outer edge of the reef flat to the surf zone. Spur-and-groove formations and highly developed live coral communities are found along the upper and lower reef slopes, respectively. Large tracts of coral shingle cover much of the hard pavement of the outer reef flat.

The causeway connecting Lelu Island with Kosrae Island at Finpukal-Mutunnenea appears to have been constructed by hand. Coral shingle was stacked to form the outer walls, with rubble, sand and shingle comprising the interior fill. Three large concrete culverts were constructed along the 700 m-long causeway, one at each end and one in the middle (KCRI atlas Map 3). The upper surface of the causeway is a compacted coral covered roadway. Construction of the Lelu airfield in 1974 on the landward side of the causeway resulted in the blockage of the middle culvert. Even with this culvert open, water circulation was much reduced after the causeway was completed. Sedimentation has increased on the landward side of the causeway, in particular, degrading reef, seagrass and fishery ecosystems.

FLORA

Seaward of the causeway (Station 12), on the reef flat between the smaller (inner) and larger (outer) reef pools, seagrasses (at least two species) were common on the sandy bottom at the time of the KCRI survey. Interspersed with seagrasses were algae: Padina was common and Halimeda was common to abundant.

Along the edge of the outer reef pool, Jania sp. and Halimeda sp. were common and there was occasional Turbinaria ornata.

Seagrass beds were observed to extend onto the reef flat seaward of the outer reef pool, with interspersed Padina and Halimeda algae; these algae were most commonly found attached to microatolls rising above the sandy bottom. Toward the outer reef flat, tall Turbinaria ornata, reaching to the water surface at high tide, dominated. Further seaward, the seagrass ended and the tall Turbinaria thinned. Caulerpa racemosa and other Caulerpa species carpeted the reef pavement, which had progressively less sand veneering it. At the reef crest, there was a dense zone of Sargassum sp., with some intermixed Turbinaria ornata (this zone was displaced by heaped-up shingle on the reef crest to the north). Beyond the Sargassum, Jania sp. was common. Encrusting coralline algae were common in the spur-and-groove zone beyond the reef crest.

On the reef slope (Station 15), Halimeda sp. was common in depressions. Caulerpa racemosa was common to a depth of 5 m; Jania sp. was common to a maximum depth of 6 m; and crustose coralline algae were abundant to a depth of about 11 m. Unidentified filamentous algae were noted on dead coral.

CORALS

Stony corals achieve their highest development on the slopes of the outer reef hole (Yenasr) and ocean-facing reef slopes. Lesser coral development was reported on the reef flats and slopes of the inner reef hole. Coral coverage varied considerably depending upon biotype: less than 1 percent for the inner reef hole, 5-10 percent for the inner reef flat, 50-75 percent on the slopes of the outer reef hole, 10 percent on the outer reef flat, about 40 percent on the upper spur-and-groove zone at the reef margin, and 80 percent on the deeper reef slopes. Over 50 species of coral were reported for all biotopes combined, and over 40 species were reported on the reef slopes alone.

In the inner reef hole, no coral species were abundant although the finger coral Porites cylindrica and small colonies of Pavona divaricata were common. Coral species common on the inner reef flat included Pavona divaricata, P. varians, microatolls of Porites lutea, and the blue coral Heliopora coerulea. Abundant corals in the outer reef hole included the blue coral Heliopora, the brain coral Favia pallida, and the staghorn coral Acropora formosa. Common corals included Porites spp., Pavona spp., Pocillopora damicornis, the stinging bubble corals Physogyra lichtensteini

and Plerogyra sinuosa, Psammocora contigua, the brain corals Platygyra daedalea and Favia spp., Diploastrea heliopora, the wire coral Cirrhipathes sp., the fire coral Millepora exaesa, the mushroom coral Fungia fungites, other staghorn coral species of Acropora, and the tube coral Goniopora lobata.

The most abundant coral on the outer reef flat was Porites lutea. Other common species included Pavona spp. and other Porites spp. There were many abundant corals on the ocean reef slope, with the robust table coral Acropora gemmifera approaching dominance on the upper slopes. Other abundant slope species included the irregular table coral Acropora irregularis, the small table coral Acropora digitifera, the branching coral Pocillopora verrucosa, the star coral Galaxea fascicularis, the fire corals Millepora platyphylla and M. dichotoma, the column coral Coscinaraea columna, and the soft alcyonacean coral Sinularia sp. At least 3 other stony corals were common on the slopes.

OTHER INVERTEBRATES

Seaward of the causeway (Station 12), on the edge of the inner reef hole, the sea cucumber Bohadschia argus was occasionally seen.

On the reef flat between the inner (smaller) and outer (larger) reef holes, the sea cucumbers Holothuria atra and Stichopus chloronotus were observed to be common to abundant.

Along the edge of the outer reef hole, the sea cucumber Bohadschia argus was common. Featherduster worms (Sabellastarte sp.) and Christmastree worms (Spirobranchus sp.) were locally common, embedded in microatolls adjacent to the reef hole. Tiger cowries (Cypraea tigris) were occasionally seen clinging to rocky overhangs. A single specimen of an oyster (Lopha sp.) was observed attached to a vertical wall of the reef hole.

On the reef flat seaward of the outer reef hole, the sea cucumbers Holothuria atra and Stichopus chloronotus were very common. The sea cucumber Holothuria leucospilota, typically found lying partially buried under a microatoll or ledge, was occasionally seen. A few skeletal remains (tests) of irregular sea urchins (clypeasteroids) were seen on the sandy bottom. Shell remains of various mollusks were found on the reef flat. Gastropod shells included Cypraea erosa, Conus pulicarius, Rhinoclavis asper, an unidentified moon snail (family Naticidae) and various small Strombus spp. Bivalve shell remains included Tellina remies, Fragum fragum, Scutarcopagia scobinata and Pitar cf. obliquatum.

Toward the outer reef flat, where Caulerpa spp. algae formed a carpet, the bright blue starfish Linckia laevigata was occasionally seen. L. multifora was also observed. Holothuria atra was a common sea cucumber all the way to the reef crest. The spider conch Lambis lambis was found once, on the inshore side of the reef crest.

The rubble area at the reef crest harbored many mollusks, small crabs, and other invertebrates. Intertidal snails (Nerita polita) were occasionally found on or near exposed coral shingle and rubble.

On the reef front, occasional individuals of the snail Turbo argyrostomus were seen, clinging to the reef pavement. Spiny sea urchins (Echinothrix calamaris) and pencil urchins (Heterocentrotus mamillatus) were seen in crevices in the spur-and-groove zone. A single large individual (approximately 36 cm in length) of Tridacna sp. was observed anchored to the bottom at a depth of about 2 m in a groove of the spur-and-groove zone. On the deeper reef slope (Station 15), no invertebrates were reported.

FISHES

On the reef flat and along the edges of the reef holes (Station 12), the most abundant groups of fishes recorded included surgeon fishes (esp. Acanthurus spp. and Ctenochaetus striatus), trigger fish (Rhinecanthus aculeatus), blennies (Amblygobius albimaculatus, and unidentified sp.), jacks (Caranx melampygus), butterfly fishes (Chaetodon sp., Heniochus chrysostomus), squirrel fishes (Neoniphon sp. and Myripristis sp.), wrasses (unidentified), emperors (especially Lethrinus harak), snappers (Lutjanus fulvus), mullet (Liza vaigiensis), damsel fishes (Chromis sp. and Dascyllus spp.), parrot fish (Scarus sp.), and moorish idols (Zanclus cornutus).

On the reef slope (Station 15), the most abundant fishes recorded included surgeon fishes (esp. Ctenochaetus striatus), trigger fishes (esp. Balistapus undulatus), caesionids (unidentified), squirrel fish (Myripristis sp.), wrasses (Halichoeres sp.), snappers (esp. Aphareus furcatus, Lutjanus fulviflamma), threadfin (Scolopsis cancellatus), sweepers (Pempheris oualensis), and damsel fish (Pletroglyphidodon dickii).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Lelu causeway area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E. A site of special note which dominates the Lelu causeway region (Map 3) is Lelu Ruins; this important site is also discussed in the Section 1 summary.

RESOURCE USE

The large, outermost reef pool in front of the Lelu causeway (KCRI

Station 12) appears to have excellent recreational diving potential, especially if water clarity in the area can be enhanced by restoring inshore water circulation near the causeway.

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

When asked about the culverts of the Lelu causeway, the interviewed fishermen indicated they thought that unblocking the central culvert, or adding additional openings near Marine Resources, may help reef fisheries (there are culverts still open in the causeway, on each side of Marine Resources, but the largest, central one is blocked). Migrations of fish (all species, but mainly rabbit fish and mullet) were said to have been blocked by the causeway. Comments of fishermen on additional resource use problems associated with the causeway, including effects on inner Lelu Harbor, are included in the Section 1 resource use summary.

WATER QUALITY

Inshore (KCRI Station 12), water in the inner reef pool was green in color and turbid, with horizontal visibility only 2-3 m; visibility on the adjacent reef flat ranged from about 4 to 8 m. The outer reef pools had a horizontal visibility of approximately 6-12 m, and the adjacent reef flat, 15-20 m. Horizontal visibility at the spur-and-groove zone was about 20 m. Offshore, on the reef slope (KCRI Station 15), horizontal visibility was in excess of 24 m (80 feet).

FOKO LIK
(Stations 10, 52, 11, 2)
(Atlas Map 3)

PHYSIOGRAPHY

This area and group of stations cover the outer headlands and reefs forming the northern boundary of Lelu Harbor and the ocean reef flats and slopes seaward of Lelu Island.

Lelu Island is a volcanic sea stack at the southern end of a large fringing reef with associated seagrass meadows. Off the island's eastern end is a series of elongate islets and storm ridges consisting of reef rock and sand. The reef islets' features were probably created during periods of heavy wave action (such as during storms) when corals and other reef material was dislodged from the reef slope and cast up on the reef flat to form coral features of rubble and shingle flats, cays, ramparts and low islets. A small semi-enclosed embayment (south of Station 10) occupies the space on the outer reef flat between the high volcanic island and low coral

islets. The reef flat beyond the coral islets and related features is very narrow (less than 100 m wide) and is slightly wider to the south opposite the entrance channel to Lelu Harbor. The outer fringing reefs off the south side of Lelu comprise the northern walls of the entrance channel (Stations 10 and 52). Windward ocean reef slopes occur beyond the eastern margin of the reef flat (Station 2) which is dominated by live corals. The outer reef flats are mostly hard reef pavement with some loose coral shingle and rubble. Within the embayment sand and seagrasses cover much of the reef flat. The reefs and promontories in this region are regularly exposed to heavy wave action from tradewind generated swells.

FLORA

Common shoreline vegetation between KCRI Stations 10 and 11 included Sonneratia, Pandanus, Scaevola, and coconut palms (Cocos nucifera). The small islets off the tip of Lelu Island did not contain any obvious mangroves, but did support Pandanus, Scaevola, and coconut palms.

The reef flat from the shoreline toward Lelu Harbor reef marker No. 2 (KCRI Station 10) was carpeted by Padina sp. Seaward, this alga was displaced by Caulerpa racemosa and Turbinaria ornata. Past the reef marker, at depths of 1 to 2 m, occasional fronds of a large red alga (Halymenia durvillaei) were found.

Algae were observed to be very sparse on the reef flat to the north, which is exposed at low tide. A bed of Turbinaria (and possibly Sargassum) was encountered during an additional walk toward the breaking waves near Station 11. Seagrasses were sparse inshore from the islets at Station 11, but became very dense toward Lelu Island. One filamentous alga (probably Gracilaria sp.) was very common among the seagrasses.

Offshore (KCRI Stations 52, 2), Halimeda was common to abundant on reef slopes; at Station 52 it was found to depths of about 24 m. Coralline algae were also common to abundant at these offshore stations; at Station 52, coralline algae exceeded 60 percent cover on the reef flat.

CORALS

Live corals are nearly absent on the outer reef flats of this area. No species were reported within the embayment or on the outer reef flat to the north. Only 3 species were reported on the narrow fringing reef facing south towards the channel including Porites sp., Pocillopora brevicornis, and small table corals of Acropora sp.

In contrast, the ocean reef slopes (Station 2 at Foko Lik) and the northern channel wall (Station 52) supported diverse and lush coral communities. Twenty-five species of corals were reported on the reef slope at Foko Lik while 30 species were reported on the channel wall. Average coral abundance was 75-80 percent on the ocean reef slope and over 50 percent on the channel wall. Live corals are found to a maximum depth of

about 15-20 m. Dead coral and a talus of coral rubble occurs at greater depths to the base of the channel wall.

Abundant coral species off the ocean reef slope at Foko Lik include Porites spp., table Acropora spp., Platygyra spp. (brain corals) and the soft coral Sarcophytum sp. Common corals included other species of Porites and Acropora, the disc coral Pavona clavus, encrusting species of Montipora, the branching coral Pocillopora verrucosa, and the brain corals Favia spp. and Favites spp. Abundant coral species off the northern channel include the brain corals Platygyra and Acropora spp. Common coral species include the stinging bubble coral Physogyra lichtensteini, other Porites spp., Favia spp., Favites spp., the purple lace coral Distichopora violacea, additional species of Acropora, and Hydnophora spp.

OTHER INVERTEBRATES

Intertidal snails (Nerita plicata) and unidentified grapsid crabs were common on rocks along the shoreline. Ophiuroids (brittlestars) were common to abundant in holes on the inshore reef flat near Station 10 (Lelu Harbor reef marker No. 2). The sea cucumber Holothuria atra was also common to abundant over most of the reef flat. At the outer edge of the reef flat, in the Turbinaria algae zone, the sea cucumber Actinopyga mauritiana was occasionally seen. Tunicates (Diademnum sp.) were common on the reef pavement. At a depth of approximately 1 m, live Trochus niloticus were encountered. Two living specimens of Tridacna sp. were seen at a depth of less than 2 m, near stands of Acropora table coral, just inside the deep dropoff into the channel.

At the reef islets (Station 11), the reef flat rubble and shingle provided habitat for intertidal snails (Nerita polita); the shells of this species were being utilized frequently by the numerous hermit crabs living on the sandy shoreward beaches of the islets. In the seagrass beds situated shoreward of the islets, occasional box crabs (Calappa sp.) were seen on the sandy bottom. Brown, erect sponges were common among the seagrasses and were quite abundant toward the shoreline of Lelu Island; this type of sponge is sometimes collected and used locally for cleaning cooking pots.

Offshore (Station 2), at depths of about 18 to 24 m, yellow sponges were reported as common. Occasional sea anemones (with associated damsel fishes) were seen.

FISHES

At the inshore areas (Stations 10, 11), which were walked at low tide, only incidental fish observations were made. At the edge of the fringing reef at the Lelu Harbor channel (Station 10), fishes noted included unidentified surgeon fishes, butterfly fishes (Chaetodon sp.), snappers (Lutjanus fulvus), and occasional unidentified parrot fish.

Offshore, at Station 2, jacks (Caranx sp.) were abundant and snappers (Lutjanus sp.) were common; occasional fusiliers (Paracaesio sp.) and groupers (Epinephelus sp.) were seen.

OTHER VERTEBRATES

Several Pacific reef herons (Egretta sacra) were observed on the reef flat during the KCRI survey. A local informant stated that these birds nest on the reef islets (KCRI Station 11). Several cardinal honeyeaters (Myzomela cardinalis) were observed flying from Lelu Island toward the trees of the reef islets (Station 11). Any of the other vertebrates discussed in the overall summary section may also occur in this region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E. A site of special note which dominates the entire Lelu Island region (Map 3) is the Lelu Ruins; this important site is also discussed in the Section 1 summary.

RESOURCE USE

The small reef islets at the northeast end of Lelu Island contain planted coconut groves and stands of Pandanus (leaves used for weaving sleeping mats).

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

WATER QUALITY

On the shallow reef flat fronting the Lelu Harbor entrance channel (Station 10), some turbidity of inshore waters was noticeable; however, seaward toward reef marker No. 3, the water cleared noticeably. This clearing was also apparent in nearshore waters of the reef slope: paper debris, mangrove seeds, and various leaves were observed in the turbid nearshore area nearest Lelu, while at reef marker No. 3 the reef was free of debris and horizontal visibility was more than 10 m. In the vicinity of the reef islets (Station 11) and across the broad, seagrass-covered reef flat to the north of the islets, silty bottom conditions prevailed but the water appeared clear. Water clarity at offshore reef slopes (KCRI Stations 2, 52) was good; horizontal visibility at Station 2 was greater than 18 m (60 feet).

LELU HARBOR
(Stations 51, 46, 47, 48, 49)
(Atlas Maps 3, 4)

PHYSIOGRAPHY

Lelu Harbor is the largest of 3 major embayments on Kosrae, measuring 3 km along an east-west axis between the entrance channel (Molsron Lelu) and Tofol and nearly 4 km along a north-south axis between the fuel pier at Tafuyat and the bridge at Inya Mutunnenea. The harbor appears to be a drowned river valley which has been colonized by coral reefs and infilled with sediments since the last ice age, when a sea level rise of about 100 m occurred about 11,000 to 8,000 years ago. The harbor is deep with many areas in excess of 20 m in depth, and the floor of the harbor is filled with deposits of fine muds and silts. Lining the perimeter of the harbor are fringing reefs, except along the south coast of Lelu Island where the reef and coastal plain are narrow. Here the high volcanic slope is close to the harbor shoreline.

At the beginning of the 20th century, the slopes of the harbor were probably dominated by living coral communities with coral rubble tali at the base of the slopes. However, a combination of environmental factors has degraded the reef slope communities including the blockage of circulation due to construction of the Lelu causeway and other dredging, filling and possibly sewage discharges. Presently only the outer channel walls and the eastern faces of southern harbor fringing and patch reefs still retain healthy reef communities. The floor of the entrance channel may be hard due to tidal currents preventing accumulation of sediments.

The reef flats surrounding the harbor vary from wide to narrow. The outer lip and margins have higher coral growth but for the most part, the reef flats are covered by sand and silt. Seagrass bed development in the harbor is presently patchy and was probably better developed prior to recent water quality stresses. The outer reef flats at Yelpong, including the patch reef flat on Wenasr, include some seagrass beds. Additional beds are located along the inner reef flat at Foko Puk, the reef forming the southern side of the entrance channel and are located along the coastal fringe at Mutunnenea near the northern limits of the Harbor landward of the causeway. There is evidence to suggest that these last seagrass beds are maintained by strong tidal currents exchanging the nearby culvert through the causeway.

A large mangrove swamp occupies most of the inner reaches of the reef platform along the western fringe of the harbor with a small freshwater swamp forest occurring in the region of Infal Kaa to Infal Tafuyat near the fuel pier. Another smaller freshwater swamp forest occurs on the landward side of the road near Muntunlik. Most shorelines are dominated by mud flats but sand and coral rubble beaches occur along the outer more exposed shorelines of the harbor.

FLORA

Sonneratia trees were common along the shoreline of the inner harbor area visited during the KCRI survey (Station 46).

Very little seagrass was seen at the Lelu Harbor reef flats visited during the survey. Seagrasses were very rare on the reef flats at Station 46, occasional at Station 48, and not observed at Stations 47 and 49 (these observations are in rough agreement with fishermen interviewed at Lelu, who indicated that Yelpong reef flat fishing has been affected by the creation of the Lelu causeway while the next reef (Wenasr) has not, and that Yelpong reef flat now has no apparent seagrasses; interview comments are included in the Section 1 resource use summary.

In contrast to the seagrasses, algae were generally common at the stations visited, especially Halimeda spp. and Caulerpa spp. At least two species of Halimeda were regularly seen, including one with large thalli, H. macroloba. The most frequently seen Caulerpa species was C. racemosa. The large red alga Halymenia durvillaei was occasionally seen on the reef flat at Stations 47 and 49. Crustose coralline algae were noted only on the reef flat of Station 49 (less than 1 percent of total cover) and on the slopes of the reef at Station 48, where they were recorded as common. No algae were reported at the shipwrecks of Station 51.

CORALS

The coral communities in Lelu Harbor differ somewhat from those on reef flat or reef slope environments in more open or exposed conditions on Kosrae. Several species and some genera were not reported outside Lelu Harbor including the knobbed coral Euphyllia cristata, an unidentified species of the brain coral Favia, the mussid coral Scolymia, the lobed coral Goniopora sp., and the vermillion tube coral Tubastraea coccinea. Wire coral (Cirphipathes sp.) achieved unusual abundance or dominance at most harbor sites.

The innermost reef areas have the least coral development, especially in the north harbor near the causeway and other recent dredge and fill sites. For example, only four coral species were reported at Station 46. Conversely, coral communities facing east towards the entrance channel and in the southern outer harbor nearer the channel achieved the greatest development. For example, at Stations 47, 48, and 49, the total numbers of coral species reported were 44, 25, and 38, respectively. Coral abundance was higher on the slopes, achieving 25 percent, 33 percent, and 50 percent average coverage respectively at Stations 47, 48, and 49 (which are progressively closer to the entrance channel in that order). Coral coverage was low on the reef flats except near the outer margins and lips and coral development is essentially absent from the lagoon floor except on the elevated surfaces of shipwrecks. For example at Station 51 nine coral species have colonized the hard elevated surfaces of several shipwrecks.

The most abundant corals in the Harbor were the lobe coral Goniopora somaliensis, the finger coral Porites cylindrica, the head corals Porites lobata and Porites lutea, Porites (Synaraea) rus, the brain coral Platygyra daedalea, the bracket coral Mycedium elephantotus, the wire coral Cirrhipathes sp., the branching coral Hydnophora rigida, and several species of table corals (Acropora spp.).

OTHER INVERTEBRATES

Intertidal snails (Littoraria scabra) were common on the trunks and lower leaves of Sonneratia trees at Station 46. Living bivalves (Mytilus sp.) and small, dark gastropods (possibly Cerithium sp.) were common on dead tree trunks at this inner-harbor station. Occasional grapsid crabs were seen on the Sonneratia trunks. Station 46 was notable for its abundance of aging shell remains of cowries, cones, other gastropods, and some bivalves on the reef flat and in the adjacent dredged channel. Some living gastropods were seen, including a few Conus eburneus and C. miles, Vasum turbinellus, and Cypraea moneta. One living specimen each of the bivalves Hyotissa cf. cristogalli (a large oyster) and Chama sp. were found on the reef flat. Skeletal remains (tests) of irregular sea urchins (clypeasteroids) were found at Station 46 and the reef flat stations visited in the outer harbor (Stations 47, 48, 49).

Reef flats in the outer half of the harbor (Stations 47, 48, 49) were observed to have more living mollusks and fresh shell remains than were seen at Station 46. Gastropod species occupying hard substrates, especially Drupa spp., Morula granulata, and Vasum turbinellus, were relatively more common at Stations 47 and 49, while gastropods observed at Station 48 included a number of sand or rubble dwelling Strombus species and occasional living Cerithium nodulosum. A few living Chicoreus sp. and Bursa sp. were found at Station 49. Various cone and cowry species occurred at these three stations. On the intertidal and shallow subtidal portions of the reef marker at Station 47 were found various gastropods, including Conus spp., Coralliophylla violacea, Cypraea caputserpentis, Drupa albolabris, and Morula granulata. Only a few bivalve shell remains were seen, mostly on the sand and rubble flat of Station 48. Few echinoderms were seen at Station 47, 48, and 49, except that the sea cucumber Holothuria atra was abundant on the sand and rubble flat at Station 48, and a few spiny sea urchins (Echinothrix sp.) were seen in small holes along the reef edge. Christmastree worms (Spirobranchus sp.) occurred in massive corals along the edge of the reef at Stations 47 and 49. Small blue and green sponges were common along the edge of the reef flat at Station 48. At the shipwrecks of Station 51, no non-coral invertebrates were reported.

FISHES

In inner Lelu Harbor (Station 46), 34 fish taxa representing 16 families were recorded. The most abundant fishes recorded included surgeon fishes (Acanthurus spp., Ctenochaetus binotatus), gobies (esp.

Acentrogobius ornatus), rudder fish (Kyphosus sp.), wrasses (esp. Thalassoma hardwickei), and snappers (Lutjanus spp.).

At reef areas in the middle to outer portions of the harbor (Stations 47, 48, 49), the numbers of taxa recorded were higher, 42, 49, and 58, respectively. Fishes reported as common at these stations included surgeon fishes (esp. Ctenochaetus binotatus), jacks (Caranx melampygus), butterfly fishes (esp. Chaetodon kleini, C. vagabundus, Heniochus varius), gobies (esp. Acentrogobius ornatus), sweetlips (Plectorhynchus nigrus), rudder fish (Kyphosus sp.), wrasses (esp. Halichoeres hortulanus, Thalassoma hardwickei), goat fishes (esp. Parupeneus cyclostomus), angel fishes (esp. Pygoplites diacanthus), damsel fishes (esp. Chromis ternatensis), and groupers (esp. Cephalopholis analis). The rabbit fish Siganus fuscescens, observed at Station 47, was the only fish species reported as abundant at any of the harbor stations. The shipwrecks at Station 51 attracted occasional fusiliers, jacks, spade fish (Platax orbicularis), snappers, scorpion fish, and rabbit fish.

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in Lelu Harbor; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E. A site of special note which dominates the Lelu Island region (Map 3) is Lelu Ruins; this important site is also discussed in the Section 1 summary. Also of note are several shipwrecks, including one wooden-hulled ship, which have been found in Lelu Harbor.

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

Fishermen interviewed indicated that construction of the Lelu causeway and the old airstrip (shown on Atlas Map 3) have affected resources and resource use in the inner Lelu Harbor area. The fishermen suggested that removing a portion of the former runway may have a beneficial affect on coral growth in the area. The fishermen also indicated they thought that unblocking the central culvert, or adding additional openings near Marine Resources, may help the fisheries of the area (there are culverts still open in the causeway, on each side of Marine Resources, but the largest, central one is blocked). Migrations of fish (all species, but mainly

rabbit fish and mullet) were said to be blocked by the causeway. The fishermen indicated that Yelpong reef flat fishing has been affected by the creation of the causeway, but that the next reef (Wenosr) has not. Additional interview comments are included in the Section 1 summary.

WATER QUALITY

In inner Lelu Harbor (Station 46), horizontal visibility at the dredged reef near the end of the old airfield causeway was poor near the surface at the time of the KCRI survey, only 2 to 3 m, due to the presence of a turbid, brackish water layer at the surface (thickness less than 1 m). Visibility was better, approximately 6 m (20 feet), below the surface layer. Only very slight water movement was observed toward the manmade causeway culvert on the slowly ebbing tide. The substrate was very silty at this location.

At Station 47, horizontal visibility was at approximatly 9 m (30 feet); some silt was present.

At Station 48, horizontal visibility at the surface was poor; a brackish water discontinuity blurred observations. Below a depth of approximately 3 m, water clarity was higher, approximately 9 m (30 feet). There was no noticeable current flow.

At Station 49, poor horizontal visibility (3 m) and a brackish water discontinuity were observed at depths of less than 3 m; below this depth, visibility was 12 m and the water was noticeably bluer in color. There was no noticable water current on the slightly ebbing tide.

Surface water turbidity, with clearer water (horizontal visibility 6-9 m) at depths below 3 m, was also observed in the central harbor area (Station 51).

FOKO PUK
(Stations 9, 1)
(Atlas Map 4)

PHYSIOGRAPHY

Foko Puk is the southern headland of the entrance of Lelu Harbor and constitutes the easternmost point of land and reef area on Kosrae. The point faces in a northeast to southeast direction and is exposed to tradewind-generated wave action which breaks frequently on the outer edge of the reef. The volcanic promontory of Ten Wak and Muntunlik is very close to the reef. Only a narrow fringe of mangrove and seagrasses occurs landward of the open reef flat. The narrow northern terminus of the large freshwater swamp forest also occurs at Ten Wak. The circumferential road generally runs close to the boundary between the mangrove forest (to

seaward) and freshwater swamp forest (to landward) at Ten Wak. A small open waterway exits through the mangrove forest and under the road and bridge to the reef at Foko Puk.

The open reef flat is well developed, achieving a maximum width of 400 m. Extensive seagrass meadows cover the inner two-thirds of the reef flats. The beach consists of coral sand and rock. The outer third of the reef flat is hard pavement overlain with loose fragments of reef rock and shingle. Some shingle tracts are elevated 30 cm or more above the reef pavement toward the surf zone corraline algae and corals become dominant and remain so on the surfaces of the well developed but gradually sloping spur-and-groove formations. Beyond, in deeper water, are luxuriant stands of line coral covering the ocean reef slopes.

FLORA

At Station 9, nearshore seagrass beds were extensive, occupying the inner two-thirds of the reef flat. These beds had a well-developed "turf" or "sod" layer on the inner half of the reef flat, but seaward this gave way to sand-veneered pavement where algae (Padina sp., then Caulerpa sp. and Halimeda sp.) predominated. Caluerpa and Halimeda algae were observed with increasing frequency through the next offshore zone (hard pavement with coral blocks and microatolls) until a zone of rubble and shingle was reached. Beyond the rubble and shingle, the reef pavement was veneered with a thin algal mat. In the wave-washed zone on the broad reef front, Jania sp. and Dictyosphaeria sp. were common, and some Valonia sp. was seen. Seaward, pink crustose coralline algae dominated. Near Lelu Harbor channel, Turbinaria replaced Jania on the reef front.

Offshore, at depths of more than 5 m (Station 1), Halimeda sp. and crustose coralline algae were common.

CORALS

Few corals occur on the reef flat. Only 5 species were reported on the outer margin, including the finger coral Porites cylindrica, microatolls of Porites lutea, encrustations of Leptastrea purpurea, broken living fragments of the fire coral Millepora platyphylla, and small ramose colonies of Montipora digitata in shallow reef depressions. Total live coral coverage was less than 1 percent.

In contrast, the open ocean reef slope at Foko Puk beyond the surf zone was characterized by abundant development by corals. Coral coverage averaged 75-80 percent. The relief of the coral community was low but species diversity was high, 36 species. Abundant species included the foliaceous yellow coral Turbinaria stellulata, the soft coral Sarcophytum, several species of corymbose corals (Acropora spp.) and several species of table coral (Acropora spp.). Common corals included the stinging bubble coral Physogyra lichtensteini, the purple lace coral Distichopora violacea, massive heads of Porites spp., encrusting Leptastrea spp., the brain corals

Leptoria phrygia and Favia spp., the mushroom corals Fungia spp., small heads of Favites spp., encrusting colonies of Montipora spp., the star coral Gaiaxea fascicularis, the column coral Psammocora digitata, and leafy growths of Echinopora lamellosa.

OTHER INVERTEBRATES

The snails Melampus flavus and Nerita plicata were common on beach rocks, and the snail Littoraria coccinea was common on tree trunks, at the shoreline area of Station 9. In the extensive seagrass beds of the adjacent reef flat, the cowry Cypraea moneta was frequently seen on seagrass blades. The sea cucumber Holothuria atra was observed to be common to abundant over most of the reef flat.

Coral blocks, rubble and shingle, and small reef holes on this reef flat provide intertidal and subtidal habitat for a wide variety of invertebrates. Intertidal organisms, especially grapsid crabs and the snails Nerita polita and N. albicilla, were observed to be common. Numerous species of cowries (especially Cypraea moneta and C. annulus) and cones (especially Conus rattus and C. eburneus) were also common. A variety of other gastropod mollusks (including some small Trochus niloticus), but virtually no bivalves, were observed. In addition to mollusks, reef flat organisms found in or near the shingle and rubble zone included a wide variety of small crabs, sea urchins (Echinothrix calamaris, Diadema savignyi, Echinometra mathaei), brittlestars (ophiuroids), and neriid polychaete worms. On the reef front, in the wave-washed zone, the sea cucumber Actinopyga mauritiana was occasionally seen.

Offshore, at depths of greater than 5 m (Station 1), yellow sponges were reported as common and Christmastree worms (Spirobranchus sp.) as occasional.

FISHES

Low tide conditions existed at the time of the survey of inshore areas at Station 9, exposing much of the reef flat and preventing most fish observations. Small, unidentified moray eels (probably Echidna nebulosa or Gymnothorax pictus) were common in the shingle and rubble area of the reef flat.

On the offshore reef slope (Station 1), at depths of 8 to 12 m (25 to 40 feet), surgeon fish (Ctenochaetus striatus) and fusiliers (Caesio xanthonotus) were reported as abundant (the C. striatus were observed in an apparently breeding aggregation of 200 to 300 individuals). Fishes reported as common at similar depths on the slope included another species of fusilier (Paracaesio sp.), squirrel fish (Myripristis sp.), and parrot fish (Scarus sordidus).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Foko Puk area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 1 summary). The region of Foko Puk (Atlas Map 4) is unsurveyed.

RESOURCE USE

The reef flat at Station 9 was found to be very rich in invertebrate species. Because of its diversity and easy access, this reef flat has potentially high educational value.

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 1 summary.

WATER QUALITY

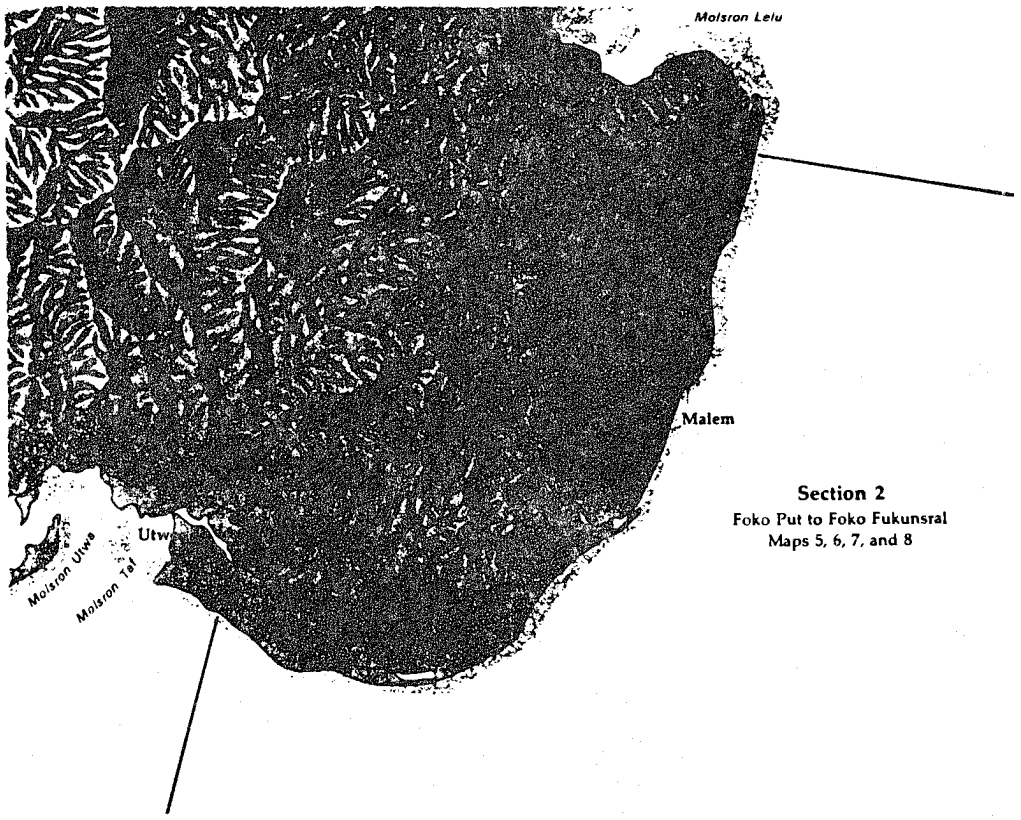
The shallow reef waters on the reef flat at the south side of Lelu Harbor (Station 9) appeared to be clear. On the reef slope (Station 1) horizontal visibility was reported as more than 18 m (60 feet).

MAP SECTION 2 (MALEM)

SUMMARY

GENERAL DESCRIPTION

This southern portion of Kosrae contains the village of Malem, which is located on the coastal strand formation on the seaward side of the very extensive swamp forest which dominates much of the northern coastal area of this municipality.



PHYSIOGRAPHY

The southeast sector of Kosrae centered around Malem exhibits a consistent set of coastal geomorphological features. Furthest inland is the volcanic "shoreline" of the island. Landward of this "shoreline" are the steep slopes of the higher interior portion of the island and a series of irregular headlands (Pilyuul, Yeseng, Mosral, Kuplu) and valleys with stream channels (Infal Pilyuum, Infal Malem, Infal Yeseng). Oceanward of the volcanic shoreline is a broad reef platform extending 0.5 to 1.0 km in a seaward direction and mostly covered with vegetation. The largest and most interior biotope on the platform is a huge continuous freshwater swamp averaging 0.75 km wide and stretching the entire length of Map Section 2. Seaward of the freshwater swamp is a narrower fringe of mangrove forest which terminates on the landward side of the coastal strand or coral island biotope. Small stands of mangroves occupy the seaward side of the coastal strand, especially near the mouths of streams.

The seaward shoreline of the strand is mostly a sandy beach. The open reef flat seaward of the beach is generally very narrow, averaging 200 m in width or less. A band of seagrasses occupies the inner half of the northern reef flats facing east. As the reef bends around clockwise to the south, the width of the reef flat diminishes to 100 m and the seagrass beds are absent. The outer half of the eastern facing reef flats and all of the more southern facing reef flats consist of a hard coral pavement covered with scattered coral rubble and tracts of coral shingle. The prevailing northeast tradewinds generate surf which breaks on the outer edge of the reef along Map Section 2. However, wave action tends to attenuate when moving south from eastern-facing to southern-facing reefs. At the south-western boundary of Section 2 (at the Utwe/Malem municipal boundary) sea conditions are nearly flat during tradewind conditions except for southerly swells breaking on the reef edge. Spur-and-groove formations are present beyond the outer edge of the reef flat and become less developed when moving clockwise from the eastern to southern boundaries of Section 2.

Luxuriant coral communities cover all ocean reef slopes below the base of the spur-and-grove formations at about 5 m depth. Live corals dominate the slopes to depths of 20 m or more. At the time of our fieldwork a typhoon passed along the south coast of Kosrae in May 1986. When we returned in August 1986, we surveyed southern facing reefs and reported major damage to live corals from wave action, probably from the May storm (Lola). Coral rubble and blocks were also thrown up on the coastal strand/coral island, with some fragments landing as far inland as the circumferential road.

Thus, we were able to witness a minor episode of a process that has probably been occurring for many thousands of years - coral island building on the outer reef flats of southern Kosrae. Over time, large accumulations of coral rubble, shingle and sand have been cast up on the outer reef flats by waves, building coral islands and blocking movement of marine waters inland of the coastal island barrier. In turn, this has facilitated development of mangrove forests and freshwater swamps completely changing the surface physiography of the reef platform nearer to the volcanic interior of the island.

FLORA

A striking feature of the vegetation of Malem Municipality is the very large swamp forest which separates the beach strand area from the basaltic uplands (Atlas Maps 5-8). Toward the western end of Malem, the swamp forest gives way to mangrove forest.

On the relatively narrow and rocky reef flats of this Section 2, seagrass beds were found two of the four inshore stations visited (Stations 7 and 8), but these beds were sparse and patchy. In the surf zone the green alga Caulerpa racemosa and other Caulerpa spp. were typically found forming a carpet on sand-veneered pavement between large reef rocks. The Caulerpa carpet generally gave way to an increasing cover of Halimeda spp. through channels in the reef crest and into the spur-and-groove zone; however, at the eastern stations visited, the relatively solid reef crests were occupied by dense beds of Sargassum (Station 8) or Turbinaria and Padina (Station 7), accompanied by Jania and other algae. Halimeda spp. and encrusting or massive coralline algae were generally common to abundant in the spur-and-groove zone. Halimeda was also found among living corals at greater depths offshore.

CORALS

Corals are confined to the ocean-facing reef slopes along the southeast coast of Kosrae because of the lack of wide or deep reef flats, the lack of reef holes, the lack of passes or channels, and the lack of embayments. Only two coral species are reported on the reef flat, microatolls of Porites lutea and branching colonies of Montipora digitata in depressions.

In contrast, the ocean reef slopes support diverse and abundant coral communities. The most common forms are corymbose and tabulate species of Acropora, staghorn and moosehorn species of Acropora, small encrusting colonies of Montipora, disk-like forms of Pavona, a number of brain coral species (Favia, Favites, Goniastrea, Hydnophora, and Platygyra), blue coral (Heliopora), fire coral (Millepora platyphylla), branching corals (Pocillopora spp.) and a number of species of Porites. Of interest was the star coral Galaxea fascicularis which was very abundant on some reef slopes.

OTHER INVERTEBRATES

As revealed by the mapped resource use data in the Kosrae Coastal Resource Atlas, wetlands inland of the long coastal strands of Section 2 are inhabited by invertebrates utilized by island residents. Coconut crabs (Birgus latro) and land crabs (Cardisoma sp.) are found in the very extensive swamp forest and associated beach strand areas, and the mangrove crab (Scylla serrata) is found in mangrove areas. Known habitats of additional invertebrates collected by residents are also revealed by the resource use symbols on the atlas maps. Highlights of invertebrate observations at KCRI stations in Malem follow.

Shoreline snails were readily found in Section 2: the most common included Littoraria scabra, on mangrove (Sonneratia) roots; L. coccinea, on dead tree trunks; Nerita plicata, on beach rock; and Nerita albicilla, on coral shingle at the water's edge. On partially submerged boulders resting on reef pavement just inside the surf zone, various other gastropods occurred occasionally to commonly, including Vasum turbinellus, various drupes, and an unidentified species of patellid (limpet). Some bivalve shell remains (Asaphis violescens) were seen occasionally among the nearshore rubble. Other mollusks were seen rarely. Some echinoderms were found, including the sea cucumbers Holothuria atra (common, on reef flat at Station 7 only) and Actinopyga mauritiana (occasional, clinging to rocks in surf zone) and brittlestars (abundant under rocks and in holes of nearshore pavement, Station 8 only). Beyond the surf zone, few non-coral invertebrates were observed. A group of squid was observed near the surface at Station 43. A sea anemone with associated fish was observed at Station 44. Occurrence of living Tridacna sp. at a depth of about 10 m was reported at Station 45. Sponges were observed on the reef slopes at Stations 43 and 44.

FISHES

Fishes recorded in Section 2 during the KCRI field survey are listed by station in Appendix D. Survey emphasis was on recording conspicuous species utilized for food. At least 91 fish species, representing 25 families, were recorded in Section 2.

At inshore areas (Stations 8, 7) incidental fish observations were made. Small, unidentified moray eels (probably Echidna nebulosa or Gymnothorax pictus) were occasionally flushed in the shingle and rubble area of the reef flat. Juvenile surgeon fishes (Acanthurus spp.) and blue damsel fishes were common on the inshore reef flat.

Fishes recorded as common or abundant on the reef front or slope at one or more of the offshore areas (Stations 42, 43, 44, 45) included various surgeon fishes (Acanthurus spp., Ctenochaetus binotatus, Naso hexacanthus), trigger fish (Balistapus undulatus), butterfly fishes (Chaetodon spp.), rudder fish (Kyphosus sp.), wrasses (Thalassoma spp., with numerous others observed occasionally), snappers (Aphareus furcatus, Lutjanus fulvus, Macolor niger), goat fish (Parupeneus multifasciatus), various damsel fishes, and parrot fishes (Scarus spp.).

OTHER VERTEBRATES

Vertebrates other than fish were only incidentally recorded during the KCRI field survey. During transits of the KCRI survey boat, several small groups of unidentified cetaceans (dolphins or porpoises) were observed offshore in the vicinity of Foko Fukunsral (Station 42). Any of the other vertebrates discussed in the overall summary section of this report may also occur in Malem.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Archaeological work in the Malem area has been limited to date, with one survey in Kuplu, one in the upper valley of Malem itself, and a brief study at Lela on the shore [26]. Malem's lack of an extensive reef undoubtedly affected resource exploitation. It definitely affected transportation; canoes travelled along a cleared channel inside the strand islets and among the mangroves. Permanent dwelling sites are found on the strand islets on the outer edge of the mangroves. These are large, single enclosures in Kuplu and a dense series of abutting, low-walled, large rectangular enclosures in Lela. Permanent dwellings were also present inland in the upper valleys and on the Kuplu plateau. In Kuplu, these were scattered house sites, often low enclosures. The swampy coastal plain behind the mangroves was the location for wet taro cultivation. Also, crops were grown about the houses.

During World War II, Malem was the center for Japanese military activities on Kosrae. Historic sites from this period have been identified. These sites are located inland of the mangroves on the coastal plain and in Malem's upper valley. They include a fighter strip (never completed), defensive caves and foundations of officers' quarters, and a hospital.

RESOURCE USE

During the KCRI survey, the reef flat at Station 9 was observed to be very rich in invertebrate species. Because of its diversity and easy access, this reef flat may be particularly suitable for teaching reef ecology.

A meeting with resource users was held at Malem on 4 August 1986. Information obtained from participants was used to map resource use in Section 2 of the Kosrae Coastal Resource Atlas. Additional information obtained from resource users is summarized below.

Notes on resource items

The interviewed fishermen noted that coconut crabs move back and forth between the ocean and forest. There used to be lots of coconut crabs. Monitor lizards are eating the young crabs. The lizards were brought into Kosrae in 1936; the Japanese brought six of them to Malem and let them go (some lizards may have also been taken to other areas on Kosrae). The lizards grow to about 1 meter in length and are green in color. Monitor lizards also eat land crabs. Land crabs are found "everywhere" in Malem: "plenty".

None of the "rare" clams (tuk) are found in Malem, nor are the popol clams. Punak clams are found here. There is a small clam (katat), found in the beach sand near the water's edge, which they eat. (For scientific names associated with these Kosraean names, see resource use overall summary section.)

No hammerhead sharks or sardines are caught in Malem. Small moray eels found on the reef flat (here and elsewhere around the island) are caught for food --"people like them better than other fish".

Resource use problems

The fishermen interviewed indicated that they didn't have a good harbor to get their boats in and out to go spear and fish, and that this keeps them from fishing as much as they would like. They launch their canoes (they have two) at the Malem River channel. They would like to get a small boat harbor at that location or at an alternative site. The chief magistrate said that the 5 year economic development plan includes a harbor for Malem but the plan was not yet in effect. There appeared to be unanimous agreement among the fishermen present at the meeting that a harbor was desirable. Participants stated that the Malem fishermen do go elsewhere on the island to fish. It's "okay" for them to do this (no social restriction or permission needed). There is no problem with others coming from elsewhere to fish in Malem.

Fishing has been decreasing, overall. Number and size of fish have both decreased. More fishermen and more fishing techniques, especially the use of the fish poison plants, were identified as causes. There is a "law" against the use of the poison plant or "op" (Derris sp.) leaves but not against use of the roots. The chief magistrate indicated he would like to change the law to abolish all use of poison plants for fishing. There is no particular location for the use of the poison plant fishing technique. Dynamite was not being used.

WATER QUALITY

The coastal waters of this section are Class AA [73]. For class definitions, see Appendix E.

The only source of discharge identified in 1979 [71] was Malem Stream, which discharged a small amount of contamination originating from a few point (toilets, pig-pens) and non-point (siltation) sources. Coastal discharge sites off Malem were investigated by the University of Hawaii in 1984 [13].

Water quality observations made during the KCRI survey are noted at each of the area descriptions which follow. At the time of the KCRI survey, inshore waters in Malem generally exhibited some yellowish coloration suggestive of mangrove/estuarine influence and were moderately turbid, although the observed turbidity was undoubtedly due in part to rainfall at some stations. Offshore, observed water clarity was generally moderate to very high.

FOKO YEWAK
(Stations 8, 45)
(Atlas Map 5)

PHYSIOGRAPHY

The coast of Kosrae north of Malem village faces the ocean in an east-southeast direction and consists of steep ocean reef slopes, spur-and-groove formations, narrow open reef flats, a narrow band of seagrasses, a beach dominated by sand, only a few stands of mangroves, and a huge freshwater swamp forest inland of the road and coastal strand. The swamp extends across the inner three-fourths of the reef platform to the base of the volcanic slopes with the island's interior. The coastal strand shoreline and reef line are nearly straight with only minor headlands and one coastal indentation at Pilyouul (at the site of Stations 8 and 45). One km north of the indentation is a bulge in the shoreline which is bisected by the municipal boundary line between Malem (to the south) and Lelu (to the north). Foko Yewak is another outward bulge of the shoreline and reef line about 1 km south of the indentation at Pilyuul. The streams in the region include Infal Pilyuum to the north and Infal Malem to the south.

Although the basement reef platform along this coast is wide (750 m) the open reef flat facing to the ocean and seaward of the strand shoreline is narrow, about 200 m wide, and is covered by a hard reef pavement. Seagrass beds cover the inner margin of the reef flat, but loose fragments of coral shingle, rubble and some boulders are strewn over the outer exposed half of the reef margin. The narrowness of the reef results in heavy wave action on the reef flat and shoreline, especially at high tide, and there are no natural channels or passages through the reef to facilitate boat access. The spur-and-groove formations were poorly defined.

FLORA

Sonneratia trees were noted along the shoreline at Station 8. Seagrass beds were found in patches and tufts on the nearshore reef flat, while algae dominated further offshore, toward the wave-washed reef crest. An unidentified alga occurred on the inshore half of the reef pavement as a brownish "scum". The green alga Caulerpa racemosa formed a sparse carpet on the reef pavement, accompanied by scattered Turbinaria ornata. The red alga Actinotrichia fragilis occurred occasionally near the reef crest, which was occupied by a dense belt of Sargassum sp. Seaward of the crest, Jania sp. and Valonia sp. were occasionally seen. In the shallow upper portion of the spur-and-groove zone, Caulerpa racemosa, C. sp., and Halimeda sp. were common in pockets between the living corals.

Offshore (Station 45), at depths of 0 to 3 m in the spur-and-groove zone, massive coralline algae were common.

CORALS

On the reef flats living corals are confined to the outer margin in depressions near the surf zone. Microatolls of Porites lutea and P.(S.) rus, encrustations of Porites lobata, branching colonies of Montipora digitata, and the brain corals Platygyra spp. and Goniastrea retiformis were common, but no coral species was abundant. Overall coral coverage was less than 1 percent. A total of 14 coral species were reported on the reef flat, but two of these, Millepora platyphylla and Acropora irregularis, consisted of live fragments broken off from the ocean reef slope by wave action.

The spur-and-groove formations occur within the surf zone immediately seaward of the reef flat and support higher coral abundance. The spur-and-groove formation varied from 0.25 to 2 m in vertical relief with some channels (grooves) wide and outer flanks of the buttresses (spurs) wide. Most surfaces were dominated by coralline algae, but several corals were abundant: the fire coral Millepora platyphylla, the branching corals Pocillopora spp., the small table corals Acropora spp., and the blue coral Heliopora coerulea. Common species included Porites lutea, the brain corals Hydnophora microconos and the moosehorn coral Acropora cuneata. Small incrustations of Goniastrea retiformis and Leptastrea purpurea were also common. A total of 13 species was reported.

Coral abundance and diversity were highest on the ocean reefs downslope from the spur-and-groove formations. However, coral coverage was only 50 percent and less than that reported at two other ocean reef slope stations nearby. Rippled sand in depressions was conspicuous (covering 10-25 percent of the bottom), a rare observation on the ocean reef slopes around Kosrae, and the abundance of sand may have depressed live coral coverage somewhat. Fourty-five species of corals were reported (Station 45) with encrustations of the star coral Galaxea fascicularis nearly dominant. Other abundant corals including the staghorn corals Acropora spp., the table coral Acropora irregularis, and the brain corals Platygyra spp. At the base and sides of the buttresses the robust corymbose coral Acropora humilis approached dominance. At least 25 other species were common on the slopes (refer to Appendix B for complete listing).

Coral morphology exhibited distinct zonation with depth on the ocean facing reef slopes. In shallow water (0-3 m) colonies were massive, encrusting or stoutly branched. On the shallow terrace or shelf below the spur-and-groove zone, corals were dominated by staghorn and table coral species between depths of 3-8 m. At depths between 8-18 m, coral communities showed mixed forms, and foliaceous species became more abundant at depths below 18 m on the steep slopes to the deeper terraces. In general corals were higher on outer submarine canyon walls and less in the sand chutes and inner canyon walls covered with sand.

OTHER INVERTEBRATES

The intertidal snail Nerita plicata was seen occasionally on shoreline rocks at Station 8. Many brittlestars (ophiuroids) were partly exposed

under rocks and in holes in the nearshore pavement. On the pavement of the reef flat, the sea cucumber Holothuria atra occurred occasionally. Some bivalve shell remains (Asaphis violescens) were seen among the coral shingle.

On the outer reef flat, near the Sargassum belt, several cowry species occurred (Appendix C). Shell remains of one small Tridacna were found near the reef crest.

Offshore (Station 45), yellow sponges were reported as common. Occurrence of living Tridacna sp. at a depth of about 10 m was noted.

FISHES

No fish observations were made on the shallow inshore reef flat (Station 8).

Offshore (Station 45), common fishes included surgeon fishes (esp. Acanthurus nigricans), trigger fishes (esp. Balistapus undulatus), butterfly fishes (esp. Chaetodon lineatus), wrasses, emperors (esp. Monotaxis grandoculis), snappers (esp. Lutjanus fulvus and the abundant Macolor niger), goat fish (Parupeneus multifasciatus), and various damsel fishes.

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Foko Yewak area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E. The Foko Yewak region (Atlas Map 5) is unsurveyed (see discussion at Section 2 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 2 summary.

WATER QUALITY

At the time of the KCRI survey, the inshore water at Station 8 was yellowish-brown in color, suggestive of heavy estuarine/mangrove

influence. Visibility at the shallow reef slope, just seaward of the heavy Sargassum beds, was only 4-6 m (15-20 feet), due in part to intermittent heavy rain at the time of the survey.

Offshore (Station 45), there was a turbid surface zone (to depth 3 m), below which the horizontal visibility was approximately 15 m (50 feet).

FOKO YESENG
(Stations 7, 44)
(Atlas Maps 6, 7)

PHYSIOGRAPHY

The physiography of the coastline south of Malem village (Foko Yeseng) is very similar to the physiography of the coast north of Malem (Foko Yewak). The predominant feature is a broad reef platform serving as the foundation to several biotopes including: a broad freshwater swamp forest abutting the higher volcanic interior of the island, a coastal strand on the seaward side of the freshwater swamp, a beach of coral sand and rubble, a narrow open reef flat, and ocean reef slopes beyong the upper reef margin. The open reef flat is narrow, averaging 150 m wide and seagrass beds are patchy in distribution, with a smaller patch in front of Malem village and a larger meadow halfway between the village and the stream, Infal Yeseng, to the south. Mangrove forests are similarly limited in distribution with the largest occuring at the mouth of Infal Yeseng and a smaller stand on the coast north of Malem village.

The shoreline and reefline are fairly straight and face to the southeast. The points of Foko Yewak to the north and Foko Yeseng to the south are little more than outward bulges from the land and reef. A semi-protected cove occurs off the village of Malem, north of Infal Malem. No passes or channels cut through the reef. Infal Yeseng stream discharges through the mangroves, forming a tidal inlet on the inner reef flat. A large pond occurs within the mangrove forest. Infal Malem stream discharges through a narrow canal and outlet to the ocean in the main part of the village. A culvert over the stream allows uninterrupted road access along the coast.

FLORA

At Station 7, beach vegetation included banana trees, coconut palms (Cocos nucifera), Scaevola, and Pandanus, with Sonneratia trees at the shoreline.

A narrow belt of very sparse seagrasses was seen just offshore, with additional small patches and tufts of seagrasses occurring on the inner half of the reef flat (with no formation of seagrass "sod").

Fine filamentous and turf algae carpeted the inshore coral shingle. Unidentified blue-green algae were abundant on the pavement in the middle portion of the reef flat. On the outer reef flat, algae of the genera Halimeda (dead and alive), Dictyosphaeria, and Cladophora were common, while Valonia occurred occasionally. In the surf zone, Turbinaria and Padina were abundant. Seaward, crustose corallines and Jania sp. were common to abundant.

Offshore (Station 44), coralline algae constituted up to 25 percent of the bottom cover, and Halimeda was recorded as abundant.

CORALS

Corals are poorly developed on the narrow reef flat probably due to its shallow nature (with few reef depressions), heavy exposure to waves, scour from water turbulence, and the presence of loose dead coral shingle and rubble on the hard reef pavement. Only 2 species were noted: Montipora digitata was uncommon while only one colony of the microatoll coral Porites lutea was reported.

In contrast live reef corals dominated the reef slopes seaward and beyond the reef margin, averaging 75-80 percent coverage. Beyond the reef edge are found the spur-and-groove features in very shallow water (0-3 m). Beyond the base of the spurs and grooves were flats of loose shingle, and coral coverage averaged less than 25 percent here. Beyond a 5 m depth, corals were most abundant to depths to 20 m and perhaps more. Fourty-three species were reported, and several were abundant including the soft corals Lobophytum and Sinularia and the following stony corals: the star coral Galaxea fascicularis and the variable species Porites (Synaraea) rus. A number of corals were common including the massive corals Porites spp., the stinging bubble coral Physogyra lichtensteini, the foliacous coral Hydnophora exesa, the brain corals Hydnophora microconos, Favia spp., and Platygyra spp., moosehorn coral Acropora cuneata, the branching corals Pocillopora meandrina, Hydnophora rigida, the table corals Acropora spp., small encrusting colonies of Montipora spp., mushroom corals Fungia fungites, the star coral Galaxea fascicularis, the fire coral Millepora platyphylla, and encrustations of Leptastrea purpurea, the stalked corals Goniopora sp., and Alveopora sp. and the smaller brain corals Leptoria phrygia and Favites spp. In shallow water the stout branched Acropora humilis dominated the bases and outer walls of the spurs.

OTHER INVERTEBRATES

Burrows of land crabs (Cardisoma sp.) were present under the beach vegetation at Station 7. The snails Littoraria coccinea and L. scabra were found on the trunks of Sonneratia trees, while Nerita plicata was found on beach rock at this station. The sea cucumber Holothuria atra was common over most of the reef flat. The few living mollusks observed included Conus ebraeus, Mitra mitra, and Cypraea moneta.

Offshore (Station 44), a large sea anemone (with associated clown fish) was seen. A blue sponge (with the form of mounds and spires) was reported as common.

FISHES

Inshore (Station 7), incidental observations of fishes were made on the reef flat. Occasional surgeon fishes (Acanthurus triostegus) and unidentified damsel fishes were noted near the surf zone.

Offshore (Station 44), the most common groups observed included surgeon fishes (esp. Ctenochaetus striatus and Naso lituratus), butterfly fishes (esp. Chaetodon lunula and C. reticulatus), rudder fish (Kyphosus sp.), wrasses (esp. Thalassoma spp.), various damsel fishes, and parrot fishes (esp. Scarus schlegeli).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at the KCRI stations in the Foko Yeseng area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 2 summary). There are a number of WWII Japanese sites behind Malem (Atlas Map 6). No sites are described in the Foko Yeseng area, but there is a coastal site to the south at Lela (Atlas Map 7).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 2 summary.

WATER QUALITY

At the time of the KCRI survey, inshore water at Station 7 was yellowish, indicative of mangrove/estuarine influence.

Offshore (Station 44), the surface water (depth to 3 m) was turbid, but deeper, visibility was greater than 24 m (80 feet).

MOSRAL
(Station 43)
(Atlas Maps 7, 8)

PHYSIOGRAPHY

Mosral includes the southeastern sector of Kosrae Island. The point of land and reef at Foko Mosral represents the southernmost spot on the island. The physiography of the region is similar to the regions to the northeast and the predominant coastal feature is the broad reef platform (over 1 km in width, which extends from the volcanic slopes of the island's higher interior seaward to the ocean reef slopes. The interior one-third to one-half of the platform is covered by a freshwater swamp forest and the outer two-thirds to one-half is mostly covered by a broad mangrove forest. The circumferential road passes through the middle of the forest with a large culvert allowing the passage of waters from the stream/inlet Inya Kuplu seaward towards the lake Inlulu Kuplu on the seaward side of the road. The floor of the "lake" and inlet is covered with seagrasses up to the road culvert. Seaward of the mangroves is the narrow coastal strand and beach which consists primarily of coral sand along southeast facing shorelines and coral rubble and shingle along southern facing shorelines to the west of the point at Foko Mosral. When moving clockwise from east to south along the coast, the open reef flat narrows to less than 50-100 m in width and is absent to the west between Foko Mosral and the next point Foko Fukunsral. The ocean reef slopes are dominated with live coral coverage. No evidence of recent wave storm damage on the reef at Station 43 was noted. All stations to the west of Station 43 facing south did show signs of recent wave damage. The most likely source was Typhoon Lola, which passed near Kosrae in May 1986, striking the southern facing coasts.

The spur-and-groove system at Station 43 is well developed, with grooves approaching 1.5 m depths and 2 m widths.

The beach showed a high steep wave cut scarp which could have been formed during the May 1986 storm. Coral sand and rubble were main components of the beach at Station 43.

FLORA

Sonneratia trees were observed at the beach. No seagrasses were seen. No algae were noted in the nearshore shingle zone. Seaward, Caulerpa racemosa was a very common alga on sand-veneered pavement between large reef rocks, forming a very dense carpet in the zone of breaking waves. Halimeda was also common there. In the spur-and-groove zone, coralline algae were abundant on reef shingle, the cover reaching approximately 50 percent. Halimeda was also abundant there. An unidentified blue-green alga was also present. At a depth of approximately 6 m, there were occasional clumps of a large red alga (Halymenia durvillaei).

CORALS

The entire reef slope margin below a depth of 3 m was dominated by live corals. In the spur and groove formations coverage averaged 33 percent with coralline algae averaging 50 percent. The rest of the area's substrate was covered with loose coral rubble. Below a depth of 3 m, live coral coverage averaged 85-95 percent with corals occupying virtually all available surfaces to depths of 20 m, the limit of KCRI diving observations. Dominant species were staghorn corals (Acropora formosa and other Acropora spp.). Other abundant corals included the plate or bracket coral Mycedium elephantotus at depth on steep slopes, finger coral (Porites cylindrica) and mound coral (Porites (S.) rus) on deeper slopes, massive coral heads of Porites australiensis, platforms of the star coral Galaxea fascicularis, and table corals (Acropora spp). At least 30 additional species were common and the total of 47 species reported was the third highest of any station on Kosrae.

Coral diversity and coverage was poor on the reef margin which is close to shore due to the near absense of a reef flat. A combination of sediment in suspense, wave damage, scour, and loose fragments of coral all tend to limit coral development here.

OTHER INVERTEBRATES

The snail Littoraria scabra was common on mangrove (Sonneratia) roots at the beach. The intertidal snail Nerita albicilla was found under shingle at the water's edge. Among the shingle and rubble of the broad intertidal zone, a few bivalve shell remains were found, including those of Pitar pellucidus and Asaphis violescens. Seaward of the shingle and rubble, on partially submerged, large (0.5 to 1.0 m diameter) rocks sitting on the reef pavement, various gastropods were found, including the snails Nerita albicilla, Drupa ricina, Drupella cornus, and Pyrene ocellata. No invertebrates were noted at the spur-and-groove zone or reef terrace, except that at least 8 squid (each approximately 20 cm in overall length) were seen swimming in a group near the surface in approximately 6 m of water. Deeper on the slope, at SCUBA depths, some yellowish-green sponges were recorded.

FISHES

Occasional small, unidentified moray eels (probably Echidna nebulosa or Gymnothorax pictus) were seen under shoreline beach shingle at Station 43. On the offshore reef slope, the most abundant fishes observed included surgeon fishes (esp. Acanthurus trigostegus and Ctenochaetus striatus), butterfly fishes (esp. Chaetodon vagabundus), rudder fish (Kyphosus sp.), wrasses (esp. Thalassoma hardwickei), emperors (esp. Lethrinus harak), and snappers (esp. Aphareus furcatus, Lutjanus fulviflamma, and abundant Macolor niger).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI Station 43; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 2 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 2 summary.

WATER QUALITY

Horizontal visibility observed inshore (Station 43) was approximately 6 m. Offshore (Station 43), visibility was 33 m (100 feet).

FOKO FUKUNSRAL
(Station 42)
(Atlas Map 8)

PHYSIOGRAPHY

Along the south coast of Kosrae west of Foko Mosral, the basement reef platform narrows to less than 0.5 km in width next to the volcanic headland of Kuplu Wan. The next outward bulge of the reef line is at Foko Fukunsral, approximately 1.5 km west of Foko Mosral. Here the basement reef platform is about 0.5 km wide, and no freshwater swamp forests are found here or to the west of the headland. The whole interior of the reef platform west to the municipal boundary (between Map Sections 2 and 3 and separating the Districts of Malem and Utwe) is covered by a broad mangrove forest, Kuplu Te. An inland waterway, Inya Kuplu, meanders along the inland boundary of the mangroves near the steep volcanic cliffs. The coastal strand is broader near Foko Fukunsral, about 250 m wide, and small mangrove stands are found along its ocean shoreline. The beach consists of coral rubble, cobbles and shingle with little or no coral sand. An open reef flat is absent at the point since the coastal strand/island extends all the way out to the reef margin, covering the reef flat.

Spur-and-groove formations are not well developed at Foko Fukunsral. Isolated ridges and blocks of accreting coral suggest that buttresses could develop at the site over time and in the absence of disrupting factors. The base of the "developing" spurs occurred at a depth of 1.5 m. In the breaker zone, the bottom environment was covered with broken corals, shingle and rubble, some of recent origin. Below a depth of 3 m and to the depth of 9 m, the ocean-facing reef slopes were littered with recently broken or overturned coral. Live coral coverage at these depths was less that 25 percent with coral rubble contributing the remaining 75 percent. At depths below 9-10 m, there was little wave damage, and live coral coverage approached its usual high abundance and diversity.

FLORA

Vegetation on the beach berm included Scaevola, Pandanus, and coconut palms. On sand-veneered pavement inside of the surf zone, and extending into the surf zone, a dense carpet of algae composed of Caulerpa racemosa, other Caulerpa spp., and Halimeda sp. was observed. This carpet formed a cover of approximately 50 percent of the bottom, but stopped abruptly at a water depth of approximately 1 m. Seaward from that point, some encrusting coralline algae were observed, but algae were not noticeable again until Halimeda sp. was seen a depth of about 10 m.

CORALS

Coral communities were hard hit by a recent tropical storm and associated waves which struck the south coast of Kosrae in May, 1968. Coral forms particularly hard hit including staghorn coral (Acropora formosa and other species), and table corals (Acropora irregularis, A. hyacinthus and others) and corymbose coral heads (Acropora humilis, A. digitifera). Few if any live and still-attached coral heads were reported on the reef margin near the breaker zone.

Abundant living reef corals at Foko Fukunsral included platforms of the star coral Galaxea fascicularis, and undamaged table corals (Acropora spp.). Common species included the small brain corals Favia stelligera and other Favia spp., the massive corals Porites lobata and others, the encrusting corals Leptastrea purpurea and Montipora spp., the fire coral Millepora platyphylla, the larger brain corals Hydnophora microconos, Platygyra spp. and Leptoria phrygia, undamaged staghorn coral (Acropora spp.), the mushroom coral Fungia fungites and the mound coral Porites (S.) rus. Most of the abundant and common species were found in deeper water below the zone of wave damage from the 1986 storm.

OTHER INVERTEBRATES

The snail Littoraria coccinea was common on dead tree trunks on the beach at Station 42. On the reef pavement inside of the surf zone, there were large, partly submerged boulders and slabs with numerous intertidal or

subtidal snails. These included a common, unidentified patellid (limpet) and occasional individuals of the snails Drupa albolabris, D. granulata, D. morum, Drupina glossularia, and Vasum turbinellus. The sea cucumber Actinopyga mauritiana was occasionally seen in the surf zone.

FISHES

Common groups on the reef slope at Station 42 included surgeon fishes (esp. Acanthurus nigricans, A. lineatus, A. blochii, Ctenochaetus striatus), butterfly fishes (esp. Chaetodon reticulatus), damsel fishes (esp. Abudefduf vaigiensis, Chromis margaritifer, C. ternatensis, and Plectroglyphidodon dickii), and parrot fishes (esp. Scarus spp.).

OTHER VERTEBRATES

During transits of the KCRI survey boat between stations, several small groups of unidentified cetaceans (dolphins or porpoises) were observed offshore in this area. Other vertebrates discussed in the overall summary section may also occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 2 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 2 summary.

WATER QUALITY

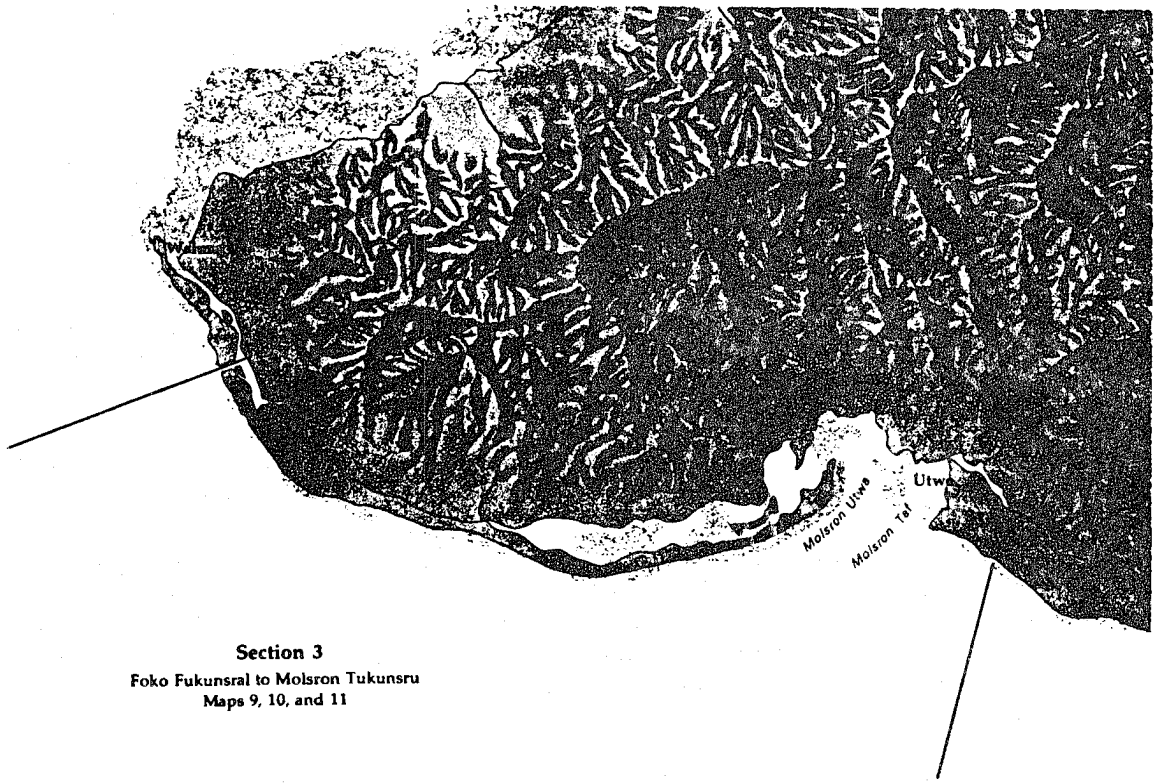
Inshore water (Station 42) was turbid, but offshore, at depths greater than 6 m, visibility was reported to be in excess of 33 m (100 feet).

MAP SECTION 3 (UTWE)

SUMMARY

GENERAL DESCRIPTION

This southern portion of Kosrae contains the village of Utwe, the least populated of the four main villages of Kosrae. The village is located on the barrier formation at the seaward edge of the mangrove forest, facing the large embayment of Utwe Harbor. The coastal road which connects Utwe with Malem was being extended westward toward Tafunsak at the time of the KCRI field survey. Also at the time of the 1986 KCRI survey, a road causeway was being constructed from the circumferential road seaward through the mangroves to the western loch of Utwe Harbor, to provide a route for transport of dredged material from the reef to the circumferential road. A channel was dredged through the nearby reef during 1986-1987 (Atlas Map 9).



Section 3
Foko Fukunsral to Molsron Tukunsru
Maps 9, 10, and 11

PHYSIOGRAPHY

Map Section 3 encompasses the southwest quadrant of Kosrae and the coastal physiography is complex, including a variety of features: ocean reef slopes, open ocean reef flats, beaches, a large embayment, interior reef holes and reef ridges, open water bodies (e.g. ponds or lakes) landward of the coastal strand, seagrass beds, mangroves, freshwater swamp forests and the volcanic "shoreline".

Utwe Harbor (Port Lottin) dominates the southeast end of Map Section 3, and the village of Utwe occupies the eastern shoreline of the embayment. Few people live elsewhere in the municipality of Utwe although agricultural plots and sheds are found along the coastal strand to the west. Port Lottin is a deep water embayment with two wide and deep inlets or lochs (Molsron Utwe to the west and Molsron Taf to the east). These inlets are separated by a shallow projecting reef formation in the middle of the embayment. Although the eastern loch connects to an inland waterway (Inya Kuplu) further to the east, the western loch (Molsron Utwe) was completely fringed by a shallow coral reef flat. This reef formation or ridge separated the outer open and pristine waters of the loch from more murky interior waters within an inland lake. Dredging in 1986-87 cut a channel through this reef barrier resulting in the mixing of interior murky waters and pristine ocean waters. As a consequence water clarity is greatly reduced and suspended sediments are accumulating in some bottom areas. In turn reef populations have declined due to degraded water quality.

A continuous reef basement platform of at least 1 km in thickness extends along the entire coastline of Map Section 3 to the boundary between Utwe and Tafunsak Municipalities. Most of the inner platform (landward of the coastal strand) is covered with mangrove forests and a few inner freshwater swamps. Inland of the mangroves and extending to the volcanic "shoreline" are freshwater swamp forests. Two open water bodies are named Lulu Nefalil and Lulu Utwa. Some seagrass beds are also found but are as not widespread. A small patch occurs on the reef extension between the two lochs and a much larger seagrass bed occurs on the inner platform to the east of Lulu Nefalil.

The beaches are mostly composed of well worn reef cobbles, shingle and boulders, but a few sand patches were evident. At present, none occupies the coastal strand nor are roads along it present. The circumferential road under construction is due to connect the villages of Utwe and Walung, and the road alignment runs along the volcanic "shoreline" inland of the coastal strand. A fill road causeway was extended from the "shoreline" to the western loch of Utwe Harbor to provide access for the transportation of dredged reef materials for use as fill in the extension of the circumferential road.

An inland waterway network (Inya Walunga) extends from the west of Utwe Harbor all the way west past the municipal boundary to the inlet at Walung. A nearby shallow channel over the reef at Molstron Tukunsru provides an outlet from the inland waterway along the southwest side, coinciding with the Municipal boundary between Utwe and Tafunsak. Several

streams also cross the reef platform and mangrove swamps forming "intersections" with Inya Walunga. These include Infal Yemulil to the northwest, Infal Falwe which traverses the freshwater swamp forest in the middle reach, and an unnamed "Infal" near the lake at Lulu Nefalil. Near the reef platform and coastal plain of the Utwe sector are steep volcanic headlands at Sipyen, Newot, Nefalil, Falwe and Yemulil near the municipal boundary.

Most of the impact from the May 1986 tropical cyclone (Lola) passing south of Kosrae was inflicted on the reefs along Map Section 3. Despite damage to the outer reef slope and beaches, live coral coverage is high both along the exposed coasts and within the lochs of the Utwe Harbor on the reef slopes. Exposed or open reef flats tend to be narrow (less than 200 m in width) due to accretion of reef rock up on the reef flats, especially during storms, causing prograding of coastal strand shorelines.

FLORA

Utwe has extensive mangrove forests, with a large area of landward swamp forest in the western portion (Atlas Map 11). A large area of seagrass occurs inland of the coastal strand at Foko Nefalil (Atlas Map 10). At the time of the KCRI field survey, seagrass beds were present on the reef flat in inner Utwe Harbor (Station 22). Silt-veneered reef pavement areas near reef edges (Stations 19, 20) in the harbor had extensive carpets of Caulerpa racemosa and scattered patches of Halimeda sp. At the harbor entrance (Stations 18, 21), recent scouring of the bottom by waves, possibly from Typhoon Lola (May, 1986) had reduced algae cover near the surface; encrusting coralline algae and Halimeda were more conspicuous at greater depths (5 to 18 m). Inshore areas along the coastline to the west of the harbor were not visited during the survey, but recent scouring by waves was apparent on the reef slopes: although encrusting coralline algae were abundant at depths of 5 to 12 m at Station 41, no fleshy algae were observed there or at Station 40 during SCUBA dives.

CORALS

Corals occupy 3 types of habitats in Map Section 3: the ocean-facing reef slopes where corals achieve high development and diversity, limited development on shallow reef flats, and high development along the slopes and margins of reefs in Utwe Harbor.

Composition of corals tend to be different in the two major coral biotopes. Inside the harbor are many branching columnar, foliaceous, staghorn and table corals where exposure to heavy wave action is less vs. open reef slope assemblages where massive species including brain corals and encrusting species are more conspicuous. Although abundance is high (at least before the 1986-1987 dredging) coral diversity is less inside the harbor on the walls in the western loch (Molsron Utwa). Total species counts did not exceed 30 species at any "inside" embayment station. Along

ocean-facing reefs, corals averaged about 40 species on the reef slopes.

Few corals were noted on the inner reef flat along the eastern loch (Molsron Taf). Although coral development is higher on Molsron Utwa, recent dredging and sedimentation caused a decline in species diversity and coverage [44]. Outside the embayment on exposed reef slopes, the 1986 tropical storm wrought major damage to corals and reefs above a depth of 10 m.

OTHER INVERTEBRATES

As shown by mapped resource use data in the Kosrae Coastal Resources Atlas, the wetlands inland of the long coastal strands of this section are inhabited by invertebrates utilized by island residents. The mangrove crab (Scylla serrata) occupies the extensive mangrove forests, and coconut crabs (Birgus latro) and land crabs (Cardisoma sp.) are found in the swamp forest in the western region. At one known shallow site with associated seagrass beds and mangrove forest in the inland inland waterway of Lulu Nefalil (Atlas Map 10), a species of clam known locally as popol is collected; this clam has been tentatively identified as a member of the family Unguliniidae (see note, overall summary section). Some known habitats of other invertebrates utilized by island residents are also revealed by the resource use symbols on the atlas maps. Highlights of invertebrates observed at KCRI stations in Utwe Municipality follow.

Mollusks and molluscan shell remains were found in the seagrass beds of inner Utwe Harbor (Station 22), especially money cowries (Cypraea moneta) and cone shells (Conus spp.). Shell remains of several bivalves valued for food were also found, including Anadara antiquata (found only at this station during the KCRI survey) and Tridacna sp. A living Tridacna was found on the reef flat at Station 20. Other invertebrates found on the reefs of Utwe Harbor included occasional sea cucumbers and large sea anemones. Intertidal snails and grapsid crabs were observed on exposed rocks in the central part of the harbor (Station 19). Inshore surf conditions at the time of the KCRI survey prevented effective inspection of the shallow reef areas for other invertebrates at the mouth of Utwe Harbor (Stations 18, 21); orange sponges were reported on the reef slope at Station 18. The surf zone and inshore areas at Stations 40 and 41 were not visited during the survey; no non-coral invertebrates were reported on the reef slopes at these two stations.

FISHES

Fishes recorded in Section 4 during the KCRI field survey are listed by station in Appendix D. Survey emphasis was on recording conspicuous species utilized for food. At least 78 species, representing 26 families, were recorded in Section 3.

Fishes recorded as common or abundant at 1 or more of the areas inside the harbor (Stations 18 thru 22) included surgeon fishes (esp. Acanthurus

spp., Ctenochaetus striatus, Naso lituratus, Zebrasoma scopas), trigger fishes (Balistapus undulatus, Balistoides viridescens, Melichthys niger), emperors (Lethrinus sp.), snappers (Aphareus furcatus, Lutjanus spp., Macolor niger), threadfin (Scolopsis cancellatus), damsel fishes (Amphiprion chrysopterus, Plectroglyphidodon dickii), and parrot fishes (Scarus spp.).

Inshore areas outside of the harbor were not visited during the KCRI survey. Fishes recorded as common or abundant at depths of 9 to 18 m (30 to 60 feet) on the reef slope and terrace (Stations 40, 41), included surgeon fishes (Acanthurus nigricans, Ctenochaetus binotatus), wrasses (Gomphosus varius, with various other species recorded as occasional), snappers (Lutjanus bohar, Macolor niger), and damsel fishes (Chromis margaritifer, Plectroglyphidodon dickii).

OTHER VERTEBRATES

A shoreline area at Foko Pe (adjacent to the name Foko Pe on Atlas Map 11) is the only site at Kosrae identified by local resource users as a place where turtles are known to have nested in the past; no presently active nesting areas are known to the residents interviewed.

Vertebrates other than fishes were only incidentally recorded during the KCRI survey. No vertebrates other than fish were recorded at the KCRI Stations in Section 3; however, any of the vertebrates discussed in the overall summary section of this report may occur in Utwe.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Utwe Municipality has received the most detailed archaeological work of all mainland Kosrae areas [2, 3, 17, 26, 27, 66, 75].

In eastern Utwe the large valleys which empty into Utwe Harbor dominate the landscape, along with their associated swampy floodplains. Most permanent house sites here have been found inland of the mangrove swamps and coastal floodplains -- in the upper valleys. A few houses sites are on small hillocks in the swampy coastal plains. Access to marine resources seems to have been down trails to mangrove channels or to the strand islets at the mouth of the Finkol River where canoes were located. Some dwelling sites were on strand islets at the mouth of the Finkol River in Taf and Finkol.

In central and western Utwe, small valleys, narrow coastal plains, shallow lagoonal waters and long islets on the outer edge of the reef flat are the landform patterns. Here, the bulk of the permanent dwellings sites are located at the interface of the mangroves and the narrow coastal plains, although house sites continued inland in Nefalil, Selmeoa, and Isra, which were evidently population centers in this area. A major complex of enclosures was present along the shore in Nefalil (Ko-C8-1). Access to the lagoon was via channels through the mangroves.

In late prehistory (A.D. 1200s-1700s), population growth evidently led to the spread of permanent dwellings onto sand, alluvial and basalt islets within the mangroves, onto the long islets on the outer edge of the reef flat.

With the population crash of the late 1800s, many of the lands of Utwe were abandoned or were occupied only by a household or two. Settlement shifted out onto the long islets, with Utwe Ma being the location of Utwa Village, until its shift across the harbor after World War II to Taf which was situated at the end of the road.

Some information on the exploitation of reef resources in this area during prehistory and the 1800s is available through faunal analysis of archaeological remains [27, 66]. Recovered remains have predominantly been marine molluscs, although fish and turtle remains have been recovered. In the Falwe and Nefalil areas, in sites dating to late prehistory (A.D. 1400s-1700s), 4 gastropod familes were commonly found (Strombidae, Cypraeidae, Turbinidae and Neritidae) and 2 bivalve families (Arcidae and Veneridae -- notably the species Anadara antiquata and Gafrarium pectinatum). This suggests exploitation of a wide variety of local reef habitats. However, at the very end of prehistory or in the 1800s, bivalves become markedly dominant in the Nefalil sites, suggesting a changing focus to the larger bivalves. Several alternative explanations for this pattern are now being analyzed.

RESOURCE USE

At one known shallow site (apparently the only one at Kosrae) in the inland waterway of Lulu Nefalil (Atlas Map 10), with associated seagrass beds and mangrove forest, a species of clam known locally as popol is collected; this clam has been tentatively identified as a member of the family Unguliniidae (see note in overall summary section).

The presence of another clam species in Utwe is also worthy of special note. Anadara antiquata, which is locally common (and valued highly as food) in some parts of Pohnpei [77], was found (as shell remains) at only one KCRI site, Station 22, in the central seagrass area of Utwe Harbor; however, this clam was known to local fishermen who approached the KCRI team at that station (see note under Utwe Harbor description, below), and it may be common in some inshore areas of Kosrae.

A meeting with resource users was held at Utwe on 31 July 1986. Information obtained from participants was used to map resource use in Section 3 of the Kosrae Coastal Resource Atlas. Additional information obtained from resource users is summarized below.

Notes on resource items

Turtles go inside the reef and feed on the seagrasses, but the fishermen catch them outside the reef, in the passes.

Resource use problems

According to interviewed fishermen, use of poison plant (leaf poison, "op sra"), not use of chlorox, etc., is the biggest problem causing fish populations to go down. It is illegal to use the poison leaves to fish. All of the fish species are decreasing because of the poison plant use. Use of the poison "scares the fish away from their living places". Poisoning is done by Utwe residents, who use approximately a 15 pound bag of poison plant. The bag is left in the water when the tide is coming in. The bag can get lost and then continues to kill fish.

The use of various (unspecified) new fishing techniques is causing some problems. Also, more people are learning to fish. The fishermen would like to establish seasons for each of the different fish species caught.

When asked if the causeway has caused any problems, the fishermen said no comment - the causeway is okay now.

When asked about the planned 1986 channel dredging through the reef, the fishermen indicated that the placement of the channel would be okay from their point of view as long as the dredger would not go out of the channel and as long as the dredger would only take material out and not add (put in) material.

When asked about existing road construction through the mangroves, the fishermen said there was no effect on fishing and reiterated that use of poison plant is the main problem. (However, following the cutting of a channel through the reef during 1986-1987 to facilitate transport of fill for the circumferential road project, massive sedimentation and reef decline at the head of the western loch (Molsron Utwe) caused major decline in many reef fishes, based on observations and additional interviews with fishermen by Maragos in May 1988 [44].)

WATER QUALITY

The marine waters of this section are Class AA, except that the area in the immediate vicinity of Utwe village is Class B [73]. For class definitions, see Appendix F.

The only source identified as affecting water quality in 1979 [71] was Finkol Stream, which discharges into Utwe Bay. This stream was described as one of Kosrae's biggest, with heavy run-offs and silt discharges year-around. Included in the discharges were wastes from point sources such as toilets and pig-pens. Coastal discharge sites off Utwe were investigated by the University of Hawaii in 1984 [13].

Water quality observations made during the KCRI survey are noted at each area description. Of particular interest were the ongoing construction of a road causeway through the mangroves and the subsequent construction of a dredged channel through the nearby reef in the west loch of Molsron Utwa (see discussions at Utwe Harbor section, below).

UTWE HARBOR
(Stations 22, 21, 20, 19, 18)
(Atlas Map 9)

PHYSIOGRAPHY

Utwe Harbor is a complex embayment on the south coast of Kosrae measuring approximately 2 km along an east-west axis and 1 km from the head to the mouth of the bay along a north-south axis. The harbor has two inlets open to the sea, Molsron Taf to the east bordering the main village of Utwe, and Molsron Utwe (Utwa) in the center of the harbor. Lulu Utwe (Utwa) forms the western side of the harbor and consists of an enclosed brackish lake blocked off from the ocean by a coral reef, Utwe (Utwa) Ma. The inner border of Molsron Utwe also had a reef serving as a barrier to another marine or brackish water body further inland, but in 1986-1987 a channel was dredged through this reef to facilitate boat and dredged plant access to a road causeway at the north end of the water body. One freshwater stream (Infal Finkol-Menka) enters the eastern harbor at Finkol Te from the north, and an inland waterway Inya Kuplu enters the eastern harbor from the east.

A large mangrove swamp borders the entire bay. Smaller fringes of freshwater swamps are found between inland margin of the mangrove and the higher volcanic slopes further inland to the north of the mangroves. Only one small seagrass bed is found on the projecting reef separating the inlets of Molsron Utwe and Molsron Taf. Coral reefs line all water bodies open to the sea in the harbor, and live coral coverage is high on the slopes which are steep. The tops of the reef flats are covered with sand, gravel, and coral rubble with some live corals along the outer margin. The bottom of the harbor is covered with fine sands and silts and is relatively flat but deep (in excess of 25 m in some places).

FLORA

On the inner reef flat of the harbor (Station 22), seagrass beds were well developed on the silt-covered bottom. On silt-veneered reef pavement at Stations 19 and 20, there were extensive carpets of the alga Caulerpa racemosa, with scattered patches of Halimeda sp., some appearing completely white (apparently recently killed). Halimeda was observed in pockets between corals to depths of at least 15 to 18 m at Stations 19 and 20.

Near the harbor entrance (Stations 18, 21), no well-defined reef flat was present. Crustose coralline algae were common in shallow water at these stations, but recent scouring of the bottom by waves had reduced the algal cover, especially at Station 18. Halimeda was common to abundant in depressions on the reef slopes, to depths of 12 to 18 m. Crustose coralline algae were also more conspicuous at these greater depths.

CORALS

The highest abundance and diversity of stony corals occur along the slopes of the harbor and on the outer deeper margins of the reef flats. Coral development tends to be higher at stations more outside the harbor (Stations 18, 19, 21) than inside the harbor (Stations 20, 22), averaging over 30 species per site outside and less than 20 species inside. Corals are lacking on the floor of the harbor, due to coverage by sediments and lower light levels. The shallower reef flats are also unfavorable to corals due to higher sand coverage and exposure to freshwater runoff, silt, dessication during low tides, and higher temperature extremes.

Surveys of corals were accomplished in Utwe Harbor during May, 1986, immediately before the start of dredging and filling operations in support of circumferential road construction. A brief survey at Station 20 was accomplished in May 1988, after dredging and cutting through the reefs. Conditions for corals are less favorable now due to higher turbidity levels in the water and accumulation of sediments on the bottom, with some corals being buried. Cutting a channel through the reef at the head of the inlet at Molsron Utwe now allows sediments previously trapped behind the reef to wash out through the channel into the open reef areas. Although coral coverage continues to be high in the inlet, some stress to corals from sediments was noted and corals look less healthy. Fish populations were noticeably lower on the reefs [44].

The outermost stations (Stations 18, 21) were exposed to large waves during the passage of Typhoon Lola south of Kosrae in May 1986. Many corals were dislodged, broken, and shattered. While normal coral coverage on the slopes is 80 percent or more, at depths less than 10 m, coverage was less than half of this due to damage from the storm. Rubble and shingle from the killed corals was found accumulating in depressions at 6-12 m. Abundant corals on the outer stations included Porties cylindrica, Porites (S.) rus, Galaxea fascicularis, Turbinaria stellulata, several species of the brain coral and staghorn coral Acropora, Pachyseris rugosa, and the fire coral Millepora platyphylla.

On inner harbor stations coral coverage was lower, 50-60 percent on the slopes, but unaffected by storm waves. The number of coral species was lower but several were abundant: the fingercoral Porites cylindrica, P. (S) rus, staghorn Acropora spp., the star coral Galaxea fascicularis, and the bracket coral Echinophyllia aspera.

Extensive patches of a soft coral (Sinularia sp.) covered portions of the reef flat at Station 20.

OTHER INVERTEBRATES

In the seagrass beds of the inner harbor (Station 22), money cowries (Cypraea moneta) were common, and shell remains of this species were abundant. Small cone shells (especially Conus ebraeus) were common. Old shell remains of several bivalves were found, including Anadara antiquata,

Tellina remies, and Tridacna sp. No sea cucumbers were seen during the brief stop at this station. On the reef flat at Station 20, a single small living individual of Tridacna sp. was found embedded in the Caulerpa-carpeted pavement. Occasional sea cucumbers (Holothuria atra) were also seen on the reef flat. A large sea anemone (maximum diameter approximately 1 m) with associated anemone fish (Amphiprion chrysopterus) was found near the precipitous edge of the reef at this station.

On the exposed rocks on the pavement at Station 19, intertidal snails (Morula sp.) and unidentified grapsid crabs were occasionally seen.

Surf conditions prevented effective inspection of inshore areas at Stations 18 and 21 for other invertebrates. Orange sponges were reported as common on the reef slope at Station 18, but no other non-coral invertebrates were noted for the reef slopes of these Utwe Harbor stations.

FISHES

During a brief examination of Station 22 in the inner harbor, turbid water conditions inhibited fish observations; only occasional surgeon fishes (Acanthurus nigricans and A. trigostegus) were recorded. At the remaining harbor areas visited (Stations 18-21), fishes were more readily observed; common groups included surgeon fishes (especially Acanthurus spp., Ctenochaetus striatus, Zebrasoma flavescens), snappers (especially Lutjanus spp.), and threadfin (Scolopsis cancellatus). At Station 18, parrot fish were common and an unidentified caesionid was abundant. Trigger fishes were common to abundant at Stations 18 and 19.

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI stations in the Utwe Harbor area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 3 summary). Of special note in Utwe Harbor is the wreck of the Leonora.

RESOURCE USE

The KCRI team briefly talked with fishermen who approached in a canoe at Station 22. These fishermen were shown some old bivalve shells which had just been picked up at this station, including Anadara antiquata (which was found only at this location during the KCRI survey) and Tellina remies. They stated that they eat both of these clams and provided the local name "punak" for A. antiquata.

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 3 summary.

Fishermen participating in the 1986 Utwe meeting were asked about possible resource problems associated with planned channel construction through the reef and the existing causeway construction through the mangroves (in vicinity of Station 20, Atlas Map 9); the fishermen indicated no problems with the proposed causeway, and no problem with proposed channel dredging as long as dredger only takes material out and doesn't add any in (see also Section 3 Resource Use Summary).

WATER QUALITY

During the KCRI survey, turbid water conditions were encountered on the reef flats in the inner portion of the embayment (Stations 20, 22). Suspended particulates at these stations, which were visited near high tide, reduced horizontal visibility near the surface to less than 2 m (6 feet) in the seagrass area at Station 22, and to only 6-8 m at Station 20. On the reef slope (depths to 12 m (40 feet)) at Station 20, horizonal visibility was greater, approximately 12 m (40 feet).

At Stations 18, 19, and 21, also visited near high tide, water clarity was much better: horizontal visibility at both surface and SCUBA depths (to 20 m) ranged from about 12 to 15 m (40 to 50 feet).

At the time of the KCRI survey, a road causeway was being constructed through the mangroves to the western loch of Utwe Harbor, to provide a route for transport of dredged material from the reef to the circumferential road, thus blocking lateral movement of water through the mangroves. Subsequently, a channel was dredged through the nearby reef (Station 20, Atlas Map 9), allowing increased mixing of interior waters with the waters of Molsron Utwe.

FOKO NEFALIL
(Station 41)
(Atlas Map 10)

PHYSIOGRAPHY

Foko Nefalil is a southern facing point of reef and land 3 km west of Utwe Harbor. It is the next to most southerly point on Kosrae Island after Foko Mosral to the east of Utwe Harbor. The coastal geomorphology in the vicinity of Foko Nefalil is fairly typical of most of the southwest coast of Kosrae. The coastal plain is about 1 km wide and rests upon the reef platform surrounding Kosrae. The volcanic headlands of Nefalil and Newot form the innermost boundary of the coastal plain, and an extensive mangrove

forest borders the volcanic slopes and covers most of the reef platform. The middle sector of the mangrove zone is an open water "lake" area, Lulu Nefalil, with one large seagrass bed on a shallow reef flat in the middle of the mangrove. The average width of the mangrove-lake-seagrass complex is 0.75 km and extends many kilometers in both directions along the south coast. An inland waterway (Inya Walunga) meanders through the complex, and one stream (Infal) discharges into the western end of Lulu Nefalil.

The coastal strand occurs seaward of the mangroves and includes a low narrow coral berm and a beach consisting mostly of coral rubble with some sand. Land areas on the coastal strand are wider on the southwest facing side of the point at Foko Nefalil. The open reef flat is narrow, averaging about 100 m in width, and the outer reef margin is very close to the shoreline. The ocean facing reef slopes are moderately steep and dominated by live coral on the deeper slopes but less in shallower water due to recent storm damage.

FLORA

The inshore area was not visited during the KCRI survey. Encrusting coralline algae were reported as especially well developed on the reef slope (depth 5 to 12 m) at Station 41. No fleshy algae were observed on the slope, possibly due to recent scouring action by storm waves.

CORALS

As with other ocean facing reef slopes around Kosrae, live coral coverage and diversity is high but has been degraded recently by storm wave damage probably from typhoon Lola which passed south of Kosrae in May, 1986. Damage however was not as extensive as reported along other southern coastlines. Average live coral coverage was 33 percent on the slopes, decreasing to less than 25 percent at depths less than 10 m and increasing to more than 60 percent below 10 m. A total of 24 species of corals were reported at Station 41; one was dominant Psammocora digitata, and several others were abundant: table Acropora spp., the star coral Galaxea fascicularis and the fire coral Millepora platyphylla. Eight other species of the genera Acropora, Symphylla, Favites, Pocillopora, Platygyra, Favia, and Leptoria were common.

Soft corals (Sinularia spp.) were observed on the reef slope.

OTHER INVERTEBRATES

The inshore area was not visited during the KCRI survey. No other invertebrates were reported on the reef slope at Station 41.

FISHES

Common groups observed on the reef slope at Station 41 included surgeon fishes (especially Acanthurus nigricans, Ctenochaetus striatus); wrasses (especially Gomphosus varius), and damsel fishes (especially Plectroglyphididon dickii).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI Station 41; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 3 summary). The Nefalil region (Atlas Map 10) has numerous sites; of special note is a major archaeological complex at Nefalil.

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 3 summary.

WATER QUALITY

At the time of the KCRI survey, a strong westerly current was present on the reef terrace (Station 41) at a depth of about 18 m (60 feet), and horizontal visibility was good, 18-25 m (60-80 feet).

FOKO PE (FOKO PA)
(Station 40)
(Atlas Map 11)

PHYSIOGRAPHY

The southwest coast of Kosrae has no conspicuous points of land or reefs and the coastal physiography is fairly typical of adjacent coastal sectors. Foko Pe (Foko Pa) is the only place name on published maps along this coast between the municipal boundary 1.5 km to the north and Foko Nefalil several kilometers to the east.

The coastal plain rests on the reef platform which surrounds much of Kosrae. At Foko Pe, the coastal plain measures nearly 1 km in width from the interior volcanic headlands (Falwe, Yemulil) to the shoreline. Next to the interior headlands are freshwater swamps. Two streams run through the swamps: Infal Yemulil through a small swamp and Infal Falwe through a much larger freshwater swamp. The streams pass through an extensive mangrove forest and connect to the inland waterway, Inya Walunga which runs between Utwe to Walung villages. The mangrove forest averages 0.75 km in width, dominating the coastal plain. The coastal strand and land areas extend to Foko Pe from the east but are absent beyond the point to the north. The beaches are confined to the east of the point and consist mostly of coral cobble, rubble, shingle and some sand. The open reef flat seaward of the shoreline narrows to less than 50 m in width to Foko Pe and is absent to the northwest. This is the result of mangroves and perhaps coastal strand habitat covering the reef all the way to its outer edge. The reef slopes are normally dominated with live corals. However, the recent passage of typhoon Lola in May 1986 caused peak damage to corals along the southwest coast, especially at Station 40. Damage was not conspicuous below a depth of 15 m and the deeper reefs were steep and still covered with live coral.

FLORA

The inshore area was not visited during the KCRI survey. No algae were reported on the reef slope at Station 40, which exhibited major residual coral reef damage from the storm waves of Typhoon Lola (May, 1986).

CORALS

Despite recent damage from storm waves, coral development is still rather high off Foko Pe with over 40 species observed at Station 40. Coral coverage in shallow water was greatly diminished as a result of storm damage. Destruction was 80 percent to depths of 9 m and live coral coverage was only 10 percent. At a depth of 10-12 m coral coverage increased to 50 percent and below 15 m increased to 80 percent or more. The dominant (surviving) species was the star coral Galaxea fascicularis and other common species included: incrustations and plates of Porites lichen; branching colonies of Acropora palifera; the blue coral Heliopora coerulea; the brain corals Platygyra spp. and Favia stelligera; the table coral Acropora hyacinthus; the branching form Hydnophora rigida; the mushroom corals Fungia spp. and Halomitra pileus; small encrustations of Cyphastrea serailea, Oxypora lacera, and Montipora spp.; branching colonies of Pocillopora verrucosa and Acropora spp.; the fingercoral Porites cylindrica; and massive species of Porites spp., Favites spp., Leptoria phrygia, and Goniastrea retiformis. The reef slope was steeper below 15 m where coral coverage was also higher.

OTHER INVERTEBRATES

The inshore area was not visited during the KCRI survey. No other invertebrates were reported on the reef slope at Station 40.

FISHES

Common groups observed on the reef slope (Station 40) included surgeon fishes (esp. Acanthurus nigricans, Ctenochaetus striatus), snappers

(esp. Lutjanus bohar, Macolor niger), and damsel fishes (esp. Chromis margaritifer, Plectroglyphidodon dickii).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI Station 40; however, any of the vertebrates discussed in the overall summary section may occur in the region.

A shoreline area at Foko Pe (adjacent to the name Foko Pe on Atlas Map 11) is the only area at Kosrae identified by some island residents as a place where turtles are known to have nested in the past (not thought to be active nesting area now).

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 3 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 3 summary.

WATER QUALITY

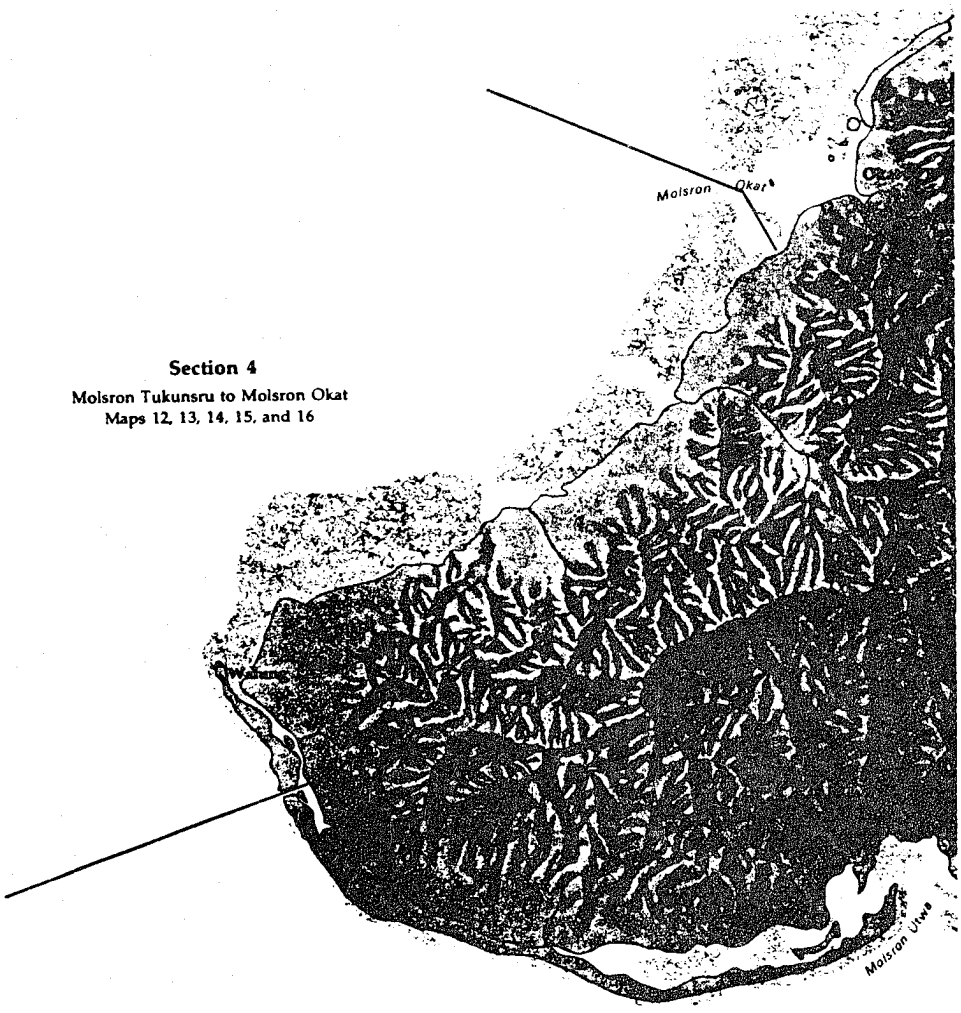
At the time of the KCRI survey, a 1-knot westerly tidal current was present at Station 40, and surface waters (depths less than 3 m) were turbid. At depths of 9-18 m (30-60 feet), horizontal visibility was very good, 15-25 m (50-80 feet).

MAP SECTION 4 (WEST TAFUNSAK)

SUMMARY

GENERAL DESCRIPTION

This western, southwest-to-northwest-facing portion of Kosrae contains the isolated village of Walung, which is situated on the barrier formation at the seaward edge of the mangrove forest and is presently reached via boat. At low tide, the broad and shallow reef flat must be crossed on foot to reach the white sand beach fronting the village. The relative isolation of the village may end if a circumferential road is completed. At the eastern end of this section, the fringing reef flat gives way to the Okat Harbor embayment.



PHYSIOGRAPHY

The coastal zone of northwestern Kosrae undergoes a major physiographic transition from its southern boundary at Molsron Tukunsru to its northern boundary at Okat. Most of the coastal plain is covered with mangroves and only a narrow exposed reef flat occurs between the southern boundary (Molsron Tukunsru) to the westernmost point of land and reef point off Walung (Foko Saoksa). Around the corner to the northeast of Walung, the open reef flat is extremely wide (approaching 1 km) with only a narrow shoreline fringe of mangroves. Seagrasses are absent on the reef flats to the south of Foko Saoksa but are very extensive along the inner third of the reef flats northeast of Walung to Okat. Except for a small patch south of Finolog at Okat, coastal swamp forests are absent from Section 4. White sand beaches occur seaward of the mangrove fringes, facing the inner open reef flats between Foko Saoksa north past Walung to the northeast to Srukames and Insiaf. Beyond this headland to the northeast, beaches are absent but the mangroves broaden to cover the inner half of the shallow reef platform.

Four channels cut through the reef or mangroves in Section 4, and the shallow passage over the reef through the mangroves at Molsron Tukunsru constitutes the southern boundary and only western boat passage through the coastal strand and mangrove from the open ocean. However, it does not cut into the reef and is only passable at mid to high tide by boat. This channel connects to the inland waterway Inya Walunga which runs between Utwe and Walung. The other three channels are found to the northeast of Walung and the outermost portions cut into the reef providing safe deeper access for boats. The innermost portions of two of the channels, Molsron Murot (near Wot school and Insiaf) and Molsron Yela (further to the northeast) become shallower and eventually merge with the shallow reef flats. The last channel Molsron Okat constitutes the northeastern boundary of Section 4 and is a deep, completely navigable passage from the ocean side through the reef toward shore.

Several deep reef holes and one shallow reef hole are found along the middle open reef flats between Molsron Okat and the northern reef point (Foko In Wiyu) near Walung. Reef corals and fishes are common around the perimeter slopes of the holes while white sand covers their bottoms. The holes vary from 2 m to 30 m or more in depth. One small coral islet is also found along the reef flat northeast of Walung, at Srukames.

The ocean-facing reef slopes are dominated by live coral, perhaps the most diverse and, abundant coral assemblages off Kosrae's ocean reefs, especially the reefs northeast of Foko Saoksa (Kosrae's westernmost point). Few observations were made south of the point but we suspect the ocean reefs are more exposed to periodic tropical storm and typhoon waves and surge.

Steep volcanic cliffs and mountain slopes covered with lush green rainforests dominate the interior of the island landward of the coastal plain. Prominent slopes and peaks occur at Lukunlulem, Polok, Insiaf, and Finolof.

The coastal strand or barrier island which runs along the entire southwestern coast from Utwe terminates at Walung at the peninsula of Saoksa. An extensive meadow of seagrasses separates the peninsula from the mangroves and separate barrier island to the northeast at Koasr. The landforms and coastal geomorphology present a spectacular backdrop to the offshore reefs, and Section 4 constitutes Kosrae's most important wilderness area.

FLORA

In the southwestern portion of Tafunsak Municipality, extensive mangrove forest, inland waterway and beach strand are present (as for much of Utwe). Inshore areas at the southwestern end of Section 4 were not visited during the KCRI survey; no seagrasses or macroscopic algae were recorded during SCUBA inspection of the reef slopes (Stations 39, 29).

Broad fringing reef flats with well-developed mangrove forest and seagrass beds occupy most of the northern portion of Section 4. Extensive seagrass beds were an obvious feature of the inshore reef flats during the KCRI survey. Seaward, the survey found there was generally a zone of relatively bare reef pavement with sparse algal cover (a notable exception being the situation at the eastern limit of this section (Station 27), where a dense bed of Sargassum and associated algae abutted the seagrass bed). Toward the reef crest, there was generally a dense carpeting of algae, especially Caulerpa spp. and Halimeda spp. No obvious beds of Sargassum or Turbinaria were observed at the reef crest areas visited in this section. Coralline algae and Halimeda were common in the spur-and-groove zone.

CORALS

The most pristine, diverse and abundant coral communities off the ocean-facing reef slopes of Kosrae occur along Section 4, especially to the northeast of Foko Saoksa and Foko In Wiyu. The perimeters of all reef holes support good coral development while the reef flats are shallow and generally lack high coral development except at the outer margin (outermost 200-300 m). The channel walls at Molsron Mwat, Molsron Yela, and Molsron Okat also support high coral development. Recent dredging and filling associated with the airfield and dock project at Okat may have stressed the southern side of Molsron Okat even though the construction was occurring at least 1 km to the east of the channel wall. A few coral species are found among the seagrasses.

Coral coverage usually exceeded 75 percent on the ocean reef slope but was depressed at the western facing south of Walung (Station 39) due to damage from the 1986 typhoon passing southwest of Kosrae. Over 40 species of corals were reported at all ocean reef stations and the two highest totals (65 species and 56 species) from anywhere at Kosrae were reported on the ocean reefs just north of Saoksa and offshore from Srukames.

OTHER INVERTEBRATES

As shown by mapped resource use data on the Kosrae Coastal Resource Atlas maps, the mangrove crab (Scylla serrata) inhabits the extensive mangrove forests of this section, and coconut crabs (Birgus latro) and land crabs (Cardisoma sp.) are found along the coastal strands. Some known habitats of other invertebrates utilized by island residents are also revealed by the maps. Highlights of invertebrate observations made at KCRI stations in western Tafunsak follow.

Shoreline areas in the southwest portion of Section 1 (Stations 29, 39) were not visited during the KCRI survey; one living Tridacna specimen was recorded during SCUBA inspection of the reef slope at Station 39.

The long sandy beach fronting the village of Walung was strewn with various mollusk shells; most notable was a pile of more than a thousand adult Trochus niloticus, which were apparently recently collected and awaiting sale. The village grounds contained some old shell remains of Lambis lambis and fragments of Tridacna spp., including what appeared to be old fragments of the largest species, T. gigas.

Invertebrates were found to be abundant and diverse over much of the broad fringing reef in the northern portion of this section. Littorine snails were common on mangrove trees at Station 27 (and probably all along the edge of the forest). In the extensive seagrass beds of the inner reef flat, the most common invertebrates seen included erect brown sponges, bivalve mollusks (shell remains, especially those of Quidnipagus palatum), and small portunid crabs. At the seaward edge of the seagrass at Station 27, a noteworthy large bed of Sargassum algae harbored a diverse assortment of invertebrates. The most obvious and abundant invertebrate on the pavement and rubble of the outer half of the fringing reef flat was the sea cucumber Holothuria atra. Toward the reef crest, cowries (especially Cypraea moneta) were common and occasional other gastropods (especially Turbo argyrostoma and Trochus spp.) and the starfish Linckia laevigata were observed. The sea cucumber Actinopyga mauritiana was occasionally observed near the reef crest or in the seaward spur-and-grove system. In channels of the spur-and-groove system at Station 30, giant clams (Tridacna sp.) and spiny lobsters (Panulirus sp.) were occasionally seen.

Near channels, e.g. at Stations 25 and 27, reef flat invertebrates were relatively more numerous and included other sea cucumbers (Bohadschia argus, Stichopus chloronotus) and the bright blue starfish Linckia laevigata. A single living specimen of the black-lipped pearl oyster (Pinctada margaritifera) was found in a small depression in the reef pavement near the reef margin at Station 27. Along the edges of the channel at Station 27, sea anemones, spiny lobsters (Panulirus sp.), a giant clam (Tridacna sp.) and an octopus were found. In the large reef hole at Station 50, the gastropod Strombus luhuanus, not seen elsewhere during the KCRI survey, was common.

Few non-coral invertebrates were reported on the reef slopes of Section 4. As noted above, a living Tridacna specimen was observed on the

slope at Station 39. At SCUBA depths on the reef slopes at Station 28, some living specimen(s) of the black-lipped pearl oyster (Pinctada margaritifera) were reported; during the entire KCRI survey, this species was observed only at Station 28 and at a nearby reef flat (Station 27, noted above).

FISHES

Fishes recorded in Section 4 during the KCRI field survey are listed by station in Appendix D. Survey emphasis was on recording conspicuous species utilized for food. At least 195 species, representing 31 families, were recorded in Section 4.

Fishes reported as common or abundant at one or more of the inshore areas of this section (Stations 50, 30, 23, 25, 27) included various surgeon fishes (Acanthurus spp., Ctenochaetus striatus), various wrasses (esp. Thalassoma spp.), threadfin (Scolopsis cancellatus), angel fish (Pygoplites diacanthus), various damsel fishes, parrot fishes (Scarus spp., Ypsiscarus ovifrons), and moorish idols (Zanclus cornutus). Parrot fish (S. dimidiatus) were abundant, and groupers (Epinephelus merra) were common, at the large reef hole fronting Walung (Station 50).

Fishes reported as common or abundant at one or more offshore areas (Stations 39, 29, 31, 24, 26, 28) included surgeon fishes (Acanthurus spp., Ctenochaetus binotatus, Naso lituratus), trigger fish (Balistoides viridescens), fusiliers (Caesio spp.), butterfly fishes (Chaetodon reticulatus and Heniochus chrysostomus, with a number of others occuring rarely or occasionally), rudder fish (Kyphosus cinerascens), emperors (Gnathodentex aurolineatus, Lethrinus microdon, Monotaxis grandoculis), snappers (Aphareus furcatus, Lutjanus spp., Macolor niger), goat fishes (Mulloidichthys flavolineatus, Parupeneus bifasciatus), threadfin (Scolopsis cancellatus), sweepers (Pempheris oualensis), various damsel fishes, parrot fishes (Scarus spp.), and groupers (Mirolabrichthys spp.).

OTHER VERTEBRATES

Vertebrates other than fishes were only incidentally observed during the KCRI survey. Four observations of unidentified sea turtles were made during a SCUBA dive at Station 28, and a Pacific reef heron (Egretta sacra) was observed on the reef crest, just inside the zone of breaking waves, at Station 30. Any of the other vertebrates discussed in the overall summary section of this report may also occur in West Tafunsak.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

This area of Kosrae has received initial archaeological survey work [3, 26], but detailed studies with excavations have occurred only at the Leap coastal site (Ko-D2-1) and the Lukunlulem enclosure complex (Ko-D12-1) [6].

Permanent dwellings along this shoreline are fairly similar to those in central and western Utwe. From Lukunlulem to Finolof, dwelling sites are found scattered along the narrow coastal plains behind the mangroves and on strand islets on the edge of the reef flat in Lukunlulem and Koasr. Permanent sites are also found on strand islets on the outer edge of the mangroves, particularly on the lengthy strands of Leap and Koasr.

The notable historic sites in this area are the major enclosure complexes of Lukunlulem and Yal at the interface of the mangroves and coastal plain. Yela, the large valley along this coast, also has numerous sites -- along the edge of the valley, on the coastal plain, on islets in the mangroves, and on stand islets on the outer edge of the mangroves. Until recently, archaeologists thought the enclosure complexes might be the ruling centers of the A.D. 900s-1300s polities on Kosrae which preceded the construction of Lelu. However, dating at Lukunlulem, and at Nefalil's Ko-C8-1, show the enclosure complexes were built primarily in the A.D. 1400-1600 period.

Reef resource exploitation in this area in prehistoric and early historic times is again poorly known at present. The only excavations where faunal material have been recovered are at Leap (Ko-D2-1), and here unfortunately the prehistoric components of the site have been eroded away [6].

RESOURCE USE

An area of reef between Molsron Yela and Molsron Okat (boundaries not marked on atlas map) has been designated as a reserve area for the marine snail Trochus niloticus, which is collected both for the shell (which is sold for commercial use) and for the meat.

During a visit by the KCRI team to the fishing village of Walung, the long sandy beach fronting the village was observed to be strewn with various mollusk shells; most notable was a pile of more than a thousand adult Trochus niloticus, which were apparently recently collected and awaiting sale. The village grounds contained some old shell remains of Lambis lambis and fragments of Tridacna sp., including what appeared to be old fragments of T. gigas.

A meeting with resource users was held 1 August 1986 at Walung. Information obtained from participants was used to map resource use in Section 4 of the Kosrae Coastal Resource Atlas. A discussion of resources used at Kosrae is provided at the overall summary section of this report. Additional information obtained from the Walung interview participants regarding resource items and resource problems is summarized below.

Notes on resource items

The fishermen stated that they throw net inside of the breakers at low tide for rudder fish. At high tide, the jacks come in over the reef flat

and the fishermen catch them by spear and net. Snappers are caught by net and by bottom fishing. Groupers are caught by spear and by bottom fishing. They use almost any small fish for bait, not just "sardine". They don't harvest any sea cucumbers here. They find turtles "everywhere outside the reef", but they know of no turtle nesting places in the Walung area.

Resource use problems

Walung's fishermen commented that fisheries are declining because of people coming from other areas (other municipalities and also off-island, e.g., the Philippines) to fish here on the reef. Almost everyone in Walung is a fisherman, even the children. When asked, the fishermen estimated the number of fishermen from outside who fish here at about "maybe 200". The increase in number of people fishing has affected the fisheries. Okat airport area fisheries have decreased, especially the mullet, parrot fish, and red fish on the reef.

Chlorox is being used in Malem and Utwe but not in Walung area. There is "no problem" with too many people using fish poison plant here.

WATER QUALITY

The marine waters of this section are Class AA except that Okat Harbor, at the eastern end of the section, is Class B [73]. For class definitions, see Appendix F.

Non-point sources affecting water quality in 1979 [71] included the good-size streams in Mwot, Lennwat, Wiyu, Yella, and Las; no point sources were identified.

Water quality observations made during the KCRI survey are noted at each of the area descriptions which follow.

TUKUNSRU
(Station 39)
(Atlas Map 12)

PHYSIOGRAPHY

The shallow channel (Molsron Tukunsru) through the coastal strand and mangroves is the most prominent feature at this site. Being the only passage over the reef to the shoreline between Walung and Utwe Harbor, Molsron Tukunsru is an important navigation channel for small boats and is subject to strong tidal currents. The channel connects to Inya Walunga, the inland waterway and main water transportation route between Walung (to the north) and Utwe (to the southwest). The ocean reef slopes are dominated by live corals despite severe damage from a May 1986 typhoon

(Lola). The outer open reef flat is narrow (100-200 m wide) because of the position of the coastal strand and barrier island on the reef platform near its outer margin. Mangroves are well developed inland from the strand, bisected in a north to south direction by the Inya Walunga waterway. A stream, Infal Lukunlulem, originates from the headland at Lukunlulem and empties into Inya Walunga 0.5 km north of Molsron Tukunsru. The total width of mangrove belt is nearly 0.75 km. The beaches along this coast are exposed to periodic storm waves and are composed primarily of coral shingle, cobble and rubble. The narrowness of the reef flat prevents seagrass development, and the nearest meadows occur to the north on the reef flats and opening to Inya Walunga between Saoksa and Koasr. Coastal swamp forests are absent at Tukunsru with the nearest swamps occurring adjacent to the headland of Yemulil just south of the municipal boundary between Sections 3 and 4.

FLORA

Virtually no shallow reef flat is present at this location; the reef slope begins immediately offshore. The shoreline area was not visited during the KCRI survey. No seagrass beds or macroscopic algae were seen during SCUBA inspection of the reef slope.

CORALS

Although 40 species of stony corals were reported at Tukunsru, coral development was depressed due to 1986 damage from typhoon Lola. Coral coverage was lower (50 percent) compared to the normal 75-80 percent on the ocean-facing reef slopes. Corals particularly hard hit by the storm included table and staghorn Acropora, with major platforms razed to rubble. Even large hemispheres of Porites were overturned and some recently living colonies were washed upon the cobble beach. Remaining substrates (50 percent) are covered with coral rubble to depths of 12-13 m. The most abundant corals included Turbinaria sp., Galaxea fascicularis, and Acropora formosa. Common corals included species of Leptoria, Montipora, Porites, Millepora, Heliopora, Echinopora, Symphyllia, Mycedium, Lobophyllia, Pocillopora and other Acropora spp.

Soft corals (Sinularia spp. and Lobophytum sp.) were common on the reef slope.

OTHER INVERTEBRATES

The shoreline area was not visited during the KCRI survey. One living adult Tridacna sp., with a shell length of approximately 30 cm, was observed during SCUBA inspection of the reef slope at Station 39.

FISHES

Common groups observed at Station 39 included surgeon fishes (esp. Ctenochaetus binotatus and C. striatus), an abundant unidentified caesionid, an unidentified wrasse, emperors (esp. Gnathodentex aurolineatus), snappers (esp. Lutjanus bohar and the abundant Macolor niger), damsel fishes (esp. Amphiprion chrysopterus, abundant Abudefduf vaigiensis, Chromis spp., and Dascyllus spp.).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI Station 39; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary). A major archaeological complex is known at Lukunlulem.

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

At the time of the KCRI survey, surface waters at Station 39 were noticeably turbid at depths less than 3 m (10 feet). Horizontal visibility was much better, approximately 20 m (70 feet) at depths of 6-20 m (20-65 feet).

FOKO SAOKSA
(Station 29)
(Atlas Map 13)

PHYSIOGRAPHY

Foko Saoksa is the westernmost point of reef for the island of Kosrae, located just offshore from the westernmost point of land, the peninsula of Saoksa. The open reef flat is about 0.5 km wide and seagrass beds carpet the inner two-thirds of the flat. The reef platform, including the open

reef flat, the coastal strand islands (Saoksa offshore and Koasr inshore), and the mangrove forest, is over 1.5 km wide with the mangroves taking up the inner half of it. A stream, Infal Panyea, discharges through the mangroves to the shoreline immediately northeast of the point and well developed sand beaches line the entire shoreline of the peninsula and seaward facing shoreline at Koasr. The ocean-facing reef slope just north of the point is dominated by live corals, and the outer margin of the reef flat is also dominated with corals. Sand cover becomes progressively more abundant on the middle reef flat until merging with the seagrass meadows. Reef areas directly off the point and to the south are more exposed to waves from tropical storms approaching from the south or southwest. As a consequence reef areas to the north of the point (Station 29) are less exposed as was the case during the fieldwork in 1986. Typhoon Lola passed to the south of Kosrae in May 1986 and yet there was little apparent damage at Station 29.

FLORA

At depths of approximately 6 to 15 m (Station 29), areas not dominated by living or dead corals had abundant coralline algae at the time of the KCRI survey. Shallower portions of the reef were not surveyed.

CORALS

Reef corals achieved peak abundance and diversity at Foko Saoksa compared to any other Kosrae field station. Over 65 species of corals were reported and coral coverage averaged 80 percent for the entire reef slope, approaching 100 percent below depths of 15 m and 75 percent at depths less than 6 m. Moderate exposure to heavy waves and the strategic location of point in the downstream reach of strong prevailing currents and perhaps eddy systems may explain the great coral development here. The dominant coral species was Galaxea fascicularis while several other species were abundant: Leptoria phrygia, Platygyra spp., Acropora hyacinthus, and Porites australiensis. The purple hard fan coral Distichopora violacea was very conspicuous and many other corals were common: Turbinaria, Heliopora, Favia, Fungia, Psammocora, Mycedium, Oxypora, other Acropora, Hydnophora, other Porites, Echinophyllia, Pavona, Favites, Echinopora, Diploastrea, and Pocillopora. At least 32 genera were reported at Station 29, and the site has excellent potential as a marine reserve on the basis of its coral development and variety.

OTHER INVERTEBRATES

Inshore portions of the reef were not visited during the KCRI survey. No non-coral invertebrates were reported during SCUBA inspection of the reef slope.

FISHES

The most common groups recorded at Station 29 included surgeon fishes (esp. Naso lituratus), fusiliers (especially Caesio caerulaureus, C. tile, and C. xanthonotus), butterfly fishes (esp. Heniochus chrysostomus), snappers (esp. Aphareus furcatus, Lutjanus bohar, and the abundant L. monostigma), goat fishes (esp. Mulloidichthys flavolineatus), threadfin (Scolopsis cancellatus), damsel fishes (esp. the abundant Chromis vanderbilti), parrot fishes (esp. Scarus sordidus), and groupers (esp. the abundant Mirolabrichthys dispar).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI Station 29; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

At the time of the KCRI survey, excellent water clarity conditions were observed offshore (bottom depths 6-15 m) near low tide at Station 29, which was in the lee of the prevailing winds and seas (refracting westerly swells, 0.3-1 m (1-3 feet) in height).

FOKO IN WIYU
(Stations 50, 30, 31)
(Atlas Maps 13, 14)

PHYSIOGRAPHY

The coastal zone of the Foko In Wiyu region (midpoint between Molsron Mwot and Foko Saoksa) is typical of the northwest coast of Kosrae including broad open reef flats wide seagrass beds, one shallow reef hole and large

mangrove forests landward of coastal strand. Some unique features include the small offshore island of Srukames and the well developed white sand benches to the west of the headland at Insiaf. White sand beaches are altogether absent along the rest of the coast to the northeast from Insiaf to Tafunsak. The reef platform is extremely wide off stations 30, 31, and 50 at Foko In Wiyu, approaching 2 km. The mangroves narrow down from the stream at Infal Panyea to the headland at Insiaf where they nearly disappear. The mangroves again become wide on the eastern side of the headland at Molsron Mwot.

FLORA

At the time of the KCRI survey, the inner half of the broad, shallow, sediment-covered reef flat was dominated by extensive seagrass beds, which gave way on the outer reef flat to reef pavement. In the vicinity of the large reef hole at Station 50, an unidentified filamentous alga occurred as attached and drifting tufts. Halimeda flakes, washed in from the seaward margin of the reef, were accumulating in the reef hole. On the reef pavement of the outer reef flat, among reef boulders, there was a sparse carpet of Caulerpa racemosa which was denser toward the reef crest. At the crest the dense belt of algae included abundant Caulerpa racemosa, occasional C. serrulata (and at least one other species of Caulerpa), abundant Halimeda sp., and occasional Turbinaria ornata. Seaward, in the spur-and-groove zone, Halimeda sp., Caulerpa racemosa, and coralline algae were common.

CORALS

Reef corals assemblages are extremely rich and diverse off the ocean-facing reef slopes (Station 31) but are nearly absent on the shallow reef flats landward of the margin. Good coral development was also observed in the deep reef hole (Station 50) around the perimeter walls. Over 56 species of corals were observed, the second highest total recorded during the Kosrae inventory, and coral coverage averaged 50 percent. Dominant corals included several species of Acropora and Galaxea fascicularis. Other abundant corals included staghorn coral (Acropora acuminata), Porites lichen and common corals included Leptoria, Leptastrea Heliopora, Millepora, Favites, Montipora, Symphyllia, Hydnophora, Echinopora, Turbinaria, Fungia, Pocillopora, Favia, and Goniopora. Over 29 species of corals were reported in the reef hole which had a maximum depth of 1.5 m. Coral coverage averaged 10 percent with the rest of the substrate covered with sand and large growths of filamentous macroscopic algae. Abundant corals in the reef hole included Porites cylindrica, and Porites lutea, and common species included Porites (S.) rus, Platygyra spp., Millepora exaesa, Porites spp., Millepora platyphylla, Acropora delicatula, Favites spp., Montipora spp., Galaxea fascicularis and a soft alcyonacean coral Sinularia sp.

OTHER INVERTEBRATES

On the sandy beach near Walung village, molluscan shell remains were common. These included a large pile of harvested Trochus niloticus shells, and scattered shells of Tridacna sp. and Lambis lambis. In the seagrass beds of the inner reef flat, bivalve shell remains (especially those of Quidnipagus palatum) were common. An unidentified brown, erect species of sponge was common toward the outer limit of the seagrass beds.

Beyond the seagrass beds, on sand and rubble, the sea cucumber Holothuria atra was common. In the large reef hole at Station 50, the gastropod Strombus luhuanus and bivalve shell remains (Gafrarium sp., Scutocarpagia scobinata, and Quidnipagus palatum) were common.

On the pavement of the outer reef flat, to the reef crest, invertebrates were frequently seen. Echinoderms included the sea cucumbers Holothuria atra (common over much of the outer flat) and Actinopyga mauritiana (found occasionally on the crest and beyond). The bright blue starfish Linckia laevigata was seen occasionally. Mollusks included occasional Lambis lambis and Turbo argyrostomus, and numerous cowries (especially Cypraea moneta; also C. arabica, C. vitellus, and C. poraria).

Beyond the reef crest, in the spur-and-groove zone, occasionally encountered invertebrates included spiny lobsters (Panulirus sp.), top shells (Trochus niloticus), and giant clams (Tridacna sp.).

FISHES

In the vicinity of the large reef hole (Station 50), common groups observed included surgeon fishes (esp. Ctenochaetus striatus), wrasses (esp. Thalassoma hardwickei), threadfin (Scolopsis cancellatus), damsel fishes (esp. Chromis atripectoralis, Stegastes nigricans), parrot fishes (esp. the abundant Scarus dimidiatus), and groupers (esp. Epinephelus merra).

At Station 30, surgeon fishes were abundant (esp. Acanthurus nigricans, A. lineatus, A. nigrofuscus, and Ctenochaetus striatus). Other frequently observed fishes included wrasses (esp. Thalassoma spp.), threadfin (Scolopsis cancellatus), damsel fishes (esp. Chromis vanderbiliti, Chrysiptera leucopoma, Stegastes nigricans), and parrot fishes (esp. Scarus sordidus). At Station 31, fusiliers (Caesio pisang and C. tile) and emperors (esp. Lethrinus microdon) were abundant.

OTHER VERTEBRATES

A Pacific reef heron (Egretta sacra) was observed on the reef crest, just inside the zone of breaking waves, at Station 30. Any of the other vertebrates discussed in the overall summary section may also occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary).

RESOURCE USE

The large reef hole at Station 50 is an important fisheries resource which attracts reef fish, particularly rabbit fish, goat fish, rudder fish, snappers and jacks.

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

The broad reef flat fronting the village of Walung has low circulation during low tide conditions, and this permits considerable heating of the water by the sun. During a morning to early afternoon visit to the village of Walung, sufficient insolation of the waters had occurred during the falling tide such that it was almost uncomfortable to walk across the reef flat to return to the anchored boat offshore. The KCRI survey team also noted the presence of warm surface layers (to depths of about 1 m) at the large reef hole (Station 50) and outside of the reef (Station 30). Horizontal visibility in the Station 50 reef hole was only about 5 m (15 feet). The warm surface layer at Station 30 contained much fragmented green filamentous algae and debris, and horizontal visibility was only about 6 m (20 feet); below this layer the water was markedly cooler and clearer, with horizontal visibility at least 10 m.

MOLSRON MWOT
(Stations 23, 24)
(Atlas Map 14)

PHYSIOGRAPHY

Molsron Murot is one of three large and deep channels cutting through the reef along the northwest coast of Kosrae between Walung and Okat. A stream, Infal Lenwot, drains through a large mangrove forest at the head of the channel and the freshwater influence may be somewhat responsible for keeping open the channel. A small coastal swamp forest may be located landward of the mangroves along the stream reach seaward of the steep volcanic headland west of Insiaf. Insiaf is a very prominent cliff which juts seaward towards the western side of the channel, reducing the average width of the reef flat from over 1.0 km to about 0.5 km. Well developed

seagrass meadows cover the inner half of the open reef flat on both sides of the channel. Although outer mouth of the channel is deep, it shoals rapidly when approaching the shoreline and boat passage is difficult at mid tide and near impossible at low tide. A small channel has been cleared from the inner southwest corner of the channel to the outermost point of the Insiaf headland to facilitate boat passage between the ocean and land and village at Leap and Insiaf. The outer channel walls and ocean-facing reef slope near Stations 23 and 24 are steep and dominated by live coral cover. The floor of the outer channel was not observed.

FLORA

The nearshore half of the reef flat at Station 23 was not visited but was observed from a distance to be covered with extensive seagrass beds. Toward the outer portion of the reef flat, the seagrass beds were thinner and patchy, with areas of sand-veneered reef rock. Occasional unidentified filamentous algae and Caulerpa racemosa were seen. Neomeris sp. occurred rarely.

Seaward, there was a zone of bare reef pavement with Acropora shingle and scattered reef boulders (to approximately 1 m in diameter), with no algae noted. At the reef crest, there was a carpet of Caulerpa racemosa (abundant), C. serrulata (common), C. sp. (occasional), and a species of Halimeda with small thalli (abundant). No Sargassum or Turbinaria species were seen. Occasional coralline algae occurred on the reef crest. The spur-and-groove zone was not surveyed.

On the reef slope (Station 24), at depths of 3 to 15 m, much of the reef was covered with an unidentified filamentous alga which appeared to be colonizing bare substrate probably created by Typhoon Lola in mid-May, 1986.

CORALS

Although corals were abundant on the outer channel walls at Molsron Mwot, notes on corals were obtained only off the ocean-facing reef slope (Station 24) to the west of the channel entrance. Few corals were observed on the shallow reef flat (Station 23) and included only Porites sp. (probably P. lutea), the blue coral Heliopora coerulea, and the branching coral Pocillopora verrucosa. Corals were more abundant on the outer reef flat margin.

Over 47 species of reef corals were observed on the ocean-facing reef slope (Station 24), a relatively high number but less than the numbers reported at the two ocean reef stations to the west (Foko In Wiyu, Foko Saoksa). Some coral species may be more sensitive to the freshwater and sediment discharges from the channel during ebb tide. Coral coverage averaged 50 percent overall on the slope but was lower (35 percent) at greater depth (12-15 m) and higher (65 percent) in shallower water (6 m depth). In shallower water in the surf zone, filamentous algae were

abundant, perhaps colonizing substrates scoured by the heavy surf during Typhoon Lola in May 1986. Many corals were abundant including Diploastrea heliopora (a species which appears adapted to higher sedimentation), Leptoria phrygia, Echinopora lamellosa, Porites lobata, Echinophyllia aspera, Acorpora digitifera, Millepora platyphylla, and other species of Acropora. Porites lutea microatolls were dominant on the outer reef flat margin while Galaxea fascicularis approached dominance on the reef slopes. A number of species were common the slopes including those of the following genera: Platygyra, Oxypora, Favites, Acanthastrea, Leptastrea, Psammocora, Turbinaria, Fungia, Hydnophora, and additional Acropora.

OTHER INVERTEBRATES

In the patchy seagrass area of the seaward half of the reef flat (Station 23), the sea cucumber Holothuria atra was abundant. Various other invertebrates were noted as rare to occasional, including the sea cucumber Bohadschia argus, the blue starfish Linckia laevigata, an unidentified species of large nemertean worm, small colonies of Zoanthus sp., and gastropods (living Trochus maculatus, shell remains of T. niloticus). Money cowries (Cypraea moneta) were common among the rocks, here and throughout the seaward rubble and shingle zone. Intertidal snails (Drupa albolabris and an unidentified opisthobranch) occurred occasionally on large reef boulders. In the carpet of algae at the reef crest, occasional sea cucumbers (Actinopyga mauritiana) were seen clinging to exposed rock, and occasional cowries (Cypraea moneta, C. caputserpentis, C. helvola) were seen among rubble.

On the reef slope (Station 24), no other invertebrates were reported.

FISHES

Along the inshore reef edge (Station 23), the most abundant fishes recorded included various surgeon fishes, wrasses (esp. Thalassoma amblycephala), threadfin (Scolopsis cancellatus), damsel fishes (Chrysiptera leucopoma, Pomacentrus pavo), parrot fishes (esp. Scarus sordidus, Ypsiscarus ovifrons), and the moorish idol Zanclus cornutus.

Offshore (Station 24), the most common fishes included surgeon fishes (esp. the abundant Naso lituratus), trigger fish (Balistoides viridescens), wrasses (esp. Thalassoma lutescens), the abundant emperor Monotaxis grandoculis, the abundant snapper Aphareus furcatus, the sweeper Pempheris oualensis, the damsel fishes Chromis vanderbilti and Stegastes fasciolatus, and various parrot fishes.

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI stations in the Molsron Mwot area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary). Of special note are the sites associated with the Mwot School.

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

At the time of the KCRI survey (falling tide), horizontal visibility at Station 23 was approximately 5 m (15 feet) on both the reef flat and on the harbor channel (Molsron Mwot) reef slope.

At Station 24, during a falling tide (near low), a strong outgoing tidal current was present along the harbor channel wall, and a surface plume of brownish-colored slightly brackish water was exiting the Walung (western) side of the channel, limiting visibility. Outside of the reef, this plume was moving offshore of the channel and not far along the reef. Horizontal visibility was about 18 m (60 feet) outside the reef.

MOLSRON YELA
(Stations 25, 26)
(Atlas Map 15)

PHYSIOGRAPHY

Molsron Yela is the middle of three deep channels which cut through the reef along the northwest-facing coast of Section 4. It was probably the most remote of any location on Kosrae prior to the construction of the Okat airfield and dock project and is still the most pristine and undisturbed section of the coast. Station 26 (ocean reef slope) and Station 25 (reef flat) were located on the northeastern side of the channel.

Overall the coastal plain consisting of the basement reef platform along this section of the coast is 1.25 km wide, of which dense mangrove forests cover the inner one-third. Also a coastal swamp forest occurs at the point where the stream Infal Yela discharges off the higher volcanic slopes in a narrow valley inland and east of the channel. The stream winds its way through the mangrove and its mouth occurs at the head of the channel (Molsron Yela). High levels of sediments and freshwater may have inhibited coral development in the channel and may explain the gap in the

reef here as well as at Murot and Okat. Seaward of the mangroves, the open reef flat is wide, averaging 0.75 km in width, and is punctuated with several small but deep reef holes to either side of the channel. Seagrass beds are not well developed in the immediate vicinity of the channel; the wide seagrass belt to the south terminates about 0.75 km from the channel and only a small seagrass patch immediately to the northeast of the channel is present on the other side of the channel. As with other ocean-facing reef slopes sites along this coast, live reef coral development is high and dominates the substrates. The walls of the reef holes also have abundant coral while sand dominates both the floor of the holes and inner half of the open reef flats. No sand beaches or coastal strand or barrier islands occur along this section of the coast.

FLORA

Thin seagrass beds were visible on the reef flat inshore from Station 25. On the seaward reef flat (Station 25), the alga Caulerpa racemosa formed an extensive carpet on the lightly sand-veneered pavement. The transition zone from the reef flat to reef slope was dominated by algae between Porites microatolls. Live corals dominated the upper reef slope, with some patches of Halimeda algae occurring in scattered patches between the corals.

Offshore (Station 26), coralline algae were reported as abundant on hard surfaces in shallow water. Living corals dominated the slope.

CORALS

Corals are well developed along the ocean-facing reef slopes adjacent to the channel. A total of 46 species were noted in a half hour survey at Station 26 and coral coverage was rich (70 percent). On the shallow outer reef flat northeast of the channel (Station 25), corals were common and a total of 8 species were reported. The walls of the reef holes probably also support lush coral growth but were not visited. The massive coral Porites lobata achieved near dominance on the deeper reef slopes, and a number of species were abundant: Diploastrea heliopora, tabulate Acropora spp., Goniopora lobata, the fire coral Millepora platyphylla, columnar colonies of Porites (S.) rus, staghorn Acropora thickets (A. acuminata), finger coral Porites cylindrica, the yellow foliaceous or plate coral Turbinaria stellulata, Porites solida, Galaxea fascicularis. At least 10 other species were common on the slopes. On the reef flat (Station 25) the most common species was Porites (S.) rus, while P. cylindrica, other Porites species, and Pocillopora verrucosa were common. Coverage was less than 10-20 percent.

Soft corals (Sarcophyton sp.) occurred occasionally on the upper reef slope (depth less than 3 m) at Station 25.

OTHER INVERTEBRATES

On the reef flat pavement of Station 25, the sea cucumber Holothuria atra and the starfish Linckia laevigata were abundant. Along the edge of the reef (depth 1 to 3 m), a rich assortment of rarely to occasionally occurring invertebrates was found, including sea cucumbers (Bohadschia argus, Holothuria atra, Stichopus chloronotus), starfish (Linckia laevigata), large unidentified sea anemones with associated anemone fish (Dascyllus sp. and Amphiprion sp.), a spiny lobster (Panulirus sp.), featherduster worms (Sabellastarte sp.), Christmastree worms (Spirobranchus sp.), gastropods (Trochus niloticus, Turbo argyrostomus), bivalves (Spondylus sp., Tridacna sp.), and a cephalopod (Octopus sp.).

Offshore (Station 26), no non-coral invertebrates were reported on the reef slope.

FISHES

Inshore (Station 25), the most abundant fishes recorded included surgeon fishes (esp. Ctenochaetus striatus), wrasses (Halichoeres sp. and Thalassoma purpureum), the angel fish Pygoplites diacanthus, the damsel fish Amphiprion perideraion, and parrot fishes (esp. Scarus sordidus).

Offshore (Station 26), the most common fishes included surgeon fishes (esp. Acanthurus nigricans and abundant Ctenochaetus striatus), the fusilier Caesio caerulaureus, the abundant emperors Gnathodentex aurolineatus and Monotaxis gradoculis, snappers (Lutjanus bohar, and abundant L. fulviflamma and L. gibbus), goat fishes (Mulloidichthys flavolineatus and Parupeneus bifasciatus), and various damsel fishes.

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI stations in the Molsron Yela area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

At the time of the KCRI survey, horizontal visibility along the Molsron Yelo reef slope was about 4-6 m (15-20 feet).

At Station 26, during low (ebbing) tide, a current was moving out the channel. A plume of brown, turbid water was present in the mouth of the channel. Outside of the reef, horizontal visibility was nearly 30 m (100 feet.

MOLSRON OKAT
(Stations 27, 28)
(Atlas Map 16)

PHYSIOGRAPHY

The middle of the channel into Okat Harbor, Molsron Okat, forms the boundary between Kosrae Sections 4 (West Tafunsak) and 5 (East Tafunsak). Physiographic discussions therefore are confined to the southwest side of the channel and adjacent coastal features to the southwest.

The physiography of southwest Okat is very similar to that of Yela with the total width of the basement reef platform averaging 1.25 km in width with mangroves fringing the inner one-third of the platform. Seagrass beds are patchy in distribution. One important clump is found northwest of the largest enclosed reef hole along this coast. A river, Infal Okat, discharges through the widest and most interior sections of the mangrove, and river discharges are probably responsible for preventing coral growth from closing off the channel. Ocean-facing reef slopes are covered with corals as with other sites but many species of coral are absent perhaps due to die off from extensive construction activity which generated silt and turbidity plumes. Coral abundance is also lower.

FLORA

At Station 27, mangrove trees (Sonneratia sp.) were abundant along the shoreline. Seaward at the mangroves, there were extensive and dense seagrass beds, with a thick "mat" or "turf", and with a common intermixed alga (possibly Gracilaria sp.). Seaward of the seagrass beds, an extensive bed of Sargassum sp. was interspersed with Halimeda spp. Further seaward, but inside of the reef crest and surf zone (which were not surveyed), the sediment-covered reef pavement had few noticeable algae except for occasional patches of Halimeda spp. (including H. macroloba) and, rarely, some Padina sp.

Offshore (Station 28), on the steep channel walls, no algae were reported.

CORALS

Perhaps due to continued stress from siltation from the former construction site on the northeast side of the channel (Molsron Okat, Station 28) coral coverage was less than normal (averaging 38 percent) and coral diversity was less (21 species reported). The most abundant corals were the fire coral Millepora platyphylla, the blue coral Heliopora coerulea, and the encrusting coral Porites lichen. The dominant coral species was Porites (S.) rus. Other common species were Diploastrea heliopora, the wire coral Cirrhipathes, encrustations of Montipora sp., and the brain corals Favia favus and Leptoria phrygia. The very steep cliff-like walls and overhangs may also have diminished coral development but shading species requiring more sunlight. Coral diversity and abundance increased further outside the channel.

In contrast, the nearby reef hole (Station 27) supported more coral species (29) and greater coral abundance (approaching 50 percent coverage), even though only a few minutes were spent in the hole. The most abundant species at depths of 6 m or less on the slopes of the hole were Acropora digitifera, Porites cylindrica and Porites (S.) rus. The most abundant species on the reef flat next to the lip of the hole were the soft coral Sinularia, Montipora digitata, Porites lutea, and Acropora digitifera. The ramose forms of M. digitata achieved dominance in some areas, forming large monospecific platforms. Other common corals on the slopes of the hole and adjacent reef flats include: Fungia fungites, Physogyra lictensteini, Leptoria phrygia, Montipora foliosa, Halomitra pileus, Millepora platyphylla, M. dichotoma, several romose and corymbose species of Acorpora, Pavona varians, and several brain coral species (Platygyra spp., Favites spp., and Favia pallida).

Soft corals (Sinularia spp.) were abundant on the reef flat near the reef hole at Station 27.

OTHER INVERTEBRATES

Intertidal snails (Littoraria scabra) were common on Sonneratia trees near the shoreline at Station 27. Seaward, in the dense seagrass beds, erect brown sponges and small portunid drabs were common. In the seaward Sargassum bed, mollusks (or their shell remains) were common and included both gastropods (Lambis lambis; Cypraea spp., especially C. tigris and C. moneta; Euchelus atrata; Natica sp.) and bivalves (Atrina sp., Chama sp., Mytilus sp.).

On the outer half of the reef flat, echinoderms were numerous and included the sea cucumbers Holothuria atra (abundant, on sand-veneered pavement) and Stichopus chloronotus (common, along channel margin), brittlestars (common, in reef holes), the sea urchin Echinostrephus sp. (rare, in reef holes), and the starfish Linckia laevigata (occasional, on pavement). Gastropod mollusks seen on the outer reef flat included occasional Cypraea moneta, small Strombus spp., and remains of Conus capitanus. A single, living juvenile specimen of the black-lipped pearl

oyster (Pinctada margaritifera) was seen in a very shallow hole in the reef pavement.

Offshore (Station 28), additional living specimens of P. margaritifera were seen on the channel wall.

FISHES

Inshore (Station 27), the damsel fish Pomacentrus pavo was common. Other fishes (Appendix D) were only occasionally seen.

Offshore (Station 28), the most common groups included surgeon fishes (esp. Ctenochaetus binotatus), butterfly fishes (esp. Chaetodon semeion), various wrasses, emperors (esp. Monotaxis grandoculis), snappers (esp. Aphareus furcatus and abundant Lutjanus fulvus), goat fishes (esp. Parupeneus bifasciatus), sweepers (Pempheris oualensis), various damsel fishes and parrot fishes, and groupers (Mirolabrichthys dispar and abundant M. pascalus).

OTHER VERTEBRATES

Four observations of unidentified sea turtles were made during a SCUBA dive at Station 28 (2 of the 4 observations were of a pair, fixing the minimimum number of individuals seen at this location as 2).

No other vertebrates were observed at the KCRI stations in the Molsron Okat area; however, any of the other vertebrates discussed in the overall summary section may also occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 4 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 4 summary.

WATER QUALITY

At the time of the KCRI survey, very clear water conditions were encountered on the reef flat at Station 27.

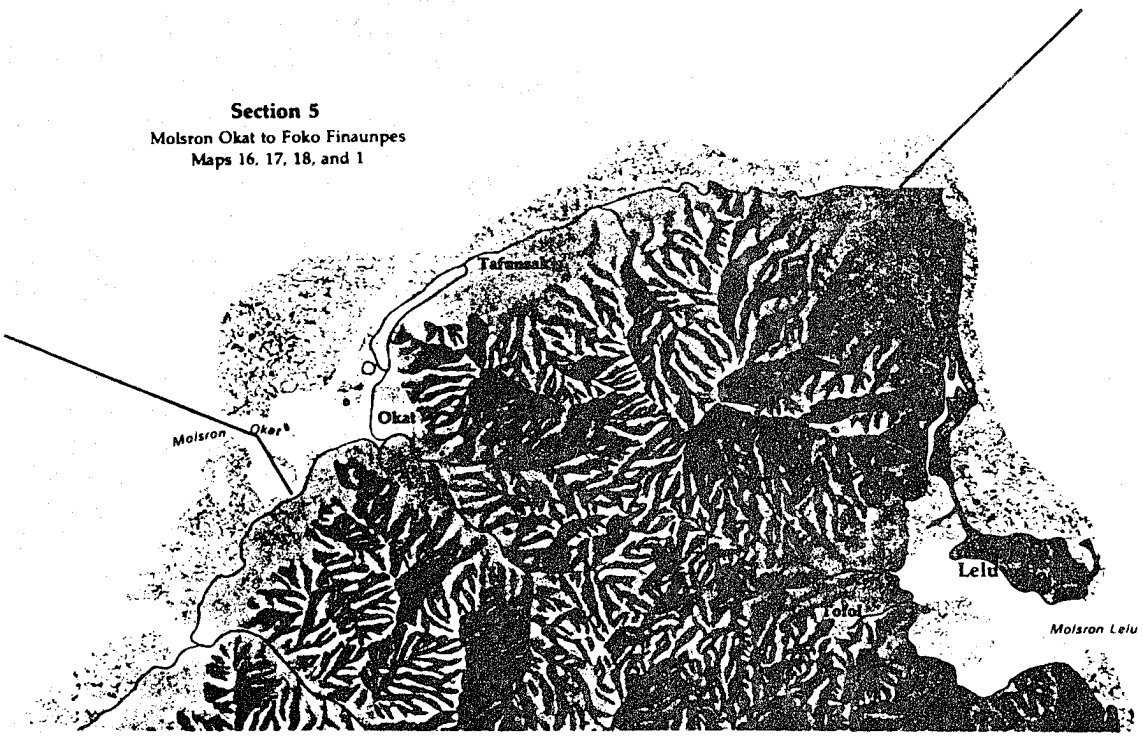
Offshore (Station 28), a slight surface current was observed exiting the channel; water was also observed moving eastward over the nearby reef flat. A surface plume of turbid, brown-colored surface water, to depth of about 1 m (3 feet) was present in the channel. Horizontal visibility was about 6 m (20 feet) in the greenish waters near the reef flat but about 18 m (60 feet) in the blue waters of the reef slope.

MAP SECTION 5 (EAST TAFUNSAK)

SUMMARY

GENERAL DESCRIPTION

This northern portion of Kosrae contains the village of Tafunsak. At the western limit of Map Section 5 is the Okat embayment, where new harbor facilities have recently been constructed. Adjacent to the new harbor facilities, on the broad reef flat at Okat, is situated the newly created reef runway of the Kosrae airport.



PHYSIOGRAPHY

Section 5 includes the north coast of Kosrae from the large natural harbor at Okat at the western boundary and along the village of Tafunsak to the northeast corner of the island at Foko Finaunpes. This section also is characterised by great diversity in physiographic features.

Within Okat Harbor the high volcanic headland of Finolof juts into the southern harbor, allowing extensive mangrove formations to the north. The harbor itself is deep and was extensively modified during construction of the Okat airfield and dock project in the early 1980s. Two patch reefs, rare in Kosrae, are found in the harbor and shallow reef holes punctuate the wide reef on the north side of the harbor. Several small islands (Kiut, Mutunyal, and Sroansak) are situated on the north side of the harbor.

Seagrass beds are extensively developed along the entire section, and mangroves form a continuous fringe along the inner margins of the open reef flat to the western outskirts of Tafunsak village. Okat River (with the tributaries of Infal, Okat and Infal Melo) is the largest stream system in Section 5, emptying into the harbor, and smaller streams occur at Infal Mutunte and Infal Sialat next to Yekula. An inland waterway, Infal Srelel, through the mangroves connects northern Okat to the open reef flats west of Takunsak. A coastal freshwater swamp forest occurs inland and south of the west end of Tafunsak village. Sandy beaches occur from west Tafunsak east to the point at Foko Finaunpes, although some sections are eroding and characterized by coral cobble and shingle beaches.

Construction at Okat also created a major fill complex (the runway and dock) on what was previously an open reef flat, and cut a channel from the northern end of Okat harbor to the open reef to the west of the runway on the landward side of the runway. Roadways, culverts and a large bridge connect the airfield and dock complex to the Kosrae mainland. Water current and circulation patterns were extensively modified as a result of the construction.

FLORA

The reef flats of Section 5 support extensive natural plant communities in the relatively undisturbed eastern half, and some apparently successional plant communities in the western half, where the airstrip and harbor facilities have been recently constructed. In the western portion, there is a sizeable area of mangrove forest on the exposed reef flat (not behind beach strand), through which the access road to the new airfield has been constructed.

The nearshore half of the broad reef flats normally support seagrass beds, which are replaced seaward by sparse algal cover on sand-veneered reef pavement, and, just shoreward of the reef crest, by a carpeting of Caulerpa spp. Sargassum and/or Turbinaria form dense stands at the reef crest. Halimeda spp. and coralline algae normally occupy the seaward spur-and-groove zone.

At the time of the KCRI survey, in the vicinity of the new airport runway project (Station 3), seagrasses were observed to be recolonizing the seaward margin of the small boat channel and adjacent portions of the reef flats. A filamentous blue-green alga (unidentified) was abundant over the middle zone of the reef flat near the runway, suggesting an ongoing active process of succession of the plant community in the disturbed areas. Seaward algal communities at Station 3 appeared to conform more or less to the "natural" pattern outlined in the previous paragraph. At the time of the KCRI survey, strong wave action and current was removing much of the accumulated dredge waste from the reef flat at the southwest end of the runway (Station 4); no seagrasses or algae were observed there except at a large reef hole. At a patch reef within Okat Harbor (Station 35), no seagrasses were observed but there was a relatively diverse and healthy algae community.

CORALS

Outside of Okat harbor the only habitat for high coral develoment are the ocean-facing reef slopes. Since these slopes face generally to the north, they are more exposed to wave action from the prevailing northeast trade wind swells but are not as exposed as the eastern-facing ocean reefs of Map Section 1. There is substantial evidence of present and past infestations by Acanthaster (crown-of-thorns starfish, a predator on live corals) which in turn has reduced the abundance and diversity of corals at some stations compared to the "normal" situation: coverage exceeding 60 percent and total diversity approaching 40-45 species.

The shallow reef flats support a limited number of coral species and abundance is generally less than 10 percent except along the outer reef margin. The two reef holes on Okat reef are shallow, less than 4-5 m in depth and support lush but small communities of coral. Prior to recent construction the walls of the inner harbor and the slopes of the patch reefs supported well developed and diverse communities of stony corals. However many of these were buried by fill or silt and others were badly damaged. Only the southern side of the outer Okat entrance channel, Molsron Okat, still supports relatively pristine and lush coral communities.

A number of studies were accomplished before, during, and after the construction which provide considerable additional information about the corals, fishes, invertebrates, algae, water quality, and circulation of the Okat Harbor region (Chun et al.[12]; Clayshulte [14, 15]; Cowan and Clayshulte [28]; Eldredge et al.[30]; and Maragos [44, 45]).

OTHER INVERTEBRATES

As shown by mapped resource use data on the Kosrae Coastal Resource Atlas maps, the mangrove crab (Scylla serrata) inhabits the extensive mangrove forests in the western portion of this section, and coconut crabs (Birgus latro) are found along the shoreline of the eastern portion. Some

known habitats of other invertebrates utilized by island residents are also revealed by the maps. Highlights of invertebrate observations made at KCRI stations in eastern Tafunsak Municipality follow.

Shoreline snails and grapsid crabs were occasionally to commonly observed wherever natural or manmade shorelines occurred in Section 5. Two species of the shoreline snails were very abundant on the east end of the new airport revetment (Station 3).

Where seagrasses dominated the inshore reef flat, tiger and money cowries were found occasionally to commonly. The silt or sand veneered reef flat pavement areas generally had numerous gastropod mollusks (especially Conus spp.) and the sea cucumber Holothuria atra, to the reef crest. On the reef crest and seaward into the spur-and-groove zone, the holothurian Actinopyga mauritiana was occasionally found clinging to the rocky substrate.

On the reef slopes of this section, there was evidence of the presence of the crown-of-thorns starfish (Acanthaster planci); this coral-eating starfish was common (and observed eating corals) at Station 36, and was occasionally seen at Station 38. The reef slope at Station 33 showed evidence of old Acanthaster infestation and damage, although only one individual starfish was seen there during the KCRI survey.

The patch reef in Okat Harbor (Station 35) had a diverse invertebrate community of annelids, mollusks, crustaceans and echinoderms (Appendix C).

FISHES

Fishes recorded in Section 5 during the KCRI field survey are listed by station in Appendix D. Emphasis was on recording conspicuous species utilized for food. At least 176 species, representing 30 families, were recorded in Section 5.

Fishes reported as common or abundant at one or more inshore areas of this section (Stations 3, 4, 5, 6, 35, 37) included surgeon fishes (Acanthurus spp., Ctenochaetus binotatus), cardinal fish (Cheilodipterus lineatus), unidentified needle fish, blennies (Salarias fasciatus), butterfly fishes (Chaetodon spp.), wrasses (Cheilinus sp., and an unidentified labrid), emperors (Lethrinus harak), snappers (Lutjanus gibbus, juveniles abundant at shallow, seagrass-covered area, Station 37), goat fishes (Parupeneus multifasciatus, and an unidentified mullid), damsel fishes (Chrysiptera leucopoma, Pomacentrus philippinus), parrot fish (Scarus sordidus), groupers (Epinephelus hexagonatus), and rabbit fish (Siganus spinus).

Fishes recorded as common or abundant at one or more offshore areas of this section (Stations 32, 33, 34, 36, 38) included surgeon fishes (Acanthurus spp., Ctenochaetus binotatus, Naso spp.), trigger fish (Odonus niger), fusiliers (Caesio spp.), squirrel fishes (Myripristis spp.), rudder fish (Kyphosus cinerascens), wrasses (Bodianus axillaris, Cheilinus

rhodochrous, Gomphosus varius, Thalassoma lutescens), emperors (Gnathodentex aurolineatus, Monotaxis grandoculis), snappers (Aphareusfurcatus, Lutjanus spp., Macolor niger), goat fish (Parupeneus barberinus), threadfin (Scolopsis cancellatus), sweepers (Pempheris oualensis), angel fish (Centropyge loriculus), various damsel fishes, parrot fishes (Scarus spp.), and groupers (Mirolabrichthys dispar).

OTHER VERTEBRATES

Observations of vertebrates other than fish were only incidentally made at KCRI stations. Two tattlers (Heteroscelus sp.) and a Pacific reef heron (Egretta sacra) were observed on the airport revetment at Station 3, and a sea snake was observed on the shallow inshore reef flat at KCRI Station 37. Any of the other vertebrates discussed in the overall summary section of this report may also occur in East Tafunsak.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

This area of Kosrae was the focus of archaeological work on the mainland between 1979-81 [17, 19, 25, 26]. Surveys took place in Okat, Loal, Putuk and Tepat, with excavations in Putuk and Tepat. Also, excavations occurred at Wiya in the coastal site and in the Wiya Bird Cave.

The northern sandy shore of Tafunsak has permanent house sites as extensive subsurface deposits up to 1.0 m deep. Pavings and postholes commonly mark former house sites. The Wiya coastal site has the earliest date for an archaeological site so far on the island, A.D. 95 $\pm$ 70. The Tafunsak-Mutunte area has yet to receive detailed study, but it probably contains remains of a very similar age.

Beyond Tafunsak, from Tepat through Okat, mangroves again envelope the shoreline. In Tepat and in the Melo area of Okat, house sites occur as scattered, individual sites. In Putuk and Loal, major complexes of enclosures are present, built out slightly from the shore into the mangroves as landfill. Those in Putuk date quite recently, to the A.D. 1700s.

Again, little is known of marine resource exploitation prehistorically in this area. Excavations in the soil areas of Tepat and Putuk yielded no faunal remains, a common occurence in soil areas on Kosrae, perhaps due to preservation factors. The Wiya coastal site yielded faunal remains, a common pattern in sand contexts, but these faunal remains have yet to be analyzed in detail. However, despite the lack of archaeological information at present, Lutke's 1827 maps show fishtraps as linear alignments from the mangroves off Okaht toward the tiny islet of Sroansak. It is not certain if remains of this historic site still are present today.

RESOURCE USE

A meeting with resource users was held on 4 August 1986 at Tafunsak. Information obtained was used to map resources in Section 5 of the Kosrae Coastal Resource Atlas. Additional information obtained from participants is summarized below.

Notes on resource items

Interviewed fishermen stated that mangrove crabs and coconut crabs are being eaten by monitor lizards. When asked who eats the monitor lizards, the fishermen stated that some Kosraeans eat them.

No turtle nesting occurs here now, nor did it historically: the only known place is in Utwe, according to the fishermen.

Resource use problems

The fishermen stated that they began fishing elsewhere, outside Okat (the reef near the airport), because the fishing at Okat is not as good now as it used to be. The fishermen estimated that the overall fish catch decreased 50 percent following airport construction. Okat was their best fishing ground before the airport. Now their best area is Walung, which isn't as good as Okat was. The area west of Okat is now better than Okat is. When asked if there is anything (other than removal of the runway) which could be done to improve the situation, the fishermen responded "No".

When asked about shoreline erosion following airport construction, the fishermen identified one area at Tafunsak (near the "boat channel" and KCRI Station 5, indicated on Atlas Map 18) which had been altered by excavation of sand used for initial road construction. The fishermen indicated that the reef flat is getting shallower from the excavated area toward the airport along the edge of the mangroves.

Regarding the dredged small boat channel at the southwest end of the runway (Atlas Map 17), the fishermen stated that sand is accumulating on the landward side of the dredged channel. They stated that they cannot go shoreward in boats across the reef at low tide. They use the dredged channel as a shortcut and noted that it is easier to use the channel going inshore than offshore. When asked whether or not the small boat channel should be dredged completely through the reef, one respondent said "Why not?" but another gave a negative response, stating that waves would then come through the reef.

Fish poisons were described as "very bad" for fishing. Chlorox is possibly being used. No dynamite is being used. Leaf poison is "very strong" (root is legal but the leaf is not); it was not clear if it is in active use in Tafunsak.

Everyone can fish any place on the island; there is no problem regarding territories.

When asked when the crown-of-thorns starfish (Acanthaster planci) began eating up the coral, the fishermen replied that it was in 1970 and that from Okat Harbor, the starfish moved "both directions". A fisherman noted that the starfish eat the corals and that when this occurs, fish go elsewhere.

WATER QUALITY

The marine waters of this section are Class AA, except that the Okat Harbor area is Class B [73]. For class definitions, see Appendix F.

Non-point sources affecting water quality in 1979 [71] included streams at Palusrik, Okat, Tafunsak, Sronsrono and Yekula. Yekula and Tafunsak streams were identified as collecting some point sources (toilets and pig-pens at Tafunsak, discharge from the high school at Yekula).

Water quality observations made during the KCRI survey are noted at each of the area descriptions which follow.

OKAT HARBOR
(Stations 35, 36, 4)
(Atlas Map 16)

PHYSIOGRAPHY

Okat is the third largest natural harbor on Kosrae, and its entrance channel, Molsron Okat, serves as a convenient boundary line between Map Sections 4 and 5. The harbor is deep and cuts through what is Kosrae's largest shallow reef platform, some 2 km wide from the ocean margin to the high volcanic island coastline. Before 1981, the harbor region was pristine and undisturbed. Closest to the volcanic slopes a thick belt of mangrove forest covered the inner one-fourth of the reef flat and a band of thick seagrass meadows covered the middle reef. The outer half of the reef (prior to airfield, roadway, and dock construction) was characterized by shallow microatoll coral and coral rubble and pavement zones. Corals were abundant in two shallow reef holes (depth 4 m or less) and along the slopes of the channels, ocean-facing reefs and patch reefs. The bottom of the harbor consists of sediment varying from sand to fine silt. The streams Infal Melo and Infal Okat coverge and discharge into the mangroves. An inland waterway Infal Srelel enters the mangrove fringe at Loal and exits further to the north about 3 km west of Tafunsuk village. Beaches are absent along the shorelines, but 3 small islands occur on the channel's north side.

Construction to date on Okat reef has resulted in the filling of the outer reef flat for an airfield embankment measuring approximately 1,800 by 150 m (5,900 by 500 feet), and auxiliary landfill to the south of the runway for the deep draft dock. Causeways, bridges and culverts were

constructed to complete the roadway from the offshore reef runway to the mainland of Kosrae. In order to obtain sufficient fill for the landfilling, the construction company excavated a "small boat" channel (borrow site) along 2 km of the inner fringe of the reef flat. Other changes due to construction include the decline and fish abundance from loss of live coral habitat and seagrass beds. One large patch reef was dredged in half to facilitate a boat channel. The construction now greatly modifies circulation conditions over Okat reef. The runway embankment now serves as a barrier to water flow generated by waves breaking on the reefs ocean edge. Instead of flowing across the reef in a landward direction, water piles up along the entire outer face of the runway and then runs downhill around the ends of the runway into the harbor at the southwest end and into the small boat channel at the northeast end. During normal tradewind conditions, water flow in the small boat channel runs towards the harbor in a southwest direction. Storms and wave action from the west may be strong enough at times to reverse flow in the channel towards the northeast, as was observed in May, 1986 during Typhoon Lola.

FLORA

Algae were nearly absent from the central (reef flat) portion of the patch reef at Station 35; Valonia sp. occurred rarely. In contrast, algae were abundant in protected pockets along the patch reef margins, where Halimeda spp. formed some dense patches. On the wave-washed rocks on the seaward margin, Halimeda macroloba and Caulerpa racemosa occurred occasionally and Padina sp. occurred rarely.

Along the margins of the reef pool at Station 4, a large seagrass species (Enhalus acoroides) was locally abundant among the living corals. Algae were rare, consisting of only some small patches of Halimeda sp., on the reef flat near the airport revetment, probably due to residual effects of dredge spoil overflow which had occurred during runway construction.

On the reef slope (Station 36), an unidentified massive coralline alga and a filamentous alga (also unidentified) were abundant. Halimeda spp. and Dictyota sp. were common.

CORALS

At Station 35, coral cover was low to moderate (5 to 25 percent) on the reef flat; Porites lutea was common and Acropora spp., including A. cf. humilis, occurred occasionally. Coral cover was very high (about 90 percent) on the shoreward upper slope of the patch reef; Porites cylindrica and P. (Synaraea) rus were common to abundant, while Acropora valida was rare.

Soft corals (Lobophytum sp., Sinularia spp., and Cladiella sp.) were observed at Station 36.

Corals have been the subject of considerable observation during the past decade in the harbor area. Initially Eldredge et al. (1979) [30], accomplished surveys of corals and other reef studies as part of a baseline survey of the harbor and reef environs prior to construction. Sets of observations on corals, one before and several during construction were accomplished by a U.S. Army Corps of Engineers ecologist (Maragos) [45]. Finally in 1986 and 1988 additional observations on corals were accomplished by Maragos during the field work for the Kosrae Coastal Resource Inventory and during a visit to Kosrae in May, 1988 [44].

Corals to some extent were found in all major habitats surrounding the harbor, although less developed on inner reef flats dominated by seagrasses and mangroves. Corals naturally attentuated near the discharge point from the Okat River near the eastern inner margin of the harbor. Elsewhere peak coral development occurred along all slopes in the natural harbor including the patch reef slopes. The greatest diversity of corals occurred along the outer channel walls and rivaled outer ocean reef slope communities in terms of abundance and diversity. Also the two shallow reef pools, including one which is now off the southwest end of the runway (Station 4) supported good coral development and the runway project was realigned and shortened to avoid destruction of the hole.

Dredging, filling, sediment accumulation, and perhaps suspended sediments during construction caused much of the coral communities along Okat Harbor's inner slopes to decline or be killed. The dock complex buried some of the coral while dredging of adjacent berthing space at the dock destroyed additional coral on the slopes. Patch reefs within the inner harbor were dredged to create additional space for the harbor turning basin and coral communities on the slopes of these reefs were destroyed except for the inner half of one reef (Station 35). Here sedimentation and other factors limit coral diversity to only a few hardy species, Porites cylindrica, P. lutea, and several species of table and staghorn Acropora. Overflow of silt from the dredging operation at the southwest end of the runway during the construction buried about 10 hectares of reef flat and filled much of the reef hole. However strong wave induced currents have flushed the silt from the flats and reef hole and some corals survived in the hole. Coral recolonization is now progressing rapidly on the hard walls of the small boat channel and the base of the runway's riprap rock.

Only the east side of the Okat channel's coral communities appeared to have escaped damage from the airfield construction (Station 36). Observations in 1986 revealed 29 species of coral and coverage of 50-60 percent. The dominant species was Porites australiensis with P. cylindrica and Acropora spp. abundant and many other species common.

OTHER INVERTEBRATES

Occasional intertidal snails (Nerita plicata) were seen on exposed rocks of the patch reef at Station 35. The gastropod Drupella cornus was common on Porites coral heads near the shoreward margins, while the sea cucumber Stichopus chloronotus was common on the wave-washed pavement on

the seaward margin. Along reef margins, a few Christmastree worms (Spirobranchus sp.) occurred in Porites coral heads, and several featherduster worms (Sabellastarte sp.) occurred in dead coral. Rocky ledges in the center of the small reef flat harbored at least 1 spiny lobster (Panulirus sp.). Some gastropod and bivalve shell remains were also seen on the reef flat (Appendix C).

At Station 4, occasional intertidal snails (Nerita plicata) and unidentified grapsid crabs were seen on revetment rocks; no invertebrates were seen in the turbid waters over the scoured bottom beyond the revetment rocks or along the edge of the reef hole (where the water was also turbid).

On the reef slope (Station 36), crown-of-thorns starfish (Acanthaster planci) were common and observed to be feeding on living corals at depths of less than 6 m, where 90 percent of the coral was dead.

FISHES

At the patch reef in the inner harbor area (Station 35), the most common taxa observed included surgeon fishes (esp. Ctenochaetus striatus and abundant Acanthurus blochii), butterfly fishes (esp. Chaetodon citrinellus), wrasses, and parrot fishes (esp. Scarus sordidus).

No fish observations were made at Station 4; turbidity and current inhibited even incidental observations of fishes.

On the reef slope (Station 36), the most common fishes included various surgeon fishes, abundant fusiliers (Caesio tile), abundant rudder fish (Kyphosus cinerascens), emperors (esp. Monotaxis grandoculis), several species of snappers, various damsel fishes (most notably, abundant Chromis vanderbilti), parrot fishes (esp. Scarus sordidus), and groupers (most notably, abundant Mirolabrichthys dispar).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI stations in the Okat Harbor area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 5 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 5 summary.

The fishermen interviewed at Tafunsak expressed concern over the overall decrease in reef fisheries at Okat which has occurred since airport construction. Comments on this and other resource use problems are included in the resource use summary of Section 5.

WATER QUALITY

At the time of the KCRI survey, surface waters at a patch reef in inner Okat Harbor (Station 35) were somewhat turbid, especially on the south end; horizontal visibility was about 6 m (20 feet).

At Station 36, on a falling tide, horizontal visibility below a depth of 3 m (10 feet) was very good, 15-25 m (50-80 feet). Surface waters were only slightly turbid.

At Station 4, areas of grayish silty clay, which had spilled over the revetment onto the reef flat during construction of the new airfield, were still present on the reef pavement; however, at the time of the KCRI survey (17 May 1986, 1300 hrs) the dredged material was in the process of being resuspended and carried eastward into the inner harbor by a very strong, surf-driven current (more than 4 knots near the revetment and about 2-3 knots out on the reef flat) which was set up around the south end of the revetment. Because of the presence of the resuspended dredged material, visibility near Station 4 was very low, approximately 1 m, eastward of the reef hole. The reef hole appeared to have been flushed of silty material and visibility there was somewhat better, at least 2-3 m. The wave-driven current around the revetment was so strong that it appeared to be pushing water in the boat channel northward past the bridge, in spite of the wave action present on the reef there also.

FOKO KIUL
(Stations 3, 32, 33)
(Atlas Map 17)

PHYSIOGRAPHY

Foko Kiul covers the Okat reef region to the northeast of Okat harbor, opposite the reef runway and small boat channel. At the reef point itself (Foko Kiul), the ocean reef bends around from a west to a north-facing orientation when heading in the Tafunsak (easterly) direction. At the point the reef platform is over 2 km wide when measured to the onshore high volcanic headland at Loal. Prior to the runway construction the outer

four-fifths of the reef flat was open with only a narrow fringe of mangroves 400 m wide hugging the innermost reef flat next to the volcanic slopes. Seagrasses covered the middle section of the reef flat while mixed coral and algae communities occupied the outer reef flat and margin. Large reef blocks and tracts of boulders, shingle and rubble are strewn over the outer reef flat, probably deposited by wave action during western or norther storms. A small vegetated coral islet, Kiul, occurs at the point and a small reef hole is located 0.5 km to the northeast of the island. The ocean-facing reef slopes are dominated by living coral communities which show signs of recent major predation by the crown-of-thorns starfish, Acanthaster planci.

The runway now occupies the zones previously between the corals and seagrass beds, particularly the seagrass beds along the southwest half of the runway which were buried during construction under the fill land. The runway itself was realigned to avoid the reef hole to the east of Kiul island and another shallow reef hole lies immediately north of the middle length of the runway, apparently undisturbed. Reduced circulation along the inner (southern) length of the runway and the dock fill caused additional decline of seagrasses. However, the changing circulation conditions on the ocean side of the runway has promoted the reestablishment of some seagrasses, while other seagrasses on the opposite (southern) side of the runway continue to survive. Corals are also resettling on the large armor rock of the northern-facing revetment.

Elsewhere seagrasses to the northeast side of the bridge have been buried or scoured by strong currents and few exist on the northeast side of the bridge in contrast to the southwest side of the bridge where seagrasses survive. Clearing and construction for the road causeway also caused destruction of some mangroves between the bridge and higher volcanic part of the island. Finally the dredged small boat channel varies between 100 to 250 m in width and 5-7 m in depth. The bottom is covered with sand but coral and other marine life are colonizing the hard walls. Due to the breakdown of the dredge by wave action during channel dredging, the outermost end (northeast end) of the channel was not cut through and a lip at a depth of 1 m stretches across the channel rendering it unsafe for boat navigation.

FLORA

At Station 3, small patches of colonizing seagrasses were found along the seaward margin of the boat channel, where extensive seagrass beds had occurred prior to airport construction. Scattered, cropped seagrass was present over the outer two-thirds of the reef flat. Some patches of crustose coralline algae were seen on the upper channel wall. An unidentified filamentous blue-green alga was common to abundant on the inner reef flat (near boat channel), while Caulerpa racemosa, Halimeda sp., and Turbinaria ornata were occasional to common. Toward the outer reef flat (into the beginnings of the surf zone), Caulerpa racemosa formed a moderately dense carpet on the reef pavement, with occasional occurrences of Neomeris sp. and Turbinaria ornata.

At Station 32, occasional Halimeda spp. were observed at a depth of 2 to 3 m (surf prevented closer shoreline approach). No algae were reported at greater depths on the reef slopes of Stations 32 and 33.

CORALS

Coral development is generally confined to the ocean-facing reef slopes (Stations 32, 33) with a small coral community present in the shallow reef hole. The outer reef flat also supports a few corals, especially microatolls of Porites lutea. Prior to the runway construction larger coral communities on the deeper middle reef flat were present including species of Porties, Heliopora and Acropora. Few corals now occur off the highly scoured northeast end of the runway but many species are now colonizing the walls of the new boat channel including: Pocillopora verrucosa, Heliopora coerulea, Porites lutea, Montipora digitata, Porites lobata, Goniastrea retiformis, Favites spp., Psammocora contigua, Pavona varians, Cyphastrea serailea, and Acropora spp. The colonies are small and overall abundance is less than 1 percent coverage.

Corals achieve peak abundance and diversity on the ocean-facing reef slopes. At Station 32 some 39 species were reported and at Station 33 further east near the small boat channel "entrance" 46 species were reported. Coverage averaged greater than 50 percent below depths of 12 m but in shallow water coral abundance was less (10 percent) at depths less than 8 m at Station 32. The prescence of many recently dead colonies suggest major predation by Acanthaster, and several of the coral eating starfish were observed feeding on corals during the 1986 surveys at both Stations 32 and 33. The most common species at Station 32 were Pocillopora eydouxi, Porites lobata, Hydnophora exesa, Leptoria phryqia, Porites lichen, Galaxea fascicularis, Diploastrea heliopora, Favia spp., Favites spp., Gonastrea retiformis, Porites spp., Acropora spp., Platygyra spp., Millepora platyphylla, and Heliopora coerulea. None of the species were abundant or dominant. At Station 33 the most abundant corals were Porites lobata, table Acropora spp. and Galaxea fascicularis. The last species dominated many substrates. Other common corals included Favia, Heliopora, Hydnophora, Leptoria, Symphyllia, Favites, Platygyra, Barbattoia, Millepora, Porites, other Acropora, Leptastrea, and Diploastrea.

OTHER INVERTEBRATES

On the runway revetment (Station 3), thousands of intertidal snails had colonized the rocks, Littoraria coccinea occupying the higher rocks and Nerita plicata the lower. Occasional unidentified grapsid crabs were also seen on the revetment. Along the shallow (depth less than 1 m) margin of the dredged boat channel, various invertebrates were seen, including occasional spagetti worms (Lanice sp.), sea cucumbers (Synapta maculata), and juvenile gastropod mollusks (Trochus niloticus). On the adjacent reef flat, brittlestars (ophiuroids) were common among reef rubble. The sea cucumber Holothuria atra was abundant here and also throughout most of the

seaward reef flat. Toward the surf zone, occasional cowries (Cypraea moneta), Trochus niloticus (live juveniles, old shells of adults), and small Strombus spp. were observed. Occasional small "button" tunicates (Didemnum sp.) and yellow and gray sponges were seen.

On the reef slopes (Stations 32 and 33), a few living gastropod mollusks were reported, including Trochus niloticus, Trochus maculatus, Drupa ricina, Astraea rhodostoma, and Drupella cornus.

At Station 32, there was abundant dead coral due to an infestation, several years ago, of the crown-of-thorns starfish (Acanthaster planci). Only 1 individual of this species was observed at Station 32, at a depth of approximately 6 m. At Station 33, there was also some evidence of minor Acanthaster activity: 1 individual was seen feeding on Favia coral in shallow water.

FISHES

Inshore (Station 3), many juvenile fishes (surgeon fishes, butterfly fishes, goat fishes, moorish idols) were observed among the rubble along the seaward edge of the dredged boat channel. A school of unidentified baitfish was seen near the surface in the channel. On the shallow reef flat at the northeast end of the airport runway revetment, young and adult surgeon fish (Acanthurus triostegus) and damsel fish (Abudefduf sordidus) were common among the revetment boulders.

On the ocean reef slope (Stations 32, 33), the most commonly seen fishes included surgeon fishes (esp. abundant Acanthurus triostegus at Station 32), fusiliers (esp. Caesio xanthonotus at Station 33), various butterfly fishes, squirrel fishes (esp. Myripristis spp.), various wrasses, emperors, snappers, goat fishes (esp. abundant Parupeneus barberinus at Station 32), sweepers (Station 32), damsel fishes (several species abundant at Station 33), and groupers (esp. Mirolabrichthys dispar).

OTHER VERTEBRATES

Two tattlers (Heteroscelus sp.) and a Pacific reef heron (Egretta sacra) were observed on the airport revetment at Station 3. No other vertebrates were recorded at KCRI stations in the Foko Kiul area; however, any of the other vertebrates discussed in the overall summary section may also occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 5 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 5 summary.

Fishermen interviewed at Tafunsak expressed concern over the overall decrease in reef fisheries at Okat following reef runway construction. Other concerns include use of the new boat channel and erosion or siltation of inshore areas possibly resulting from its construction. Comments are included at the resource use summary of Section 5.

WATER QUALITY

At the time of the KCRI survey (17 May 1986, 1100 hrs), on a falling tide, horizontal visibility on the reef flat at Station 3 was fairly good, 9-12 m (30-40 feet), with a light current flowing toward the boat channel. Stronger currents (1-2 knots) was present along the northeast toe of the revetment, flowing into the boat channel. In the channel, the water was green in color and turbid, with a noticeable refractive discontinutiy and horizontal visibility of only about 4-5 m (15 feet). Much flotsam (seagrass thalli, mangrove litter, various other leaves) was present as windrows along the edge of the channel. As the tide continued to fall, the current in the channel reversed, flowing east at 1-2 knots. Thus it appears likely that Okat Harbor waters were entering the small boat channel. Current conditions observed during the KCRI survey were probably atypical because of the unusual surf conditions which set up strong current entering the harbor area around the southwest end of the airfield revetment (see Station 4) due to strong westerly surf generated by Typhoon Lola. Normally, northeast tradewind wave conditions prevail with water currents moving at 1-2 knots down the channel in a NE to SW direction [28, 44, 45].

At Stations 32 and 33, active surf conditions and turbid water were observed in nearshore areas (horizontal visibility only 6 m (20 feet) at Station 32). Visibility was reported as good in deeper waters at these stations.

TAFUNSAK VILLAGE
(Stations 37, 38, 5)
(Atlas Map 18)

PHYSIOGRAPHY

The coastal plain off the western side of Tafunsak village undergoes a west-to-east transition from a narrow open reef flat and wide mangrove belt to a wide open reef flat and seagrass beds. The mangroves drop out at the west end of the village and a small coastal swamp forest occurs inland

(south) of the village. The reef basement platform upon which all of the above communities rest averages a consistent 1 km in width until it reaches the volcanic headland at Malsu. Seagrass beds cover the inner half or more of the open reef flat and scattered corals, reef pavement, and algal beds occur along the outer reef margin. Live corals dominate the ocean-facing reef slopes. A sandy beach occurs along the shoreline of the village but is absent off the mangrove forests to the west. The village rests on a coastal strand formation which also terminates to the west. One small stream, Infal Mutunte, discharges from the volcanic slopes through the Mutunte part of the village to the shoreline and reef. Recently the shoreline off western Tafunsak village has been eroding, according to the villagers. They believe the erosion was caused by the construction contractor for the airfield project when he excavated reef materials off the reef flat to build a road and gain access to Okat.

FLORA

Sonneratia mangrove trees were noted along the shoreline at Station 5. Seagrass dominated the inner one-half to two-thirds of the reef flat at Stations 5 and 37. The seagrass beds were particularly dense in the slightly deeper "canoe channel" just offshore and parallel to the shoreline at Station 5, and in the large, shallow reef pool at Station 37. Padina sp. was occasional to common in the seagrass beds at both stations.

Along the edge of the reef pool at Station 37, algae of the genera Sargassum, Halimeda, Caulerpa, Dictyosphaeria, Jania, and Galaxaura were intermixed with the seagrass. An unidentified, filamentous blue-green alga occurred in tufts over much of the reef flat.

On the outer reef flat at Stations 5 and 37, the seagrass beds gave way to sand-veneered rock, then bare pavement. Caulerpa racemosa was a common to abundant alga of the outer reef flats. The genera Neomeris, Padina, Sargassum, and Turbinaria occurred rarely to occasionally. Some coralline algae were seen on the reef crest. Turbinaria and Sargassum formed a dense zone at the reef crest of Station 5.

On the reef slope (Station 38), Halimeda spp., Dictyota sp., and coralline algae were common.

CORALS

Most live corals are confined to the ocean-facing reef slopes off Tafunsak (Station 38) and typical of Kosrae as a whole. A few corals were reported on the middle reef flat within the seagrass zone (Station 5), including Porites (S.) rus, P. cylindrica, P. lutea, Psammocora contigua, Platygyra daedalea, Heliopora coerulea, Favites abdita, Goniastrea retiformis, Acropora digitifera and Favites flexuosa, species all typical of shallow open reef flats in Micronesia. Only one species, Pocillopora damicornis, was reported in the inner seagrass zone (Station 5).

In contrast 42 species of corals averaging 80-90 percent coverage were noted on the ocean reef slope (Station 38). Some recently dead coral was noted, probably from Acanthaster predation, but not in the magnitude reported at ocean stations to the west. Acanthaster was seen eating a Favia species. The coral communities were rich, healthy and lacking loose rubble or sediments. The dominant coral on the reef was Galaxea fascicularis, and several others were abundant: Platygyra spp., Hydnophora exesa, Porities australiensis, and Acorpora spp. Corals of the genera Montipora, other Acropora, Goniastrea, Echinopora, Goniopora, Stylocoeniella, Fungia, Turbinaria, Hydnophora, Pavona, Diploastrea, Favites, Mycedium, Symphyllia, Favia, Porites (Synaraea), Heliopora, Leptoria, Pocillopora, Lobophyllia, and other Porites were common.

Soft corals (Palythoa sp.) were observed on the slope at Station 38.

OTHER INVERTEBRATES

Occasional tiger cowries (Cypraea tigris) were seen near rubble patches along the edges of deeper nearshore portions of the seagrass beds at both Stations 5 and 37. Money cowries (C. moneta) were seen occasionally in the seagrass beds and on rubble along the edge of the shallow reef pool at Station 37. Synaptid sea cucumbers (Ophiodesoma sp.) were seen rarely in the canoe channel seagrass beds at Station 5. The sea cucumber Holothuria atra was occasionally seen in the seagrass beds and also throughout the outer reef flat. At least 4 species of living cones (Conus spp.) were seen on the sand-covered reef pavement of the outer reef flat at Station 5.

On the reef slope (Station 38), some feeding by the crown-of-thorns starfish (Acanthaster planci) on corals of the family Faviidae was reported, but only a minor amount of dead coral was observed. Giant clams (Tridacna sp.) were reported as common and yellow sponges as abundant.

FISHES

Fish observations were not made at the inshore area at Station 5. In the shallow, seagrass-dominated reef pool at Station 37, fishes were diverse; the most abundant groups recorded included cardinal fish (Cheilodipterus lineatus), common around rocks; emperors (Lethrinus harak); snappers (esp. Lutjanus gibbus, a school of 50+ individuals); goat fish (Parupeneus multifasciatus), damsel fishes (esp. Chrysiptera leucopoma); juvenile parrot fishes (esp. Scarus sordidus); groupers (esp. Epinephelus hexagonotus); and rabbit fish (Siganus spinus). Three sting-rays (Dasyatis sp.) and 1 blacktip reef shark (Carcharhinus melanopterus) were observed in this nearshore reef pool.

On the adjacent reef flat at Station 5, the most commonly observed species included blennies (Salarias fasciatus), an unidentified species of wrasse, goat fish (Parupeneus multifasciatus), various damsel fishes (esp. Chrysiptera leucopoma), juvenile parrot fishes (esp. Scarus sordidus), and rabbit fish (Siganus spinus).

On the reef slope (Station 38), the most abundant fishes reported included surgeon fishes (esp. Ctenochaetus striatus and Naso vlamingi), trigger fishes (esp. Caesio xanthonotus), various butterfly fishes, squirrel fishes (esp. Myripristis murdjan), rudder fish (Kyphosus cinerascens), various wrasses (esp. Cheilinus oxycephalus), emperors (esp. Gnathodentex aurolineatus), snappers (esp. Lutjanus fulvus), sweepers (Pempheris oualensis), angel fishes (esp. Centropyge loriculus), numerous damsel fishes (esp. the abundant Abudefduf vaigiensis and Chromis xanthura), and groupers (esp. Mirolabrichthys dispar).

OTHER VERTEBRATES

A sea snake was observed at KCRI Station 37; the yellow-and-black banded snake was approximately 30 cm in length and was moving slowly across the shallow inshore reef flat (water depth approximately 15 cm). No other vertebrates were recorded at the KCRI stations in the Tafunsak Village area; however, any of the other vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 5 summary).

RESOURCE USE

In the seagrass beds near the shoreline at Station 37, the KCRI survey team found shells of 8 individuals of Tridacna sp. in a single pile on the bottom; the giant clams had apparently been harvested elsewhere on the reef and the shells subsequently deposited at this location.

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 5 summary.

WATER QUALITY

At the time of the KCRI survey, the quiet inshore waters were quite clear in the vicinity of Station 37; horizontal visibility exceeded 15 m (50 feet) in the reef hole, and the densly packed seagrasses growing there were generating abundant gas bubbles on their thalli and in the water column.

At Station 5, a 0.5 knot current flowing east, with moderate 0.5-1 m (2-4 feet) wave action and little wind; water clarity was very good in the boat channel, with horizontal visibility of about 15 m (50 feet).

No turbidity was reported at Station 38.

FOKO MALSU
(Stations 6, 34)
(Atlas Map 18)

PHYSIOGRAPHY

The volcanic headlands at Maku and Wiya jut seaward into the open reef flat narrowing the latter to 400 m in width compared to 600-700 m in width opposite the point of reef at Foko Malsu about 0.5 km west of Stations 34 and 6. The inner one-half of the open reef flat is covered with dense seagrass beds while the outer half consists of reef pavement with scattered corals and coral rubble. The inner reef flat off the rock quarry nearly emerges at low tide and the beach consists of basaltic blocks and boulders off the headland and small white sand pockets to either side of it. Offshore the ocean reef slopes are dominated by living corals with well developed spur-and-groove formations present along the upper edge. Mangroves are absent from this stretch of the shoreline and the nearest coastal swamp forests are 2 km to the west off west Tafunsak. The nearest mangroves are 2 km to the east at Inkoeya. There are no defined stream courses directly off the volcanic headland although a small stream (Infa Yekula) and waterfall spill off the volcanic cliffs along the eastern face of the headland at Yekula. A series of crescent-shaped sand deposits project offshore along the shoreline between Tafunsak and the northeast point at Finaunpes. These serve as sites for manual collection of sand by the villagers.

FLORA

The inshore half of the reef flat at Station 6 was covered with thick seagrass beds, which thinned seaward. The alga Caulerpa racemosa carpeted the reef pavement of the outer reef flat, replaced by a dense bed of Turbinaria ornata and Sargassum sp. at the reef crest. Crustose coralline algae were abundant from the reef crest seaward into the spur-and-groove zone.

On the reef slope (Station 34), live corals dominated the bottom and no macroalgae were reported.

CORALS

Corals are absent or very rare from the inner reef flats dominated by seagrasses, and only a few species were reported on the outer margins of the reef flat at Station 6, including: Porites lutea microatolls, and ramose Montipora digitata heads. We were able to swim off the reef margin into the spur-and-groove formation and examine the coral communities there. Over 20 species of corals were present, approaching 35-50 percent coverage. The abundant species were Acropora gemmifera, A. variabilis, A.

hebes, A. irregularis, A. valida, A. digitifera, Pocillopora damicornis, P. verrucosa, Millepora platyphylla, Porites lutea, and several others were common.

Corals achieved great abundance (averaging 70 percent cover) and high diversity (at least 39 species) on the ocean-facing reef slope further offshore from Station 6, at Station 34. Staghorn thickets of Acropora accuminata covered large expanses of the slope and Galaxea fasciçularis was also abundant. Other common corals included species of Turbinaria, Heliopora, Psammocora, Symphyllia, Platygyra, Favites, Pocillopora, Millepora, Porites, Fungia, Goniastrea, Acropora, Leptoria, Favia and Hydnophora.

OTHER INVERTEBRATES

On the lava boulder beach at Station 6, intertidal snails were common and included Melampus flavus (occasional, on high intertidal rocks), Littoraria coccinea (common), Nerita albicilla (occasional), N. polita (rare), N. plicata (common), N. squamulata (rare), and Clypeomorus sp. (rare). On the nearshore reef flat, between rocks, were found occasional shell remains of some gastropods (Apollon gyrinus, Polinices tumidus, small Strombus spp.) and bivalves (Quidnipagus palatum and Scutarcopagia scobinata). The sea cucumber Holothuria atra was common on the reef flat all the way to the wave-washed zone. In the dense Turbinaria zone at the reef crest, the sea cucumber Actinopyga mauritiana was occasionally seen.

Live corals dominated the reef slope (Station 34); no non-coral invertebrates were reported.

FISHES

At the inshore area (Station 6), only incidental observations of fishes were made; occasional surgeon fish, butterfly fish and moorish idols were noted.

Offshore (Station 34), the most abundant fishes reported included various surgeon fishes (esp. Acanthurus nigricans, Ctenochaetus striatus, Naso lituratus), fusiliers (abundant Caesio tile and C. xanthonotus), butterfly fishes (esp. Chaetodon multifasciatus), squirrel fishes (Myripristis adustus and abundant M. murdjan), rudder fishes (esp. Kyphosus cinerascens), various wrasses (esp. Gomphosus varius and Thalassoma lutescens), snappers (esp. the abundant Macolor niger), threadfin (Scolopsis cancellatus), sweepers (Pempheris oualensis), various damsel fishes (esp. the abundant Chromis vanderbilti and C. xanthura), parrot fishes (esp. Scarus sordidus), and various groupers (esp., abundant Mirolabrichthys dispar).

OTHER VERTEBRATES

No vertebrates other than fish were recorded at KCRI stations in the Foko Malsu area; however, any of the vertebrates discussed in the overall summary section may occur in the region.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Information on specific archaeological and historical sites is listed by atlas map number in Appendix E (see also the Section 5 summary).

RESOURCE USE

Resource use information obtained from a meeting with with local resource users (see Methods) has been mapped with symbols onto the Kosrae Coastal Resource Atlas maps. Additional resource use information obtained from the interviews is presented in the Section 5 summary.

WATER QUALITY

At the time of the KCRI survey at Station 6, a storm (Typhoon Lola) was hitting the other side of Kosrae, and thus a "leeward" condition existed at Foko Malsu, with modest wave action (0.5-1 m); currents were slack and visibility was poor offshore (horizonal visibility was only about 5-6 m (15-20 feet)).

At Station 34, a strong tide-driven current was present, setting to the west at 1 knot, but shifting to the east. No loose sediment or rubble was observed on the reef, and no turbidity was reported.

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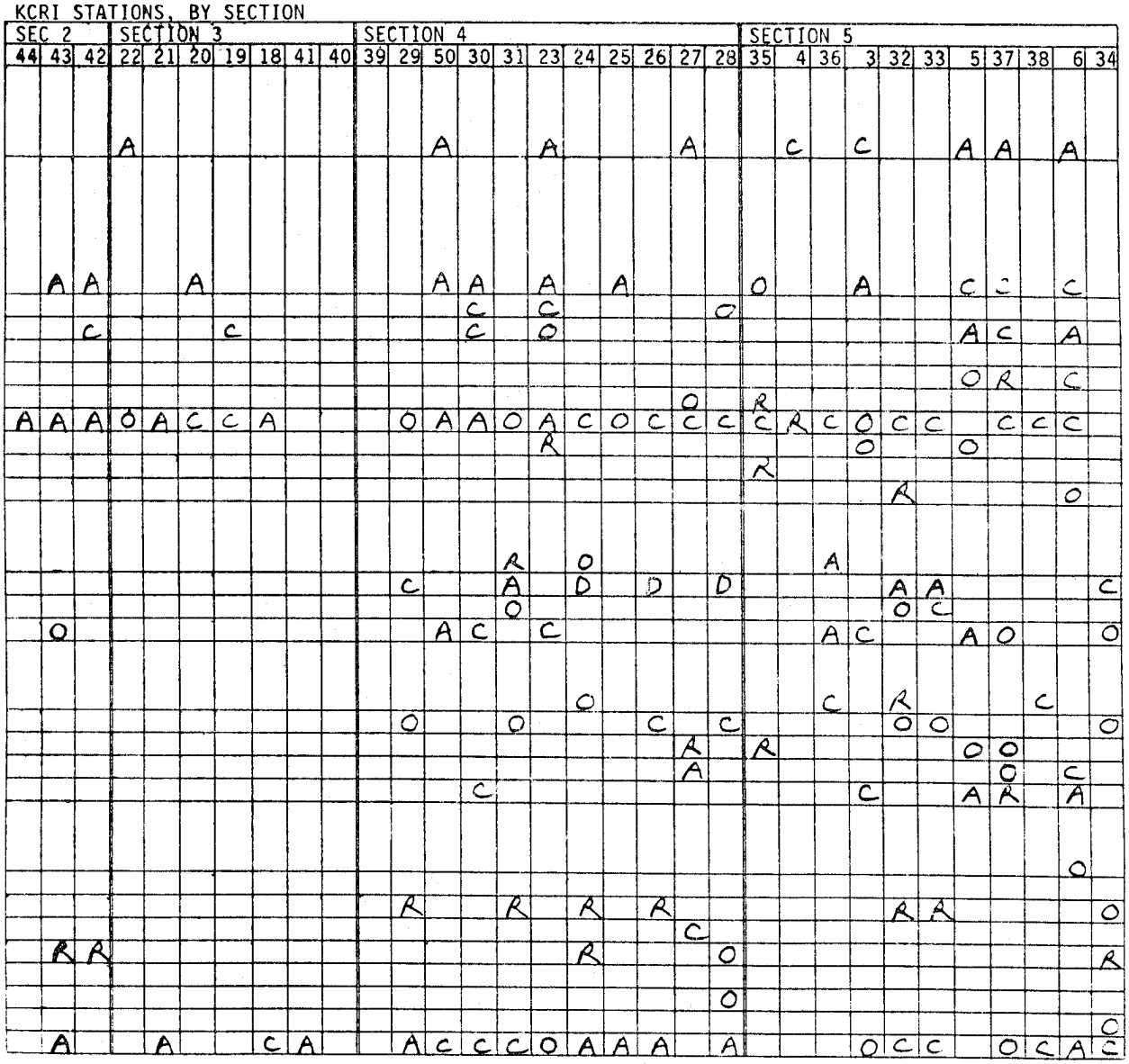
APPENDICES

APPENDIX A. MARINE PLANTS RECORDED AT KCRI FIELD STATIONS.
Symbols: D=dominant, A=abundant, C=common, O=occasional, R=rare (see METHODS for definitions).

	KCRI STATIONS, BY SECTION																				
	SECTION 1																		SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
ANTHOPHYTA																				
Unidentified seagrasses	A		O		A		A					R		O		A		O		O
ALGAE																				
CHLOROPHYTA (greens)																				
Caulerpa racemosa	C		C		A	C						C	C	R	C	O		C		A
C. serrulata	C		C		A															
C. sp.	C		C		C			O				O				O		A		
Cladophora sp.																				C
Dictyosphaeria cavernosa																C				C
Halimeda macroloba					O							O	O	O						
H. spp.	C	C	C	C	A	C			C	A		C	C	C	O	C	C	C		C
Neomeris annulata																				
Valonia sp.	C		C													C		O		O
Unid. green (filamentous)																		O		
CYANOPHYTA (blue-greens)																				
?Hormothamnion sp.																		C		
Microcoleus lyngbyaceus																				
Schizothrix calcicola																				
Unidentified blue-green	C				C															A
PHAEOPHYTA (browns)																				
Dictyota sp.																				
Lobophora sp.																				
Padina sp.	C		O		C		O	O								C		A		A
Sargassum sp.	A		D		C													A		
Turbinaria ornata	C		C		A		O	C								C		A		A
RHODOPHYTA (reds)																				
Actinotrichia fragilis																		O		O
?Astrotrichium sp.																		C		O
Desmia hornemanii																				
Gracilaria sp.							C													
Halymenia durvillaei			R					R					O		O					
Jania sp.	C				A	C										C		O		C
Peyssonelia sp.																				
Porolithon sp.																				
Unidentified corallines	C	D	O		O	A		C	A					C	D	D	C	A	C	C

KCRI STATIONS, BY SECTION

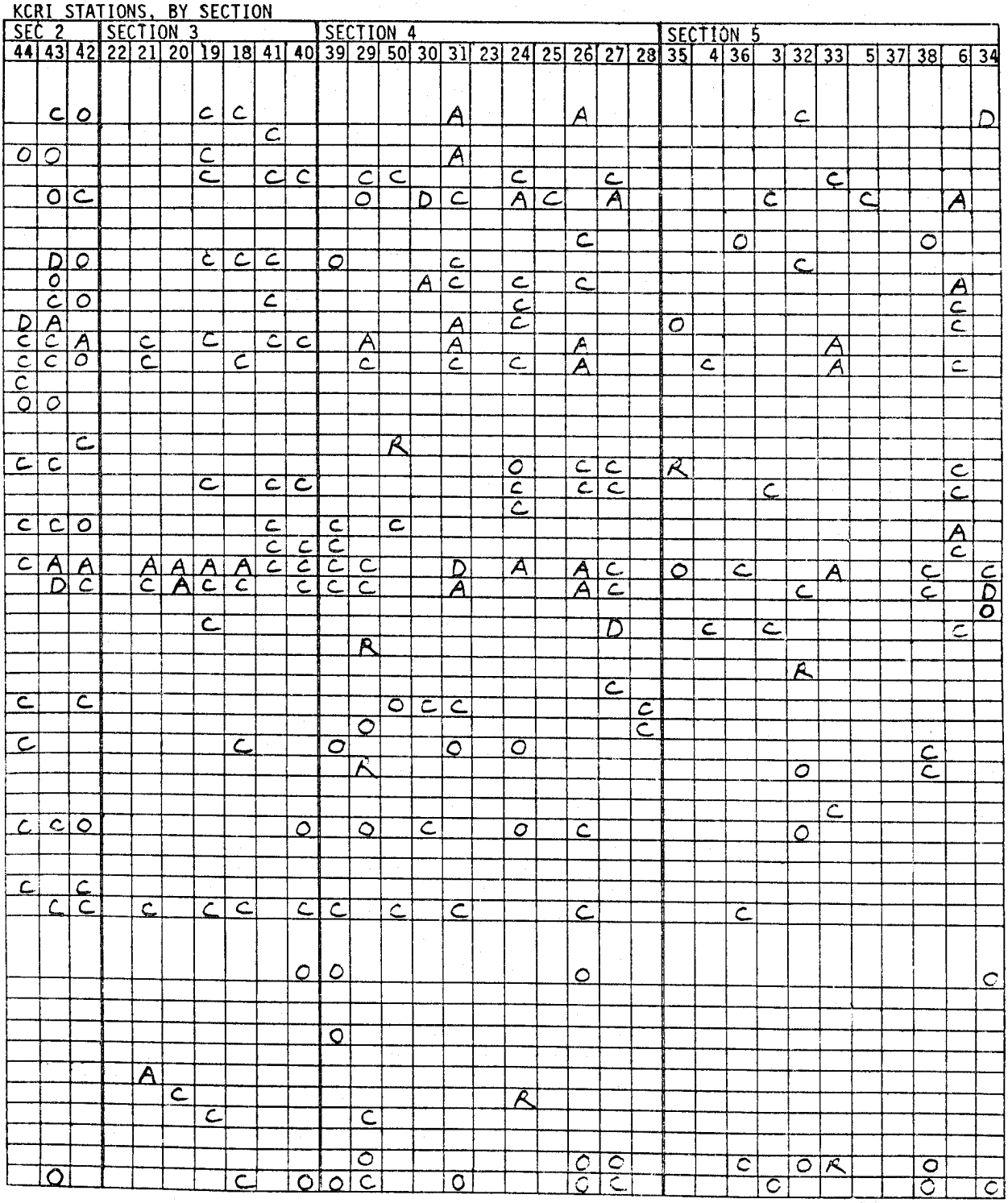


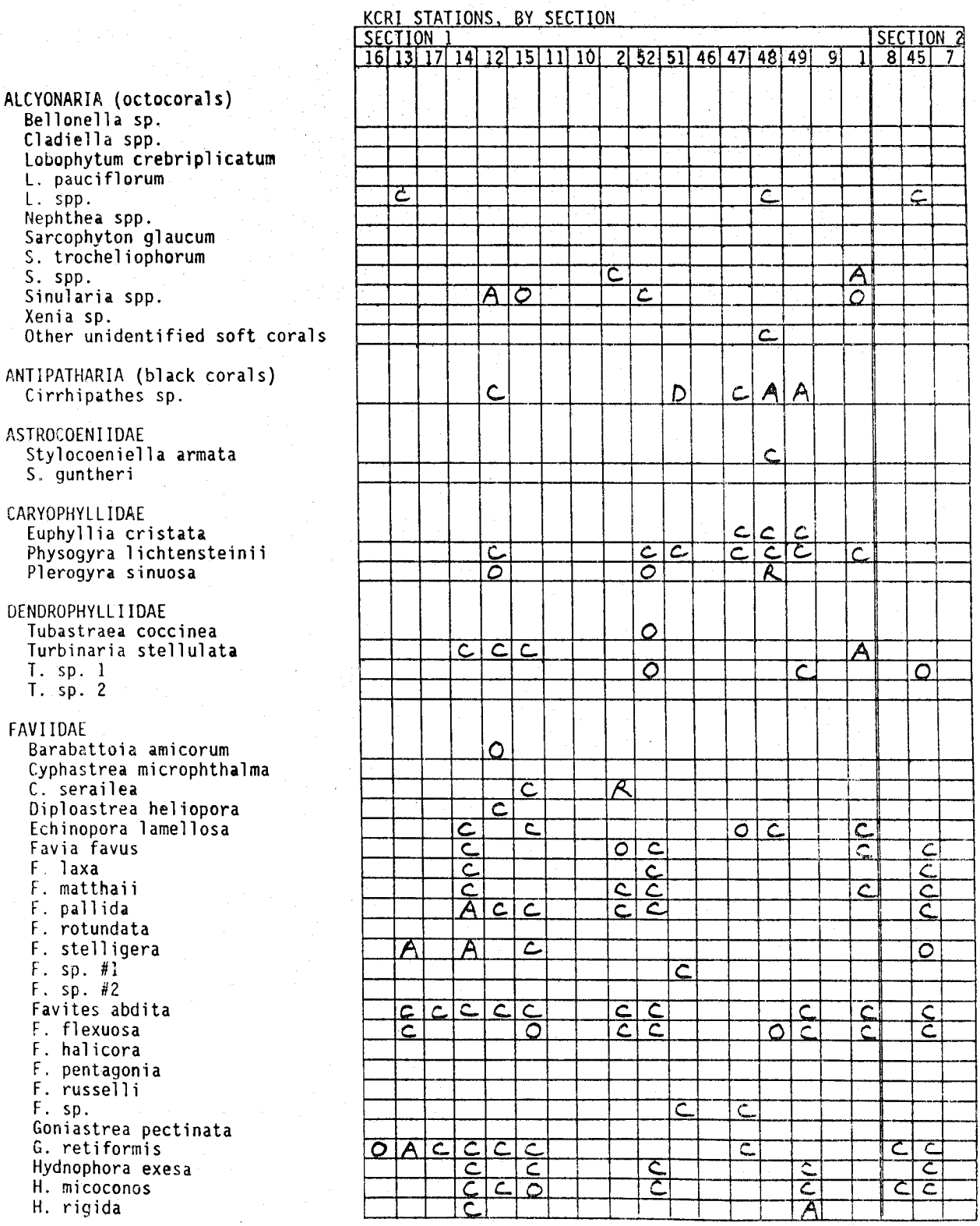
APPENDIX B. CORALS RECORDED AT KCRI FIELD STATIONS.
Symbols: D=dominant, A=abundant, C=common, O=occasional, R=rare (see METHODS for definitions).

KCRI STATIONS, BY SECTION

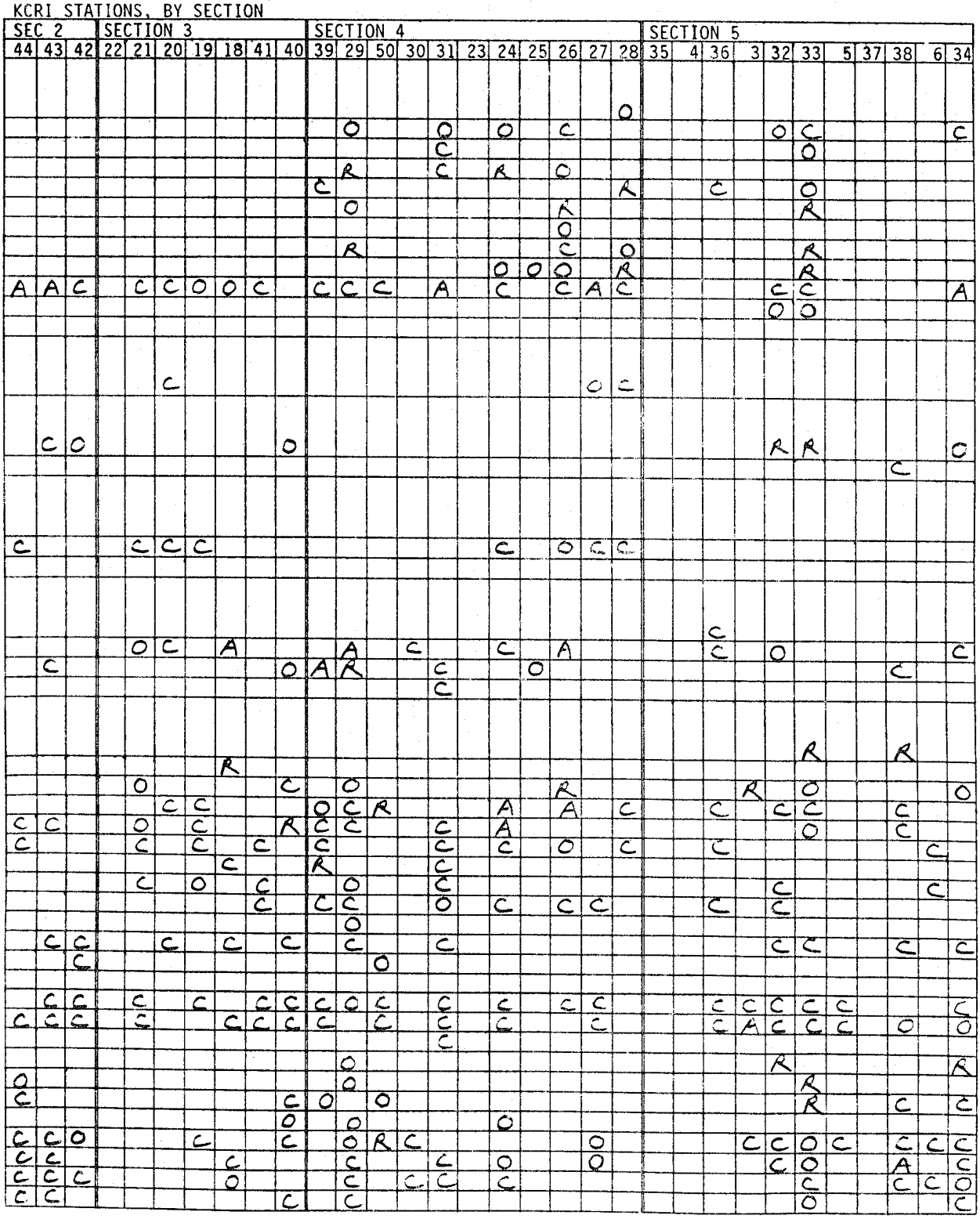
	SECTION 1																	SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
ACROPORIDAE																				
Acropora acuminata		A			C	A													A	
A. cerealis																				
A. cytherea		A											C		C					
A. delicatula					C								C	C	C					
A. digitifera	C		C		A													A		
A. echinata														R						
A. florida																				
A. formosa		A			A	A							C						A	
A. gemmifera					A										A			A	C	
A. hebes																				
A. humilis															C				D	
A. hyacinthus		A		A	C				A								A		C	
A. irregularis		A			A								C					O	A	
A. monticulosa																				
A. nasuta													O							
A. squarrosa													O							
A. syringodes																		C		
A. valida													C		C				O	
A. variabilis									A								A			
A. vaughani																				
A. (Isopora) cuneata																		C		
A. (I.) palifera																		O	C	
A. spp. (tables)	C	D		A	C	A		O	A	C	O		C	C	C		A		A	
A. spp. (staghorns)		A		A		A				C	O		C						A	
Montipora caliculata																			O	
M. digitata			C													C		C		O
M. ehrenbergii																				
M. floweri									C								C			
M. foliosa		C																		
M. foveolata					C	C														
M. granulosa									C								C			
M. hispida				C															O	
M. hoffmeisteri																				
M. marshallensis														O						
M. monasteriata									C								C			
M. tuberculosa				C		C							C						O	
M. verrilli						C								O						
M. verrucosa		O																		
M. sp. (tuberculate)													C						R	
M. spp.				C		C													C	
AGARICIIDAE																				
Gardineroseris planulata				R													O			
Leptoseris explanata													R							
L. mycetoseroides													R	O						
L. scabra																				
L. sp.													R							
Pachyseris rugosa													C		C					
P. speciosa																				
Pavona clavus				O					C										O	
P. divaricata					C									C						
P. explanulata										O			R						C	
P. varians		O		O	C					O			O	C	C					

KCRI STATIONS, BY SECTION




KCRI STATIONS, BY SECTION
SECTION 1
SECTION 2
16 13 17 14 12 15 11 10 2 52 51 46 47 48 49 9 1 8 45 7
ALCYONARIA (octocorals)
Bellonella sp.
Cladiella spp.
Lobophytum crebriplicatum
L. pauciflorum
L. spp.
Nephthea spp.
Sarcophyton glaucum
S. trocheliophorum
S. spp.
Sinularia spp.
Xenia sp.
Other unidentified soft corals
ANTIPATHARIA (black corals)
Cirrhipathes sp.
ASTROCOENIIDAE
Stylocoeniella armata
S. guntheri
CARYOPHYLLIDAE
Euphyllia cristata
Physogyra lichtensteinii
Plerogyra sinuosa
DENDROPHYLLIIDAE
Tubastraea coccinea
Turbinaria stellulata
T. sp. 1
T. sp. 2
FAVIIDAE
Barabattoia amicorum
Cyphastrea microphthalma
C. serailea
Diploastrea heliopora
Echinopora lamellosa
Favia favus
F. laxa
F. matthaii
F. pallida
F. rotundata
F. stelligera
F. sp. #1
F. sp. #2
Favites abdita
F. flexuosa
F. halicora
F. pentagonia
F. russelli
F. sp.
Goniastrea pectinata
G. retiformis
Hydnophora exesa
H. micoconos
H. rigida

KCRI STATIONS, BY SECTION



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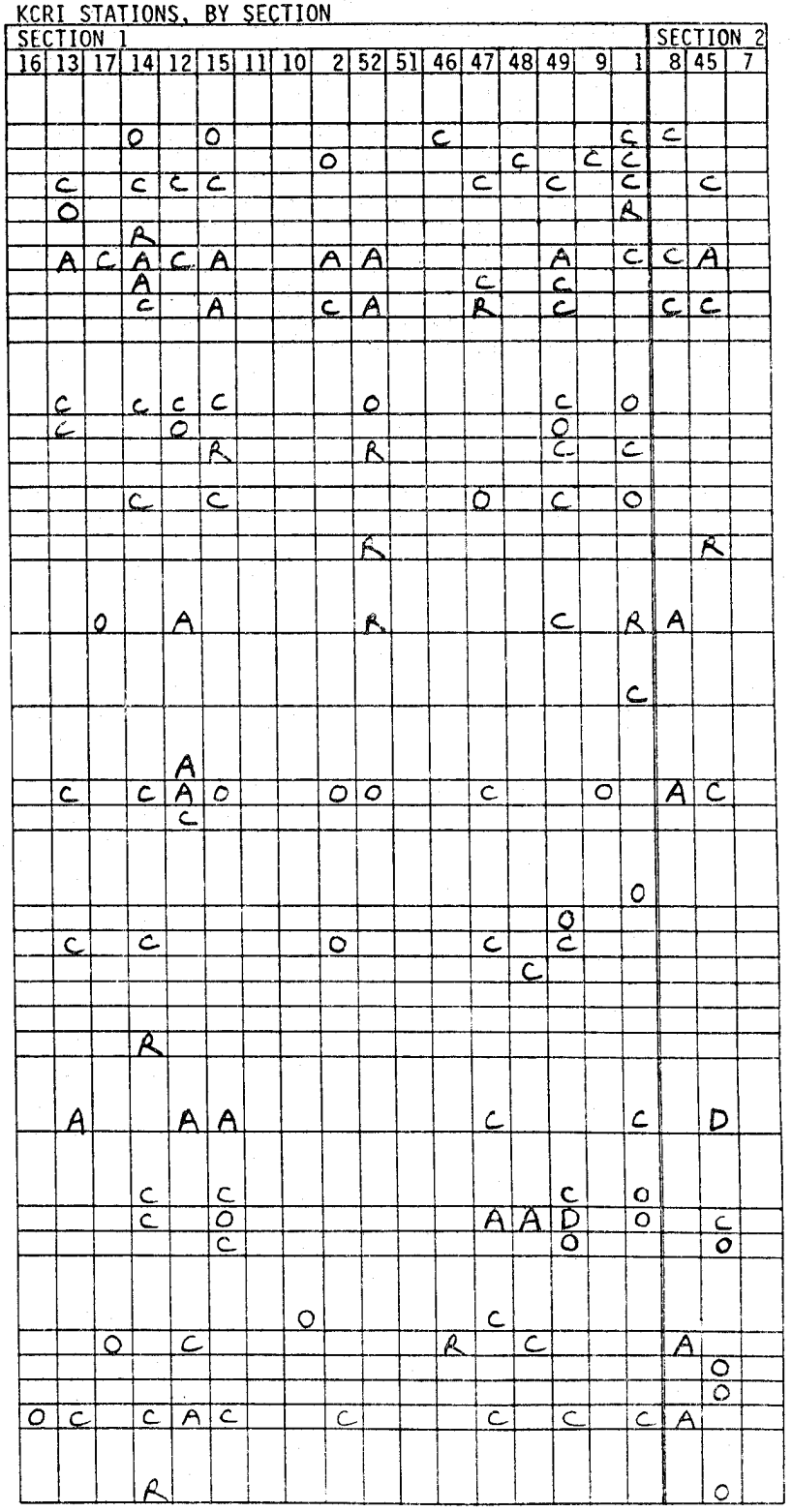
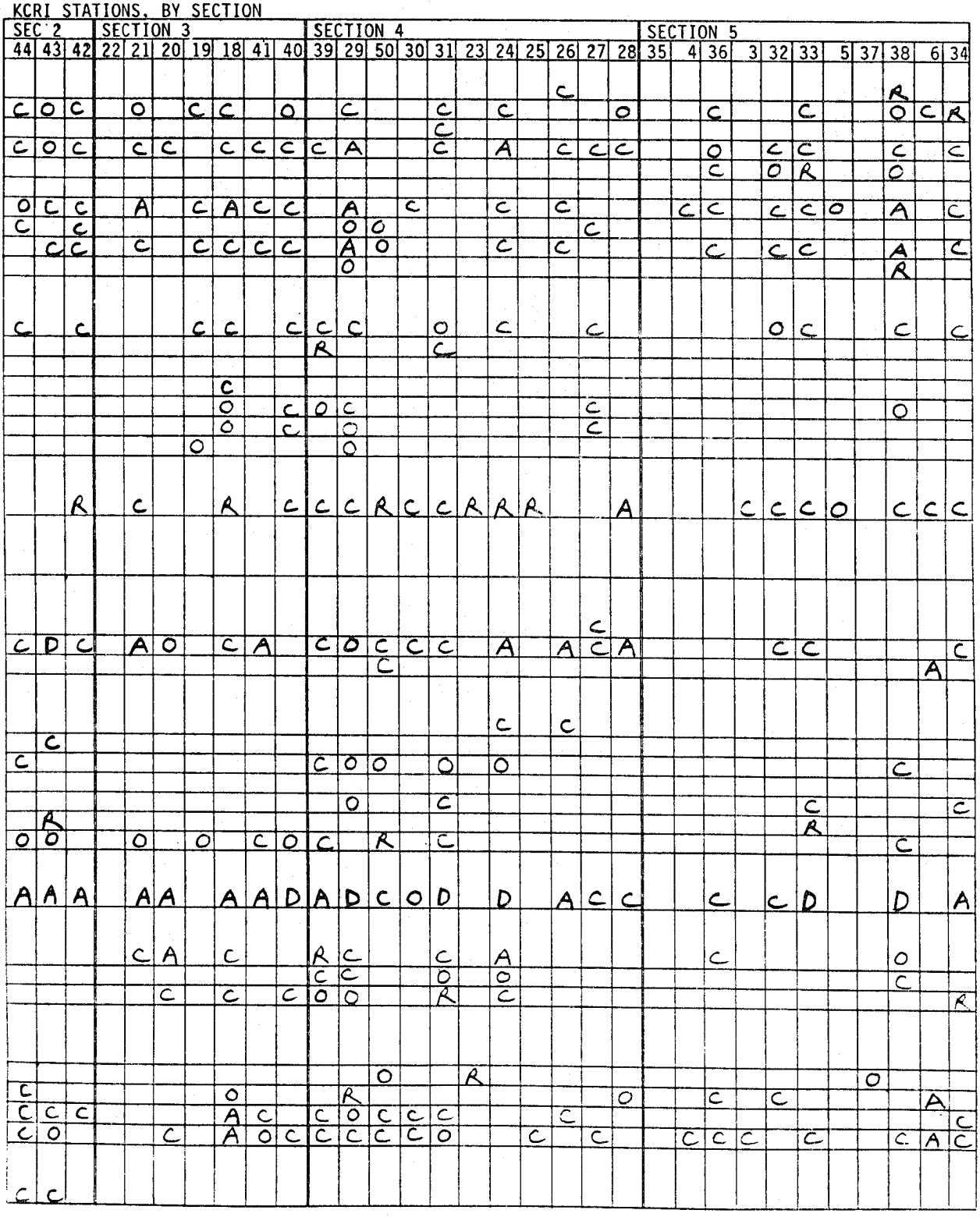


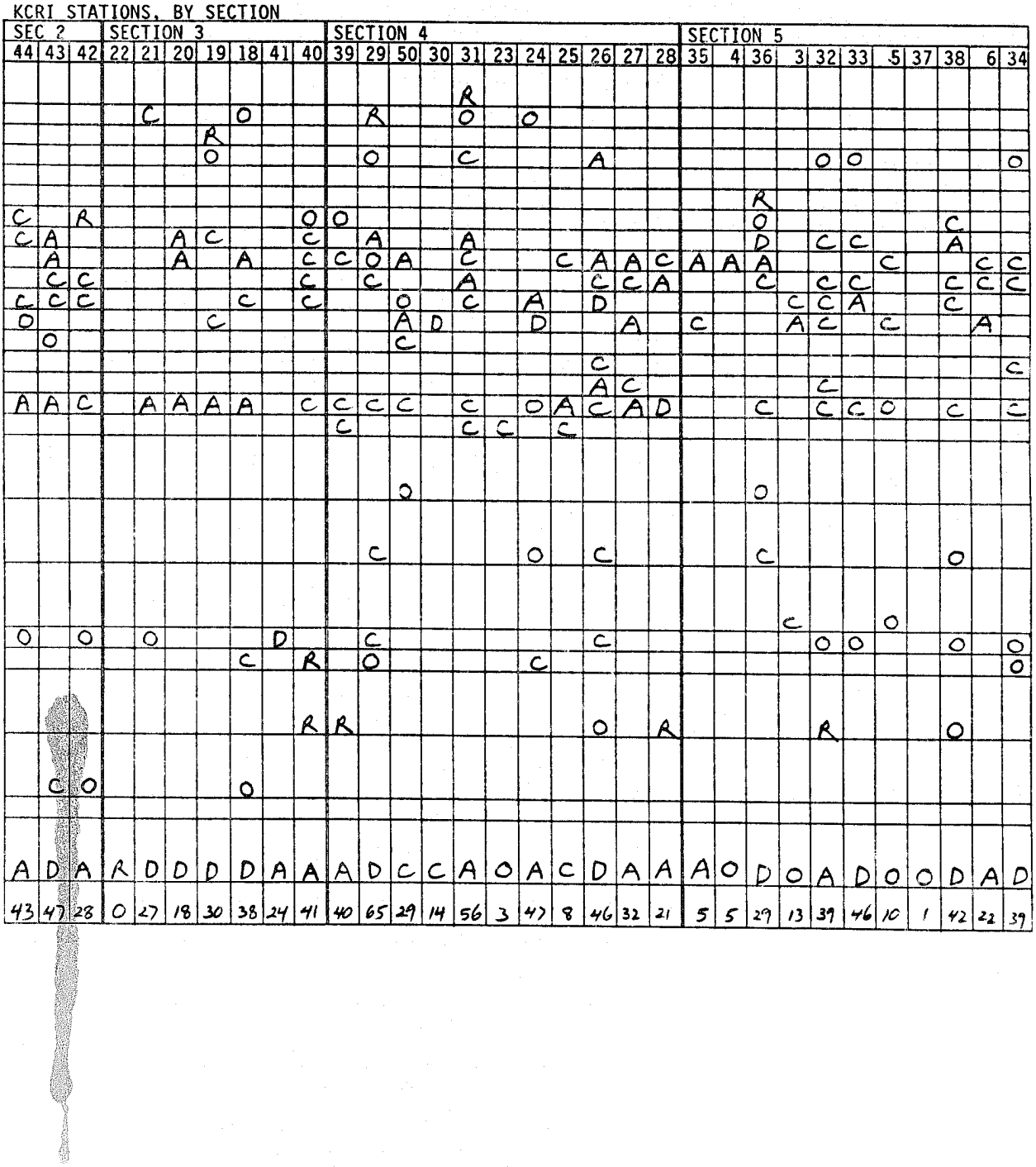
KCRI STATIONS, BY SECTION



KCRI STATIONS, BY SECTION

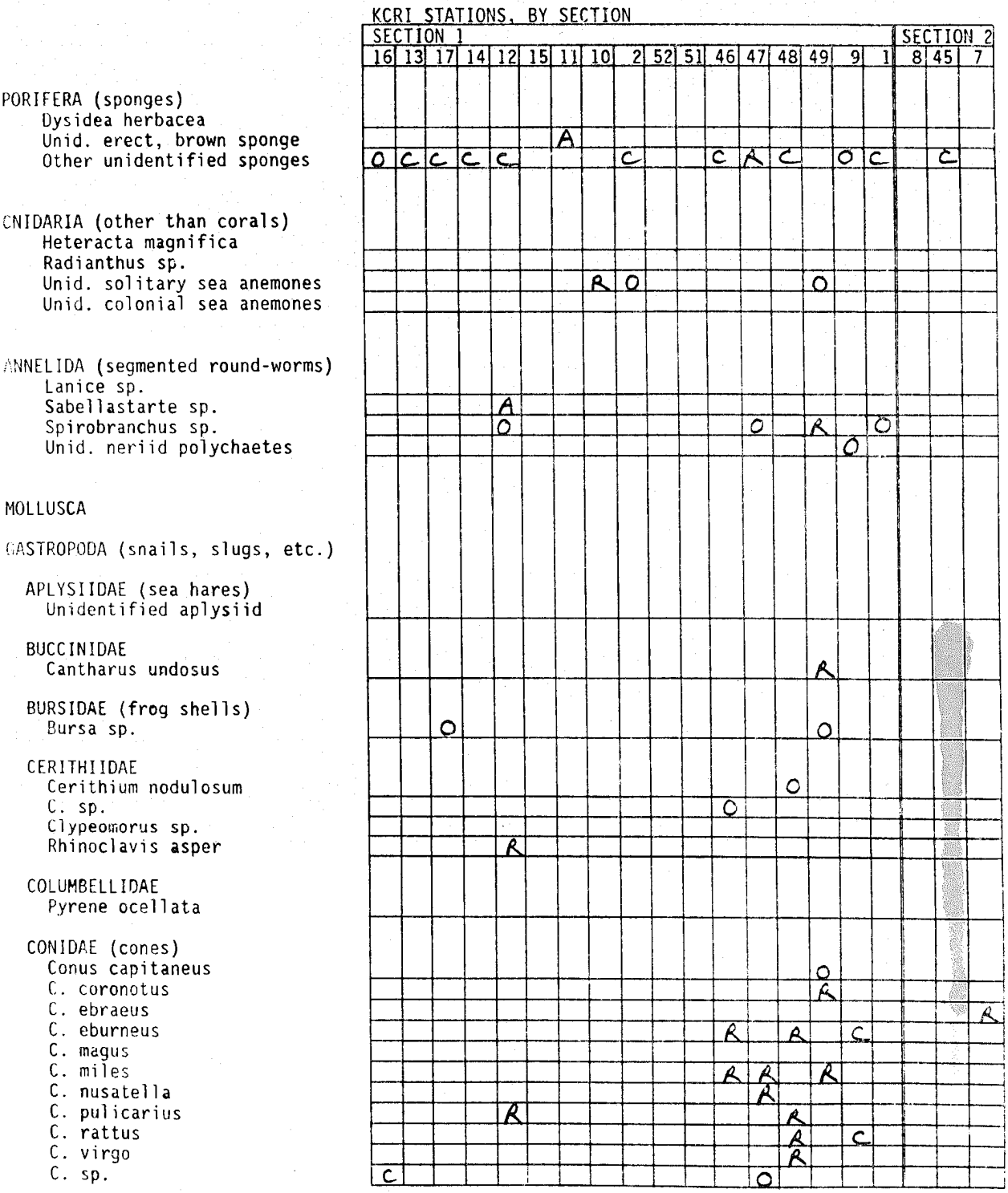
	SECTION 1																SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
A. verrilliana																				
Goniopora columna				C		C							C							
G. djiboutiensis													R							
G. lobata				C	C				R											
G. somaliensis											C		A	D	D					
G. sp. (large polyps)																				
G. sp. (with lobes)															C				O	
Porites australiensis									C										C	
P. cylindrica	C	C		C	C					C			A	A	D	C		C		
P. lichen					C				R	C	C		C					O	C	
P. lobata		O		O		C			A	C	C		A		C		C	C	C	
P. lutea	C		C	C	A					C		A	D	A	A	C	C	C		R
P. murrayensis																				
P. nigrescens													C							
P. solida		O			C															
P. (Synaraea) rus	C	C	A	C	C				C	C			O	A			C	C		
P. spp.								C												
SIDERASTERIDAE																				
Coscinaraea columna				C	A															
STYLASTERIDAE																				
Distichopora violacea										C							C			
THAMNASTERIDAE																				
Psammocora contigua					C								R					C		
P. digitata						O									C		C		O	
P. nierstraszi				C		O						R	R							
TUBIPORIDAE																				
Tubipora musica																				
ZOANTHARIA																				
Palythoa sp.				C																
Zoanthus sp.				O																
OVERALL ABUNDANCE	R	D	O	D	C	D	–	O	D	D	O	R	R	A	A	R	D	C	A	R
TOTAL NUMBER OF SPECIES	7	28	9	42	41	36	0	3	25	30	9	4	44	25	38	5	36	22	45	2

KCRI STATIONS, BY SECTION

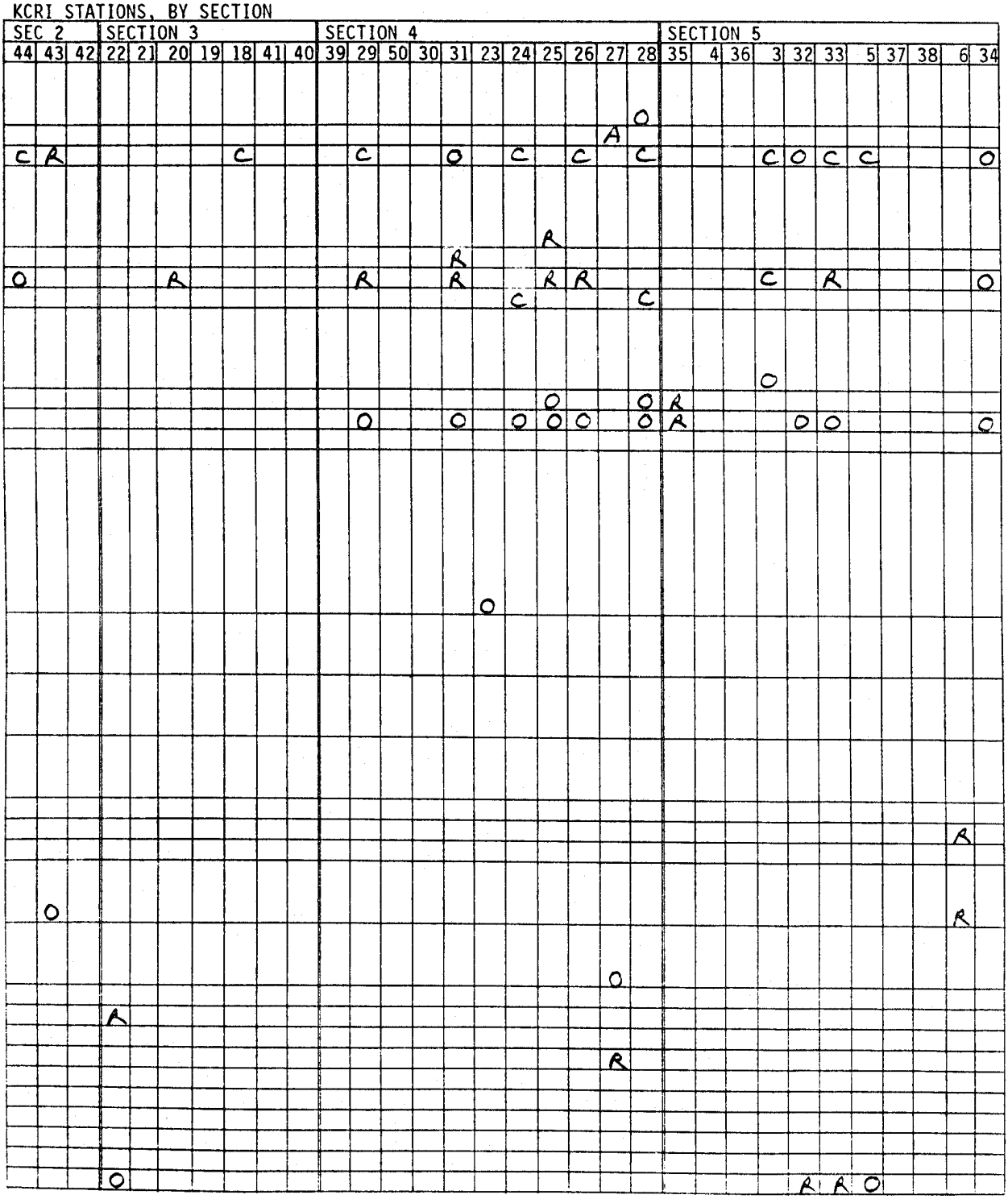


SEC 2			SECTION 3							SECTION 4										SECTION 5										
44	43	42	22	21	20	19	18	41	40	39	29	50	30	31	23	24	25	26	27	28	35	4	36	3	32	33	5	37	38	6	34
A	D	A	R	D	D	D	D	A	A	A	D	C	C	A	O	A	C	D	A	A	A	O	D	O	A	D	O	O	D	A	D
43	47	28	0	27	18	30	38	24	41	40	65	29	14	56	3	47	8	46	32	21	5	5	29	13	39	46	10	1	42	22	39

APPENDIX C. INVERTEBRATES, OTHER THAN CORALS, RECORDED AT KCRI FIELD STATIONS.
Symbols: A=abundant, C=common, O=occasional, R=rare (see METHODS for definitions).



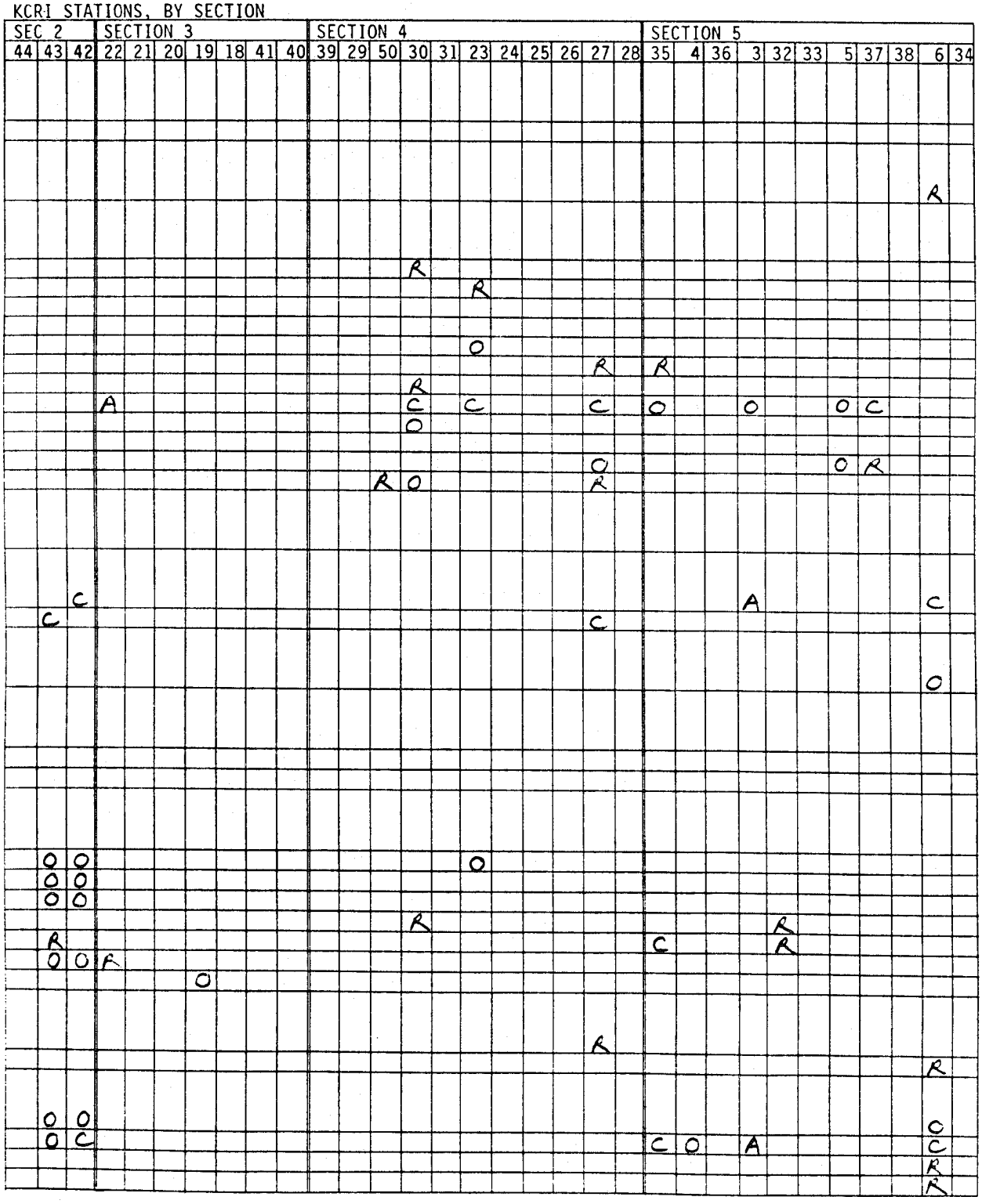
KCRI STATIONS, BY SECTION

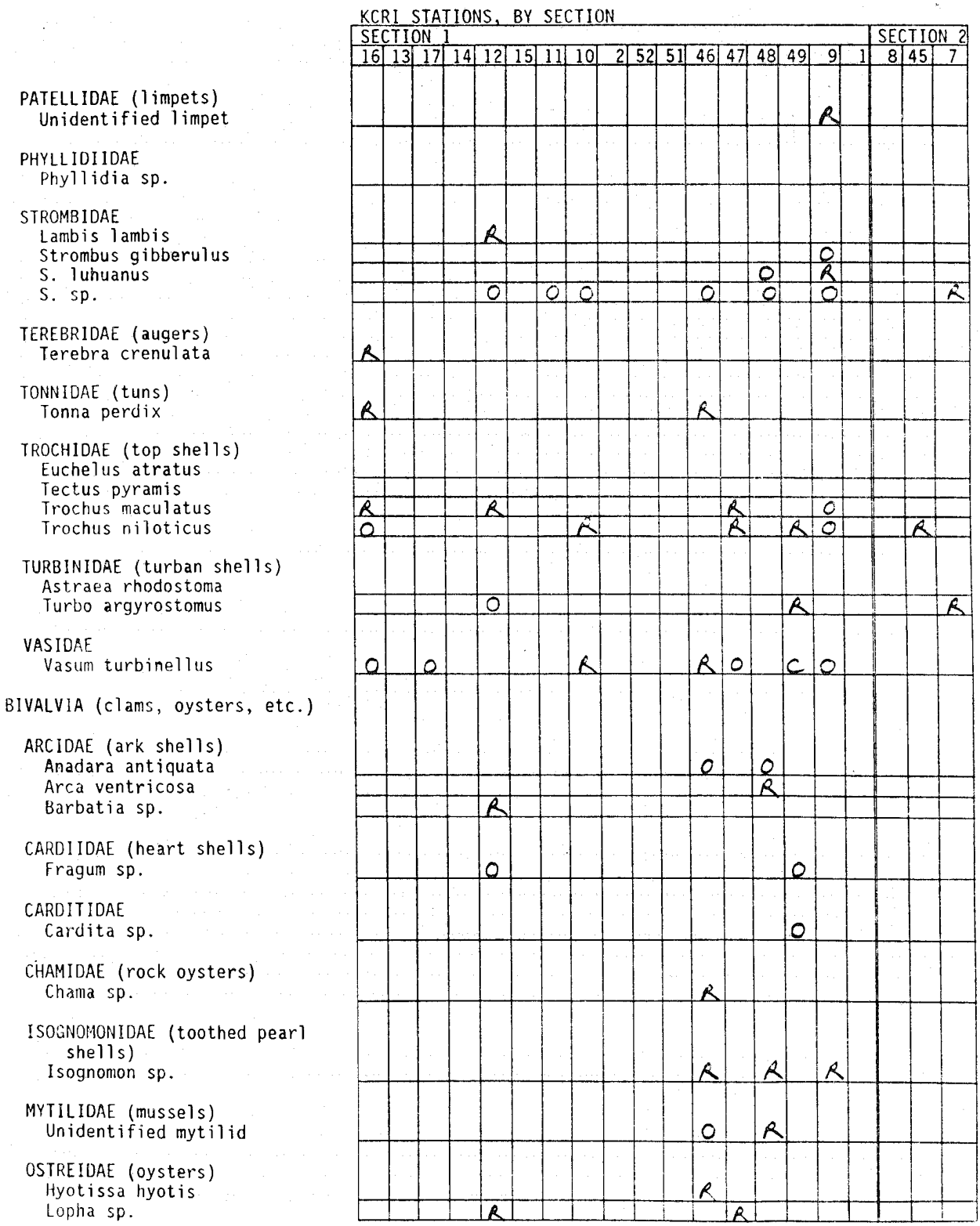


KCRI STATIONS, BY SECTION

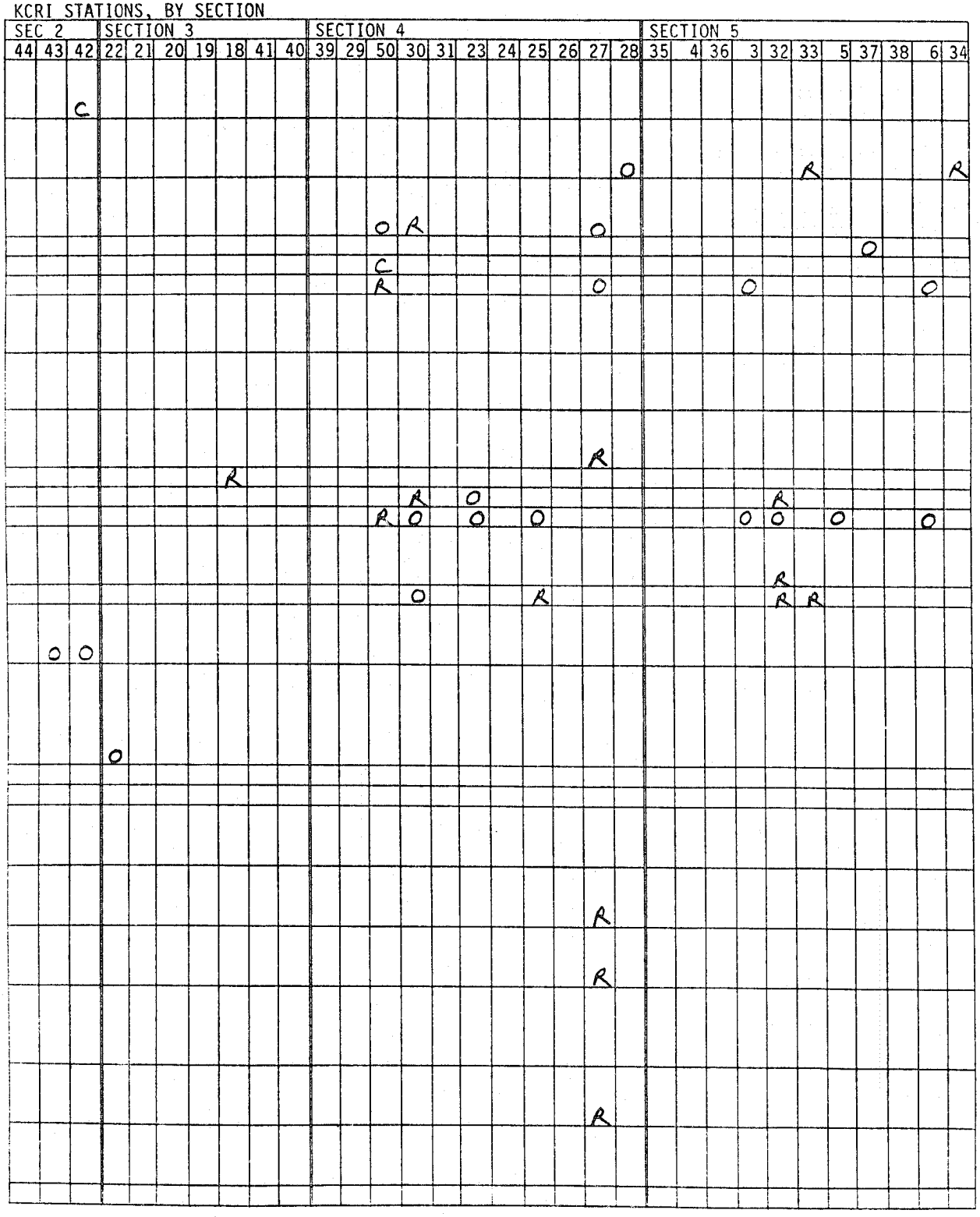
	SECTION 1																	SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
CORALLIOPHILIDAE																				
Coralliophila pyriformis													R	R						
C. violacea														O						
CYMATIIDAE (tritons)																				
Apollon gyrinus																				
CYPRAEIDAE (cowries)																				
Cypraea annulus	C		O									R		R						
C. arabica	R															O		R		
C. caputserpentis													C			O		R		
C. erosa					R							O		R		O				
C. fimbriata																R				
C. helvola													R		O	O				
C. isabella												R				R				
C. lynx																				
C. moneta	A		O									C		O	O	A		C		O
C. poraria																O				
C. talpa																R				
C. tigris					O															
C. vitellus																				
HARPIDAE (harp shells)																				
Harpa sp.															R					
LITTORINIDAE (periwinkles)																				
Littoraria coccinea	C		O													O				O
L. scabra												C								O
MELAMPIDAE																				
Melampus flavus																C				
MITRIDAE (miters)																				
Mitra mitra															O					O
M. sp.															R					
Strigatella paupercula	C				R															
MURICIDAE																				
Chicoreus sp.															R					
Drupa albolabris													R		R					
Drupa glossularia																				
Drupa morum																				
D. ricina	O														R					
Drupella cornus																				
Morula granulata													O		C					
M. sp.																				
NATICIDAE (moon snails)																				
Natica sp.					R															
Polinices tumidus																				
NERITIDAE (nerites)																				
Nerita albicilla	C															C				
N. plicata	C						C	C								C		O		O
N. polita	O				O		C	C								C				
N. squamulata																				

KCRI STATIONS, BY SECTION




KCRI STATIONS, BY SECTION
SECTION 1
SECTION 2
16 13 17 14 12 15 11 10 2 52 51 46 47 48 49 9 1 8 45 7
PATELLIDAE (limpets)
Unidentified limpet
PHYLLIDIIDAE
Phyllidia sp.
STROMBIDAE
Lambis lambis
Strombus gibberulus
S. luhuanus
S. sp.
TEREBRIDAE (augers)
Terebra crenulata
TONNIDAE (tuns)
Tonna perdix
TROCHIDAE (top shells)
Euchelus atratus
Tectus pyramis
Trochus maculatus
Trochus niloticus
TURBINIDAE (turban shells)
Astraea rhodostoma
Turbo argyrostomus
VASIDAE
Vasum turbinellus
BIVALVIA (clams, oysters, etc.)
ARCIDAE (ark shells)
Anadara antiquata
Arca ventricosa
Barbatia sp.
CARDIIDAE (heart shells)
Fragum sp.
CARDITIDAE
Cardita sp.
CHAMIDAE (rock oysters)
Chama sp.
ISOGNOMONIDAE (toothed pearl shells)
Isognomon sp.
MYTILIDAE (mussels)
Unidentified mytilid
OSTREIDAE (oysters)
Hyotissa hyotis
Lopha sp.

KCRI STATIONS, BY SECTION

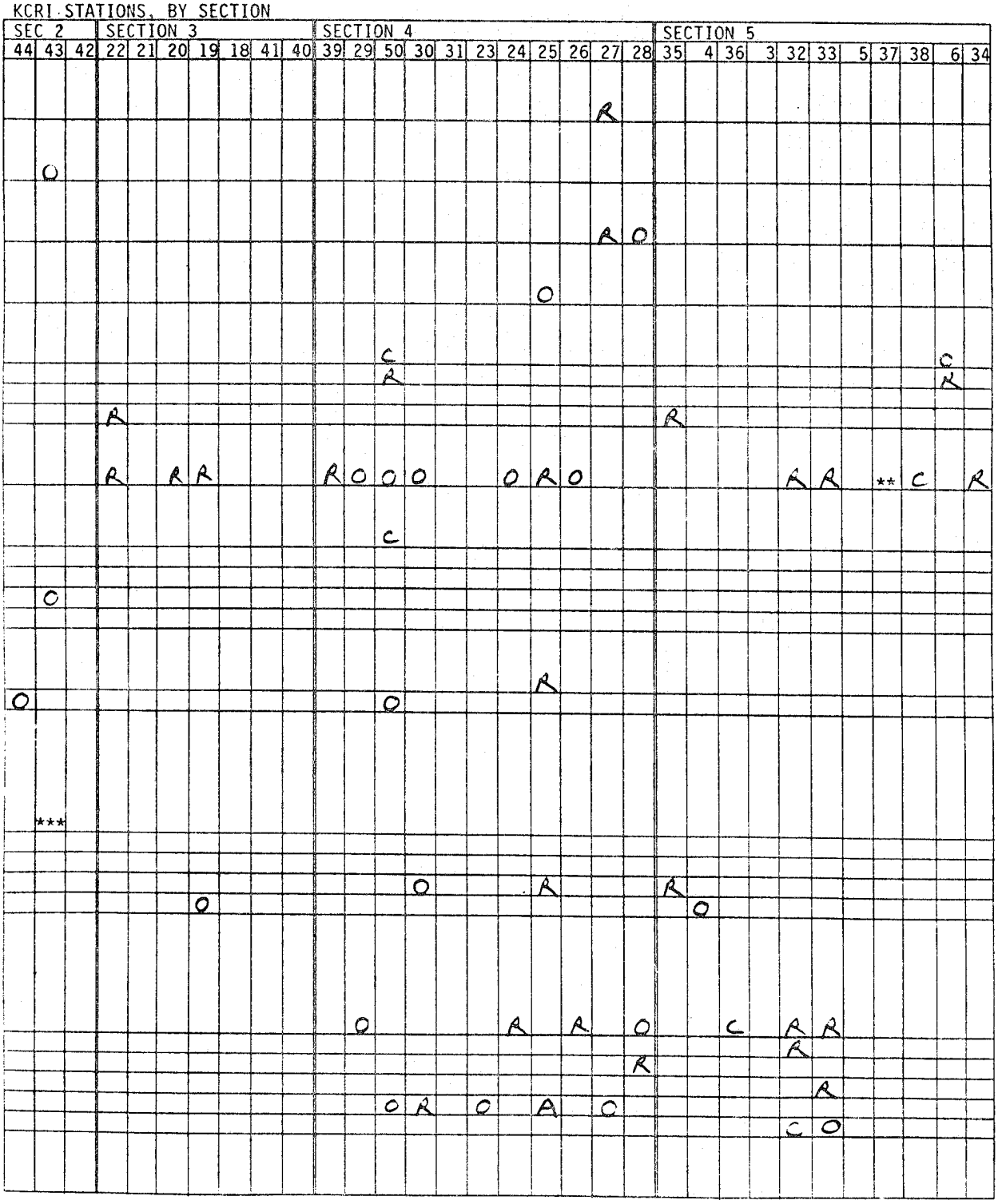


KCRI STATIONS, BY SECTION

	SECTION 1																	SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
PINNIDAE (pen shells)																				
Atrina vexillum														R						
PSAMMOBIIDAE (sunset clams)																				
Asaphis violescens	O				O		C	C								R		O		
PTERIIDAE (pearl oysters)																				
Pinctada margaritifera																				
SPONDYLIDAE (thorny oysters)																				
Spondylus sp.																				
TELLINIDAE (tellens)																				
Quidnipagus palatum	O															R				
Scutarcopagia scobinata					O								R							
S. sp.															R					
Tellina remies					O									R						
TRIDACNIDAE (giant clams)																				
Tridacna sp.					R			O										R	O	
VENERIDAE																				
Gafrarium cf. pectinatum	R											R								
Periglypta puerpera					R			R					R	O						
Pitar cf. obliquatum					O															
Pitar pellucidus																				
Pitar sp.												O								
CEPHALOPODA (octopi, squid, etc.)																				
Octopus sp.																				
Unidentified squid																				
ARTHROPODA																				
CRUSTACEA (lobsters, crabs, etc.)																				
Birgus latro																				
Calappa sp.							R													
Cardisoma sp.																				*
Panulirus sp.																				
Unidentified grapsid crabs	O							C				O				O				
ECHINODERMATA																				
ASTEROIDEA (starfishes)																				
Acanthaster planci																				
Culcita novaeguineae																				
Echinaster luzonicus																				
Fromia sp.																				
Linckia laevigata					C															
L. multifora					C															
CRINOIDEA (crinoids)																				
Unidentified crinoids)																				

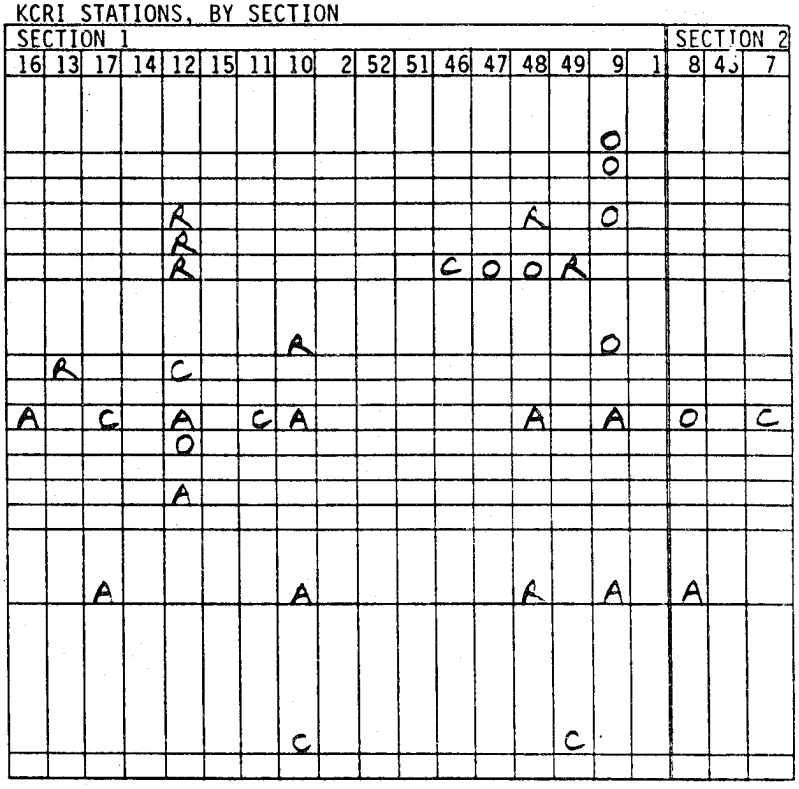
* Burrows found.

KCRI STATIONS, BY SECTION



** Pile of shells from 8 harvested specimens.
*** One adult crab observed on road at night in general vicinity of this station.

KCRI STATIONS, BY SECTION



ECHINOIDEA (sea urchins)
- Diadema savignyi
- Echinometra mathaei
- Echinostrephus sp.
- Echinothrix calamaris
- Heterocentrotus mammillatus
- Unidentified clypeasteroid

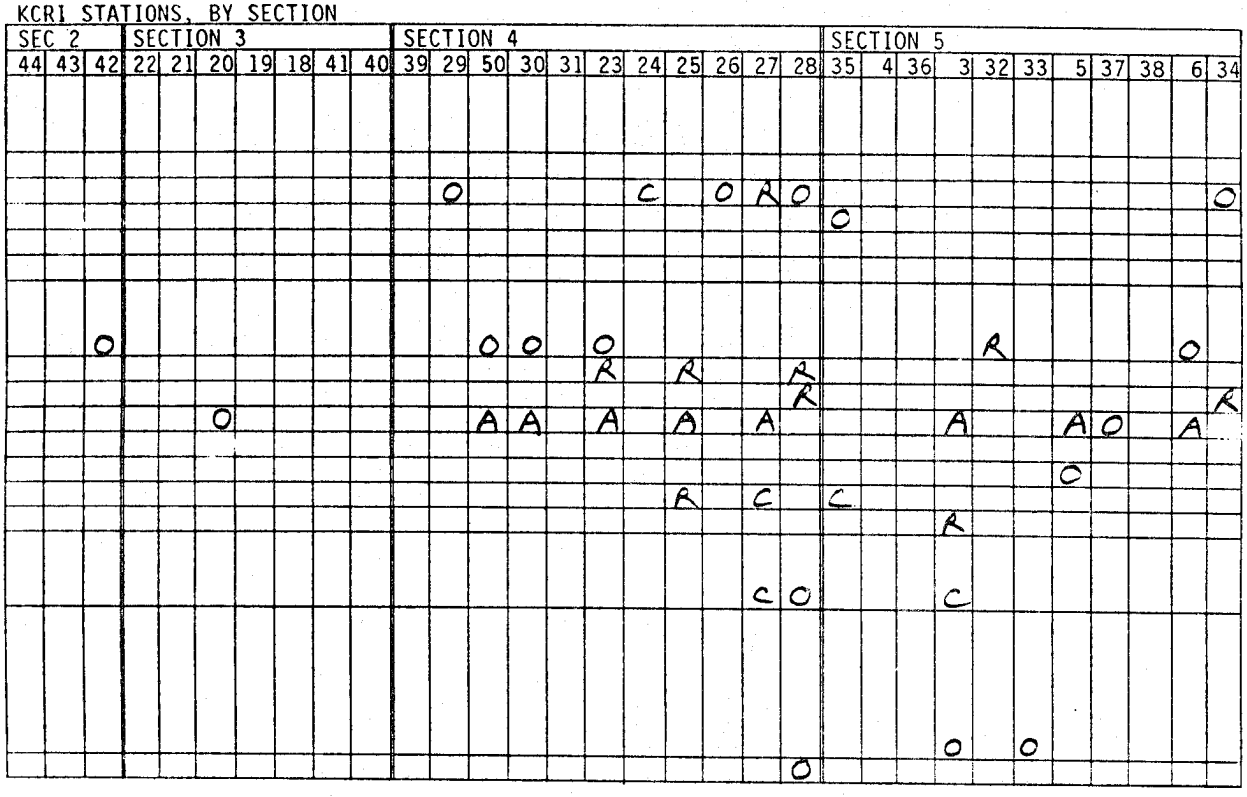
HOLOTHUROIDEA (sea cucumbers)
- Actinopyga mauritiana
- Bohadschia argus
- B. graeffei
- Holothuria atra
- H. leucospilota
- Ophiodesoma sp.
- Stichopus chloronotus
- Synapta maculata

OPHIUROIDEA (brittlestars)
- Unidentified brittlestars

CHORDATA

TUNICATA (tunicates)
- Diademnum sp.
- Unid. colonial tunicates

KCRI STATIONS, BY SECTION

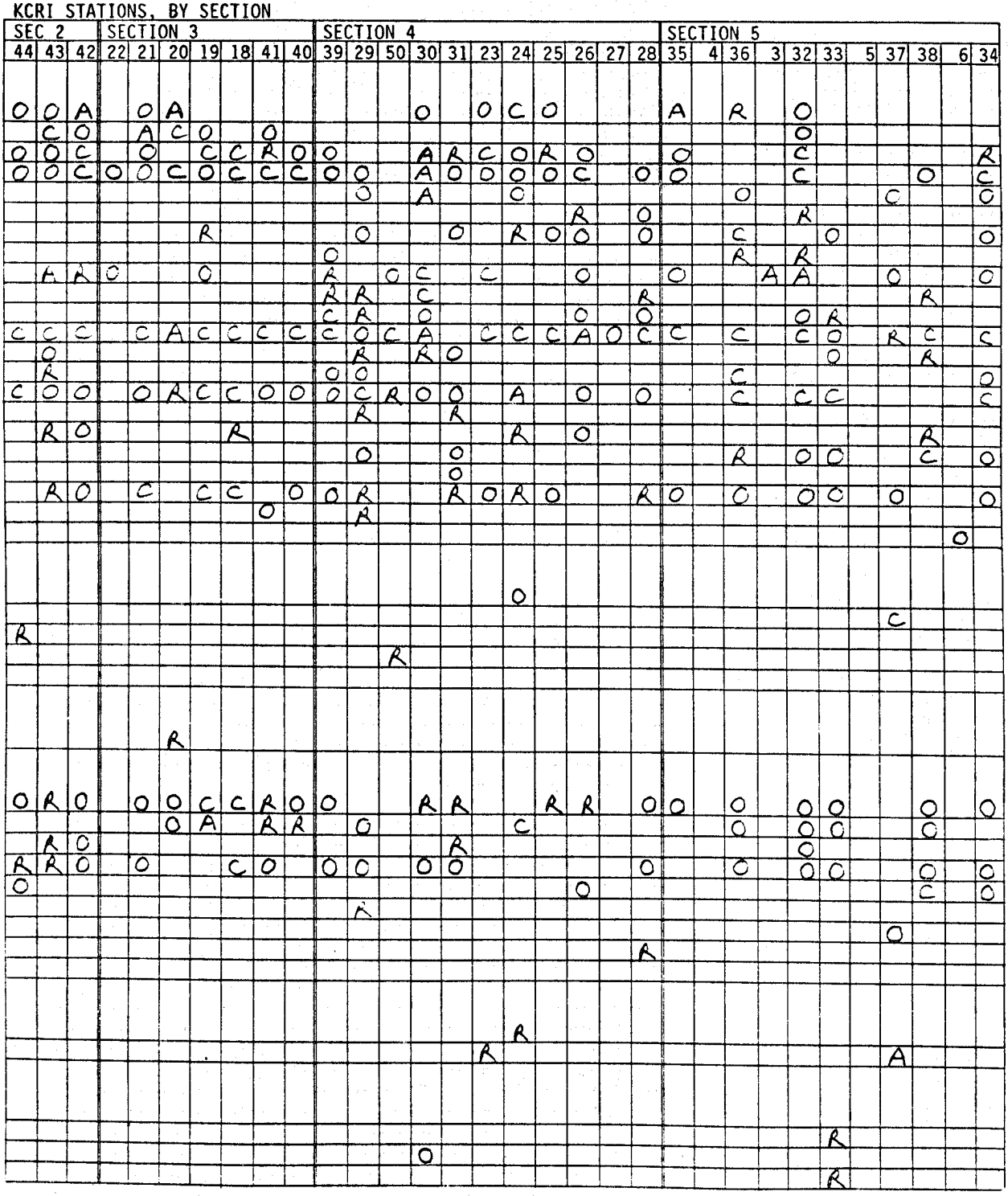


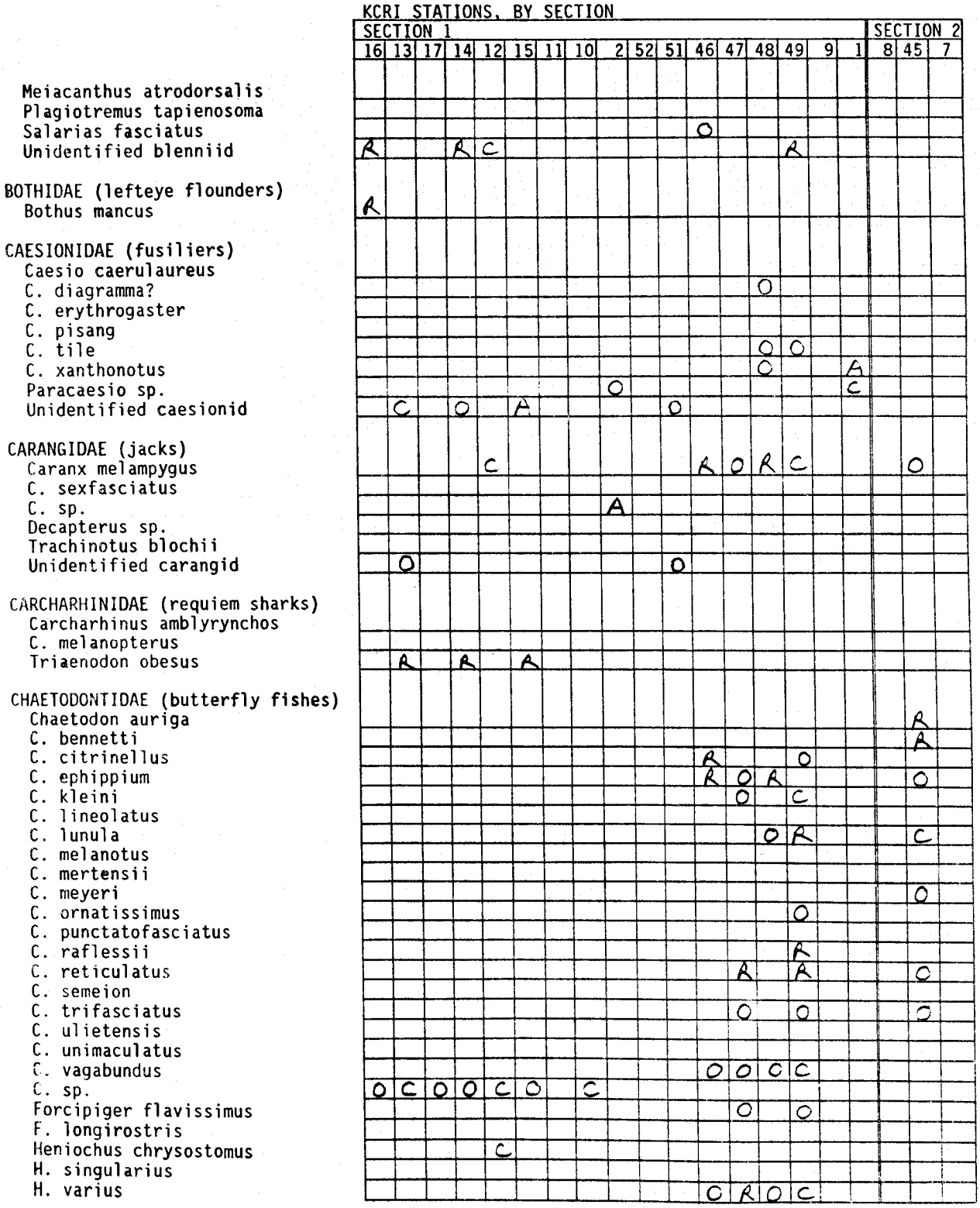
APPENDIX D. FISHES RECORDED AT KCRI FIELD STATIONS.
Symbols: A=abundant, C=common, O=occasional, R=rare (see METHODS for definitions).

	KCRI STATIONS, BY SECTION																		
	SECTION 1																SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
ACANTHURIDAE (surgeon fishes)*																				
Acanthurus blochii		C			C							C	O	O	O				O	
A. guttatus					O															
A. lineatus		O		O	C	O						O	O		O					
A. nigricans		O		O	C	O							O		O				C	
A. nigrofuscus																				
A. olivaceus		O				R														
A. pyroferus													O		O				R	
A. thompsoni													R							
A. triostegus	C		C		C							O			O					O
A. xanthopterus																				
Ctenochaetus binotatus																				
C. striatus		C		C	C	C						C	C	O	C		A		O	
Naso brevirostris																				
N. hexacanthus																			R	
N. lituratus		C		C		O													O	
N. thynoides																				
N. unicornis		O		O		R														
N. vlamingi																				
Zebrasoma flavescens																				
Z. scopas														O						
Z. veliferum																				
Unidentified acanthurid								C						R						
APOGONIDAE (cardinal fishes)																				
Apogon novemfasciatus																				
Cheilodipterus lineatus																				
C. macrodon																				
C. sp.												R		O						
Unidentified apogonid					O									O						
AULOSTOMIDAE (trumpet fishes)																				
Aulostomus sp.																				
BALISTIDAE (trigger fishes)																				
Balistapus undulatus		C		C		C							O		O				C	
Balistoides viridescens		O		O		O							R						O	
Melichthys niger																				
M. vidua																			O	
Odonus niger																				
Pseudobalistes flavimarginatus																				
Rhinecanthus aculeatus	O				C															
Sufflamen bursa																				
Sufflamen sp.		O		O		O														
BELONIDAE (needle fishes)																				
Tylosurus crocodilus																				
Unidentified belonid																				
BLENNIIDAE (blennies)																				
Amblygobius albimaculatus					C															
Cirripectes variolosus																				
C. sp.																				
Ecsenius bicolor																				

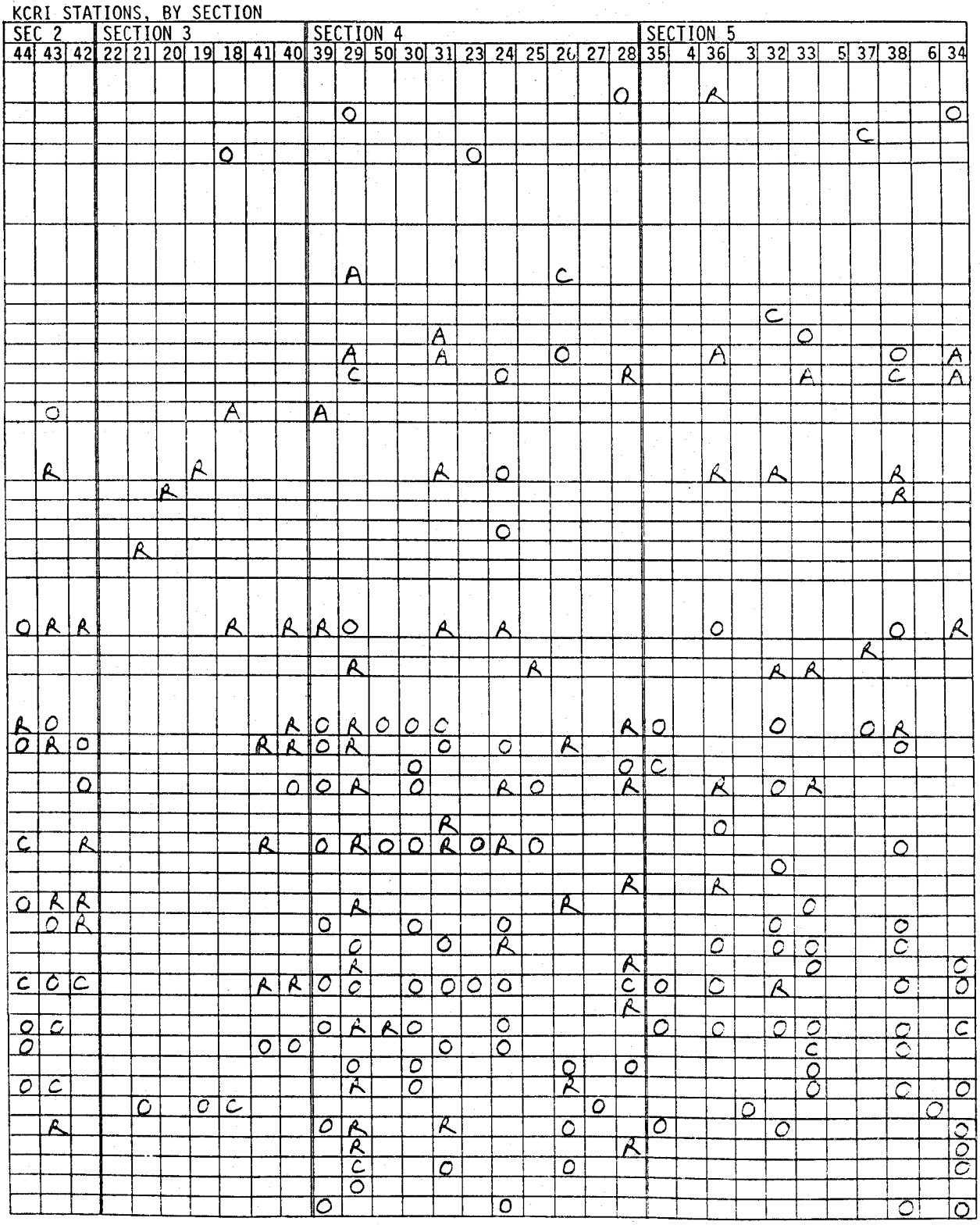
* Following the changes of Randall (1987), observations recorded as A. mata are listed here as A. blochii, and observations of A. glaucoparieus as A. nigricans.

KCRI STATIONS, BY SECTION

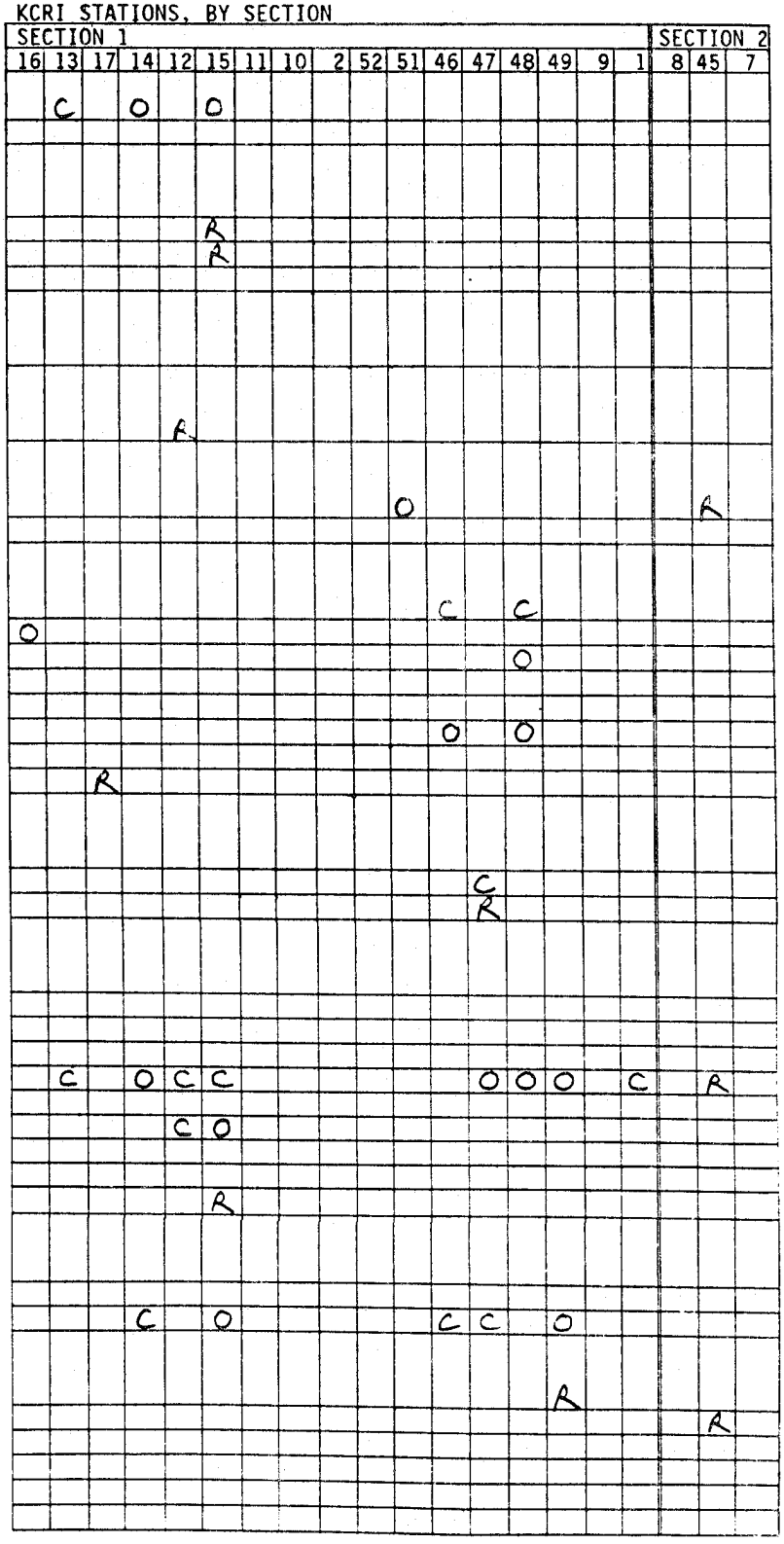



KCRI STATIONS, BY SECTION
SECTION 1
SECTION 2
16 13 17 14 12 15 11 10 2 52 51 46 47 48 49 9 1 8 45 7
Meiacanthus atrodorsalis
Plagiotremus tapienosoma
Salarias fasciatus
Unidentified blenniid
BOTHIDAE (lefteye flounders)
Bothus mancus
CAESIONIDAE (fusiliers)
Caesio caerulaureus
C. diagramma?
C. erythrogaster
C. pisang
C. tile
C. xanthonotus
Paracaesio sp.
Unidentified caesionid
CARANGIDAE (jacks)
Caranx melampygus
C. sexfasciatus
C. sp.
Decapterus sp.
Trachinotus blochii
Unidentified carangid
CARCHARHINIDAE (requiem sharks)
Carcharhinus amblyrynchos
C. melanopterus
Triaenodon obesus
CHAETODONTIDAE (butterfly fishes)
Chaetodon auriga
C. bennetti
C. citrinellus
C. ephippium
C. kleini
C. lineolatus
C. lunula
C. melanotus
C. mertensii
C. meyeri
C. ornatissimus
C. punctatofasciatus
C. raflessii
C. reticulatus
C. semeion
C. trifasciatus
C. ulietensis
C. unimaculatus
C. vagabundus
C. sp.
Forcipiger flavissimus
F. longirostris
Heniochus chrysostomus
H. singularius
H. varius

KCRI STATIONS, BY SECTION



KCRI STATIONS, BY SECTION



H. sp.
Megaprotodon trifascialis

CIRRHITIDAE (hawk fishes)
Oxycirrhites typus
Paracirrhites arcatus
P. forsteri
Unidentified cirrhitid

DASYATIDAE (sting rays)
Dasyatis sp.

DIODONTIDAE (porcupine fishes)
Diodon hystrix

EPHIPPIDAE (spade fishes)
Platax orbicularis
P. pinnatus

GOBIIDAE (gobies)
Acentrogobius ornatus
A. sp.
Amblygobius albimaculatus
Nemateleotris magnifica
Ptereleotris evides
P. sp.
Valenciennea strigata
Unidentified gobiid

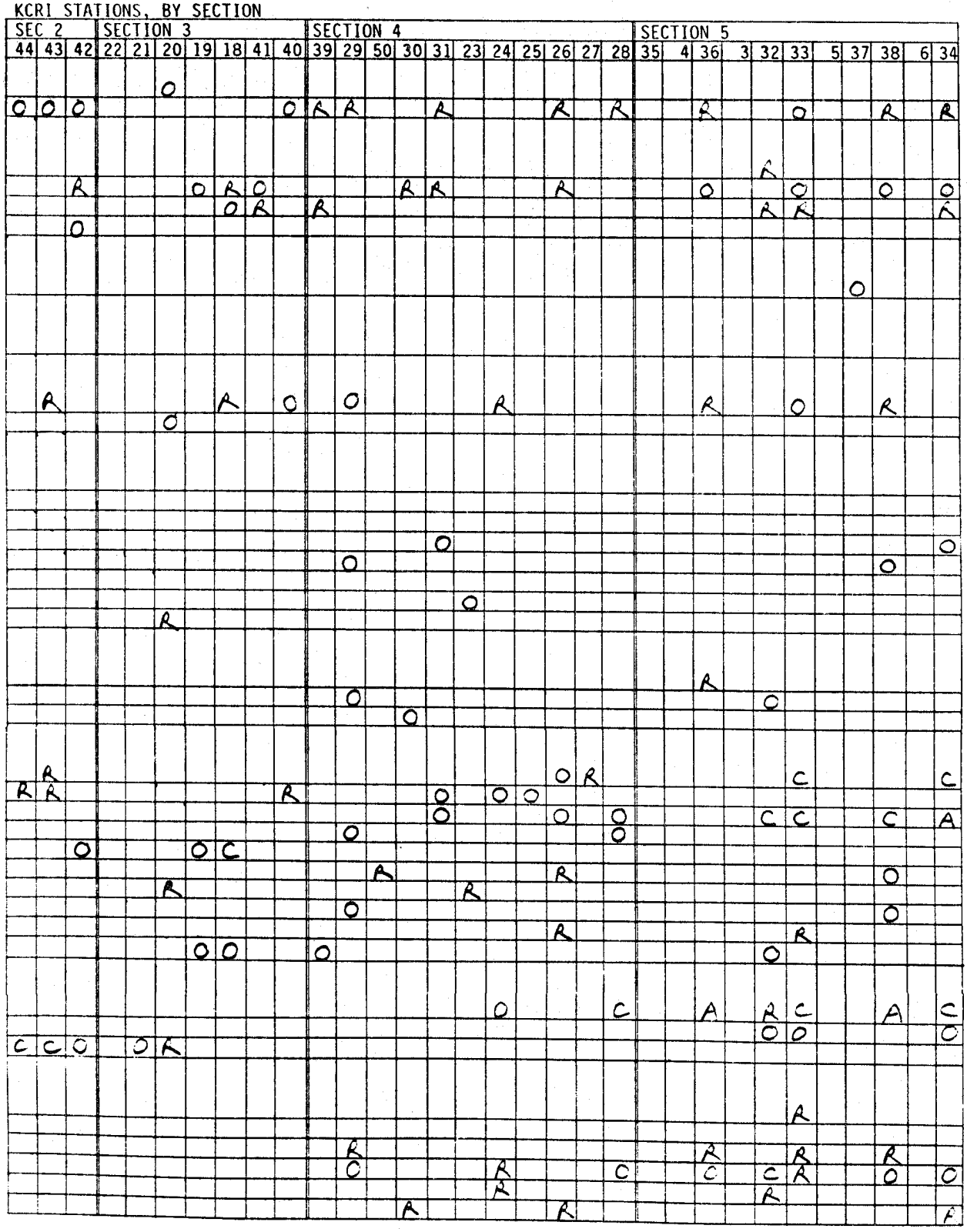
HAEMULIDAE (sweetlips)
Plectorhynchus nigrus
P. pictus
P. sp.

HOLOCENTRIDAE (squirrel fishes)
Myripristis adustus
M. berndti
M. murdjan
M. violaceus
M. sp.
Neoniphon sammara
N. sp.
Sargocentron caudimaculatum
S. spinniferum
S. tiere

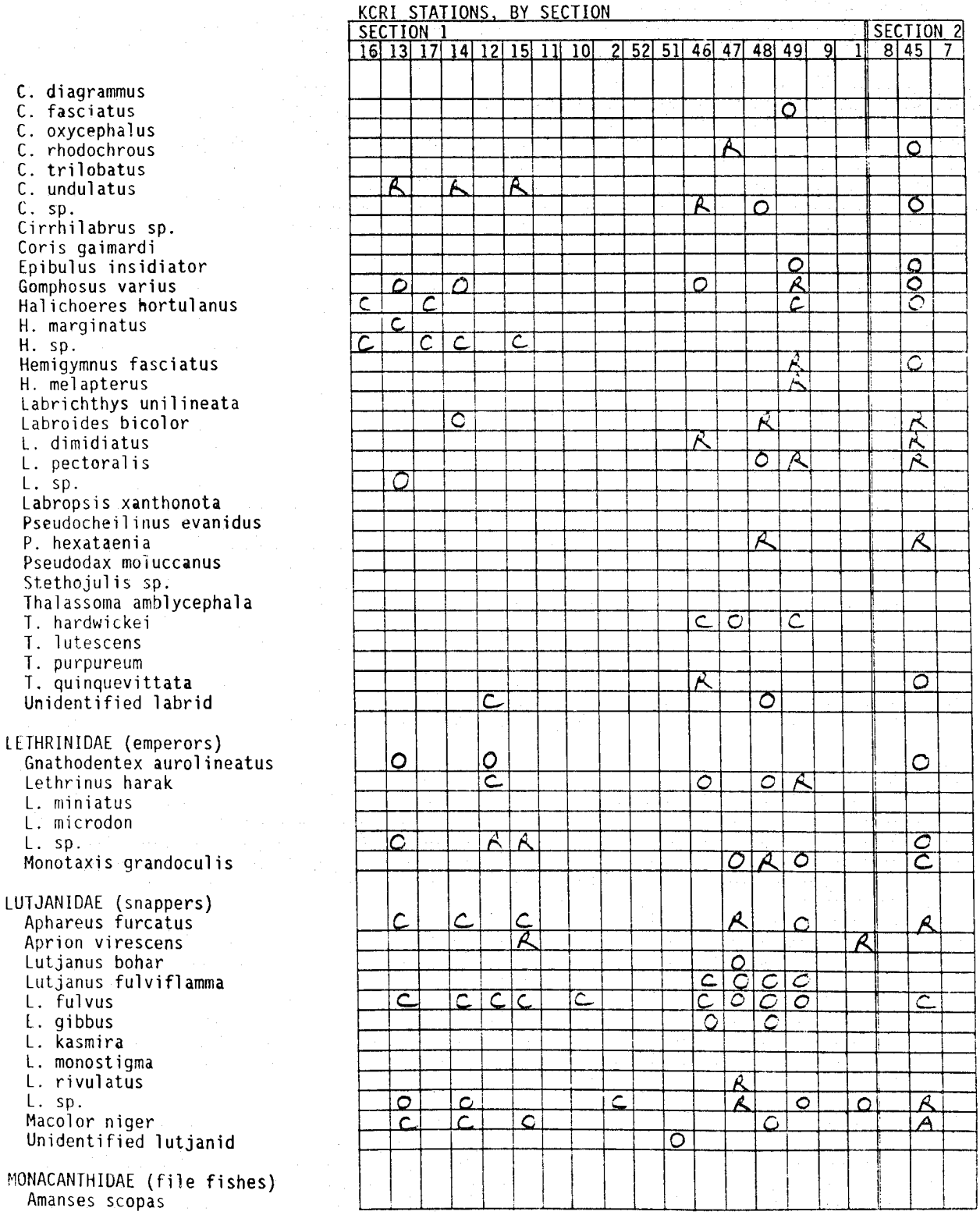
KYPHOSIDAE (rudder fishes)
Kyphosus cinerascens
K. lembus
K. sp.

LABRIDAE (wrasses)
Anampses caeruleopunctatus
A. melanurus?
A. twistii
Bodianus axillaris
B. mesothorax
Cheilinus chlorurus

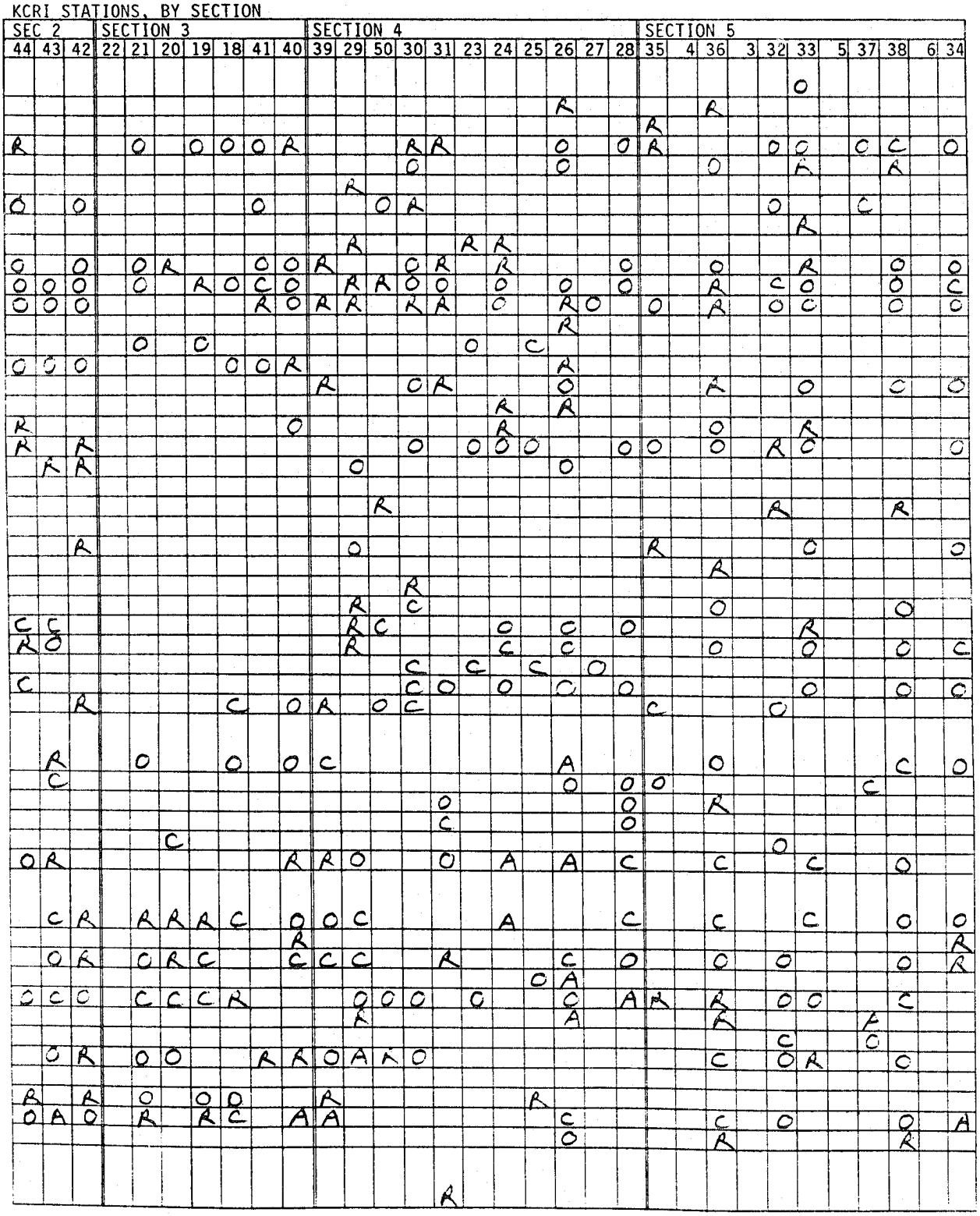
KCRI STATIONS, BY SECTION



KCRI STATIONS, BY SECTION



KCRI STATIONS, BY SECTION



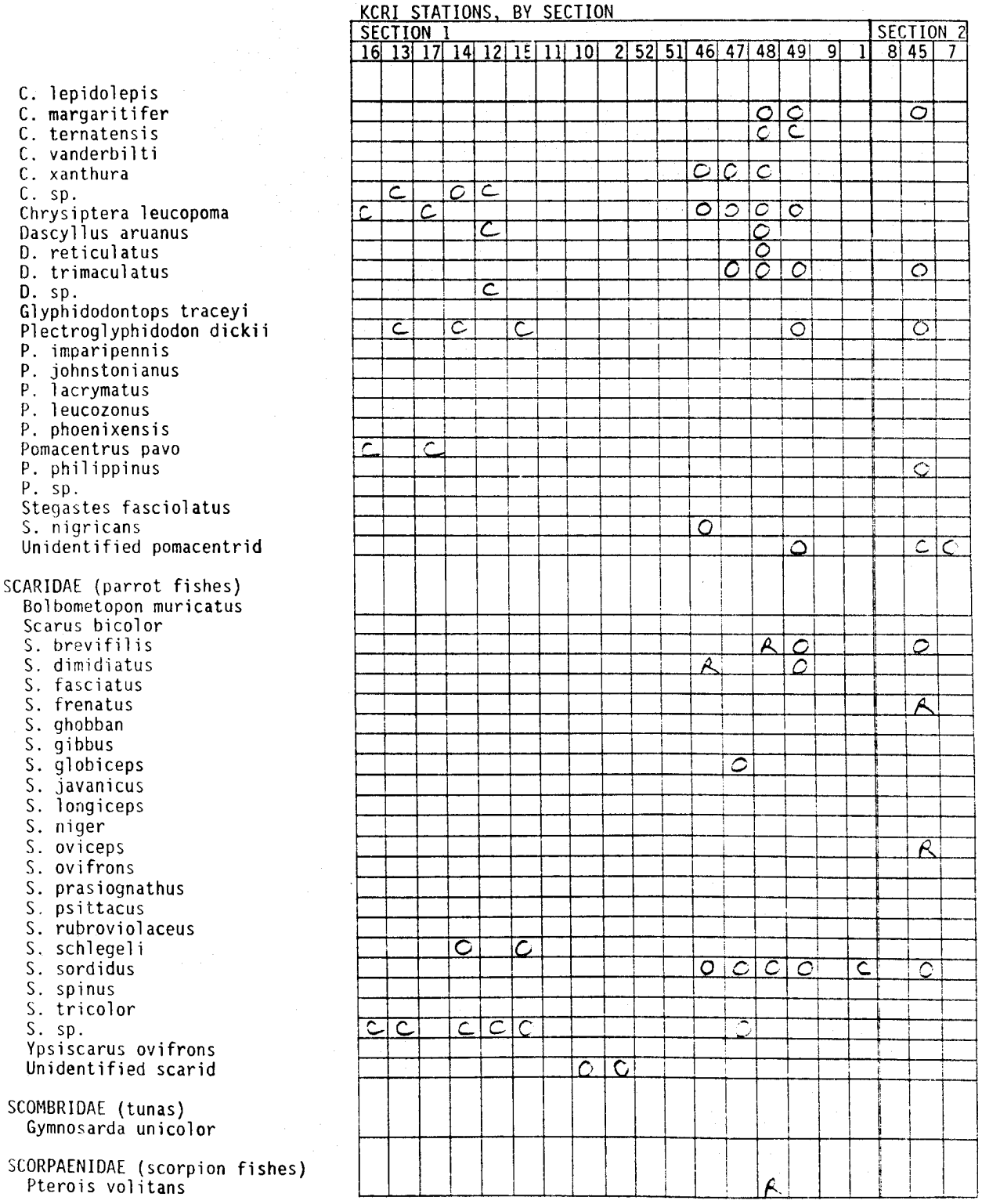
KCRI STATIONS, BY SECTION

	SECTION 1																	SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
Cantherhines dumerili																				
Unidentified monacanthid																			R	
MUGILIDAE (mullets)																				
Liza vaigiensis					A															
MULLIDAE (goat fishes)																				
Mulloidichthys flavolineatus																				
M. vanicolensis												O								
Parupeneus barberinus														R	O					
P. bifasciatus																				
P. cyclostomus														C						
P. indicus															R					
P. multifasciatus	O	C		C		O						O	C	R	O				C	
Unidentified mullid	O			O		C														
MURAENIDAE (moray eels)																				
Gymnothorax pictus																				
G. sp.																				
Unidentified muraenid					O															
NEMIPTERIDAE (threadfins)																				
Scolopsis cancellatus	R					C							O		O					
OPHICHITHIDAE (snake eels)																				
Myrichthys colubrinus																				
OSTRACIONTIDAE (box fishes, cow fishes)																				
Ostracion meleagris						R														
PEMPHERIDAE (sweepers)																				
Pempheris oualensis		C		C		C													R	
POMACANTHIDAE (angel fishes)																				
Centropyge bicolor													R	R	O					
C. flavissimus																			R	
C. heraldi																				
C. loriculus																				
C. multifasciatus																				
C. shepardi(?)																			O	
C. vrolicki															C					
C. sp.		O																		
Pygoplites diacanthus					R								O	C	O		C		R	
POMACENTRIDAE (damsel fishes)																				
Abudefduf coelestinus																				
A. sordidus																				
A. vaigiensis																				
A. sp.	R		R																	
Amblyglyphidodon aureus																				
A. curacao																				
Amphiprion chrysopterus		O			R										O				O	
A. clarkii																				
A. perideraion															O					
A. sp.					O															
Chromis atripectoralis																				

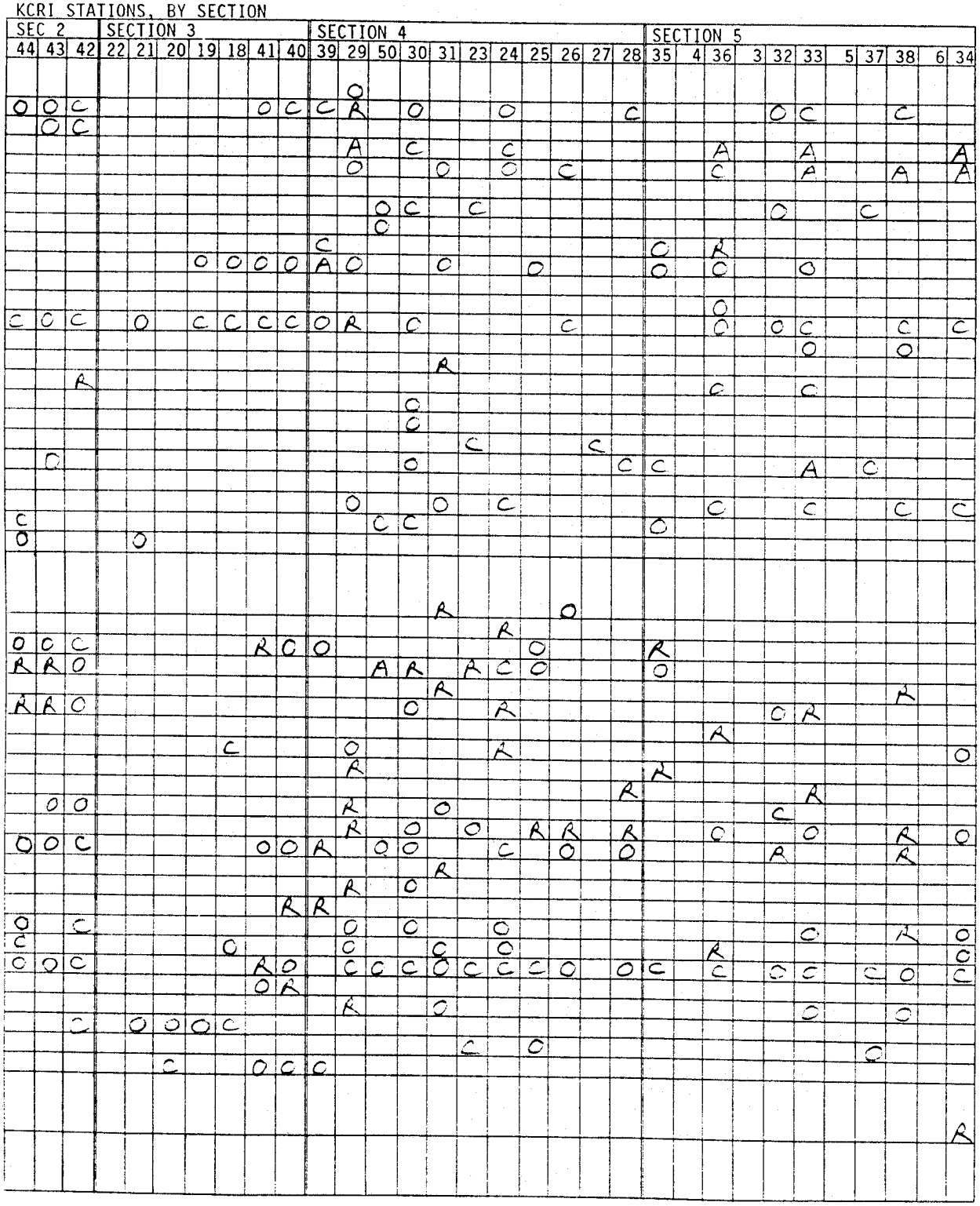
KCRI STATIONS, BY SECTION

SEC 2			SECTION 3							SECTION 4										SECTION 5										
44	43	42	22	21	20	19	18	41	40	39	29	50	30	31	23	24	25	26	27	28	35	4	36	3	32	33	5	37	38	6	34
								O			R														A					R
				O	O						C							C												O
					O							R												A						
											O	R	O	R	R	O		O		C			C			O			O	O
																R														
																O		C													
	O	O		O	O					O					R	R	O			O		R		O	R		C	O		O
				R	C	C																	A							
																												R		
													A		R		O		O									R		
	O			A	A	O					C	C	C		C	O		O			O			O				O		C
																												R		
						R					R																			
		R					O				O		R			C		O		A					C	O			C		C
														R				O			O			O						
										O				R																
											R							R		O					O	O			C		O
																				R										
														R		R							C		O				O		O
		R			O					O	R						C	R		R	R		O		R	R				
																					O					O			O	
	O	C								A			C				O			O			C		C			O	A	
						R																								
														O						O			R							
O					O	O	C	R	O	C											O		O			O				
C						O			O		O		O				C	O	R				O		O					O
	C									C		C																O		

KCRI STATIONS, BY SECTION



KCRI STATIONS, BY SECTION



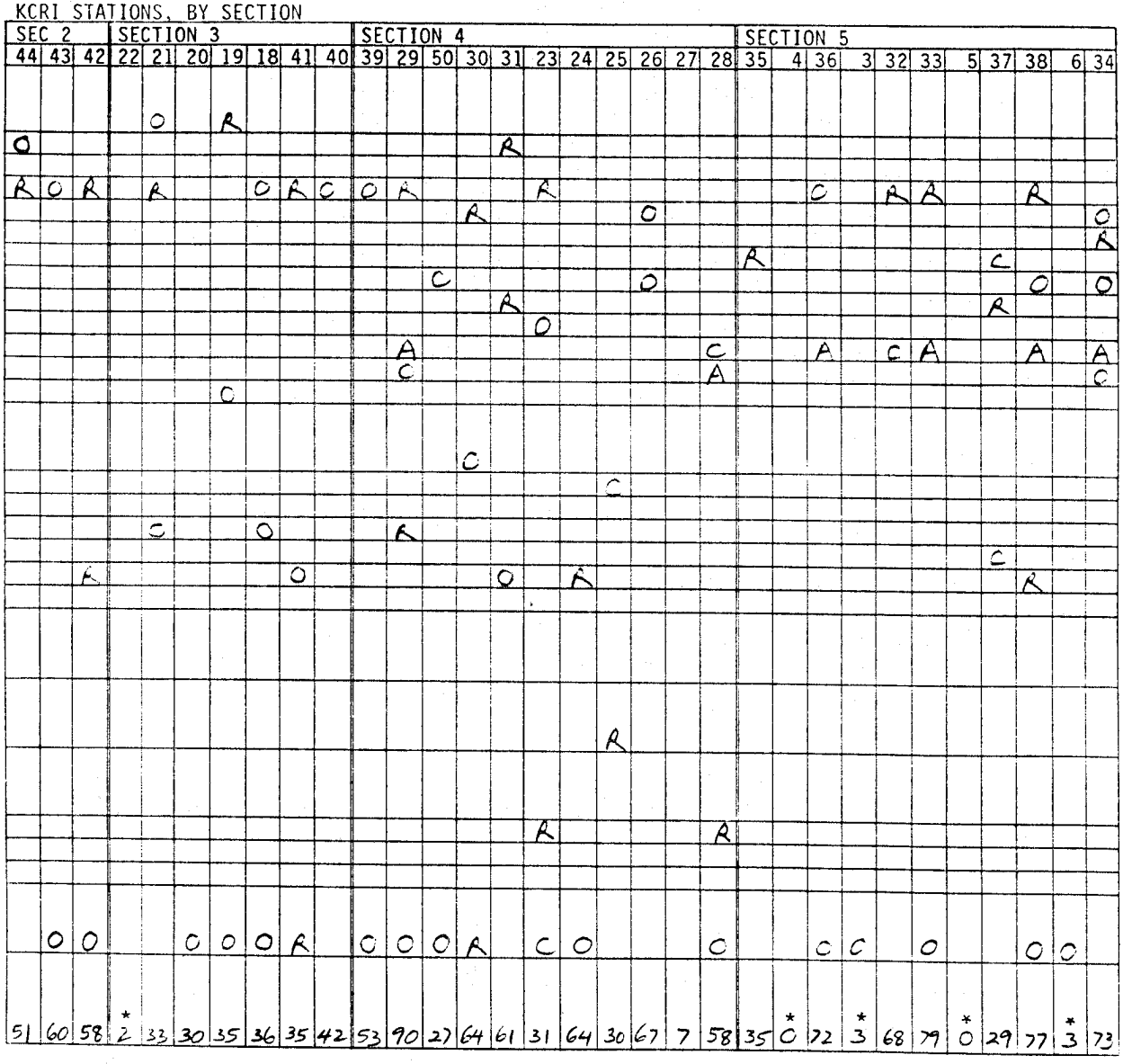
KCRI STATIONS, BY SECTION

	SECTION 1																	SECTION 2		
	16	13	17	14	12	15	11	10	2	52	51	46	47	48	49	9	1	8	45	7
SERRANIDAE (groupers)																				
Aethaloperca rogaa																				
Anyperodon leucogrammicus																				
Cephalopholis analis													C	O	O					
C. argus		C				O													O	
C. urodelus				O															O	
Epinephelus fuscoguttatus																				
E. hexagonatus												R								
E. merra												R		O	R					
E. microdon																				
E. sp.					O	R			O											
Mirolabrichthys dispar																				
M. pascalus																				
Unidentified serranid											O									
SIGANIDAE (rabbit fishes)																				
Siganus argenteus																				
S. fuscescens																				
S. guttatus												O	A							
S. puellus																				
S. spinus																				
S. virgatus																				
S. sp.					O						O									
SPHYRAENIDAE (barracudas)																				
Sphyraena barracuda		O		R															R	
SYNODONTIDAE (lizard fishes)																				
Saurida gracilis																				
TETRAODONTIDAE (puffers)																				
Arothron hispidus														R						
A. meleagris																				
A. nigropunctatus																				
Canthigaster solandri														O						
ZANCLIDAE (moorish idols)																				
Zanclus cornutus		C		O	C	O						O	C	O	O		O			
NUMBER OF (CONSPICUOUS) FISH TAXA RECORDED **	15	36	9	33	33	37	* 0	* 4	5	* 0	6	34	42	49	58	* 0	8	* 6	57	* 2

* Stations for which fish list was not compiled; observations were incidental only.

** Number of species represented may be slightly higher or lower. Survey emphasis was on identifying conspicuous species possibly used for food. Totals reflect many factors which affected sampling effort and are given only to provide a general indication of occurrence.

KCRI STATIONS, BY SECTION



APPENDIX E.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES: INFORMATION ON SPECIFIC SITES

The following information was compiled and provided by Dr. Ross Cordy, Head Archaeologist, Historic Sites Section, Division of State Parks, Hawaii State Department of Land and Natural Resources, Honolulu. The list is presented here, with only minor modifications, in order to indicate the types of sites known in the various coastal areas of Kosrae. Reference map numbers (underlined) are those of the Kosrae Coastal Resource Atlas. Individual site numbers are not published on the atlas maps; rather, archaeological site symbols have been used in the atlas to indicate approximate locations of known sites.

MAP 1

1. Wiya Coastal Site, Wiya fal (Ko-D15-1). Subsurface deposits up to 1.0 m in depth in sand. Remains of permanent housing area. Dates back to A.D. 95 $\pm$ 70; the earliest dated site on Kosrae so far.

2. Wiya Bird Cave, Wiya fal (Ko-D15-2). Cave with deposits at its entrance. Numerous burials reportedly removed prior to World War II, during Japanese guano excavations. Date of A.D. 1300s from one-third the way down in the deposits. Cave is location of traditional stories.

[Yekula to Finaunpes Area. Sand area with permanent housing at European Contact. Yekula was the location of a sacred place of one of the island's major deities, Sinlakuh. Subsurface deposits highly probable.]

MAP 2

Unsurveyed.

MAP 3

3. Lelu Ruins (Ko-A1-1). The Lelu Ruins include all the flat land on Lelu Island and the small islets of Yenasr, Yenyen and Pisin. Ruling center of entire island from A.D. 1400s until recently. Over 100 walled dwelling, sacred and mortuary compounds. Central compounds with massive basalt walls, similar to Nan Madol on Pohnpei. Much of island and all small islets are artificial, prehistoric landfill. Fill dates back to A.D. 1200s, massive walls to A.D. 1400s. Earliest deposits so far to A.D. 900s. Primary ruins now part of Lelu Ruins Historical Park.

[The hill of eastern Lelu Island, Finol Poro, was undoubtedly used for agricultural purposes prehistorically, so it too could be considered a site or part of the Lelu Ruins complex.]

[Numerous stone alignments, which were the remaining foundations of fishtraps, were reported for the reef flat between Yenasr and Yenyen

Islets. These were destroyed by various construction activities in the 20th Century.]

4. Ko-A10-1, Japanese Cemetery, Innem fal. 1925 cemetery.

5. Ko-A10-2, Innem fal. Concrete water catchment, from plantation, Japanese period.

[Sites up Innem upper valleys. Thirty-four sites, mostly agricultural and permanent house sites.]

[Sites up Tofol upper valley. Twenty-six sites, mostly agricultural and permanent house sites.]

[Three shipwrecks & 1 plane in Lelu Harbor. Two wrecks are Japanese cargo ships sunk during war. One wooden-hulled ship found in harbor. Plane immediately post-war.]

MAPS 4 & 5

Unsurveyed.

MAP 6

[Japanese fighter strip, which was almost completed during war, is located behind Malem on the coastal plain.]

6. Japanese storage cave, Malem fal. World War II.

7. Japanese period cave, Malem. World War II.

8. Remains of Japanese commanding officer's residence, Malem. World War II.

9. Japanese officers' cave, Malem. World War II.

10. Japanese period cave, Malem. World War II.

11. Platform = remains of Japanese hospital, Malem. World War II.

MAP 7

12. Lela Coastal Site, Lela fal (Ko-B4-1). Series of low-walled dwelling compounds with deposits on strand islet fringing the mangroves. Undated.

MAP 8

13. Ko-B5-14, Kuplu fal. Platform & enclosure = permanent dwellings. Undated.

14. Ko-B5-13, Kuplu. Enclosure = permanent dwelling. Undated.

15. Twelve sites, predominantly permanent house sites, scattered on upland plateau of Kuplu fal (Ko-B5-1 through -12).

MAP 9

16. Rectangular alignment of large basalt blocks off Utwe Village, Taf fal. According to oral traditions, this site was a prehistoric stockpile of raw material destined for the Lelu Ruins.

17. Leonora Shipwreck. Brig belonging to "Pirate" Bully Hayes sank in storm in 1874 in harbor. Copper-sheathed hull intact.

[Utwe Ma. Location of Utwe Village from the 1860s to the 1940s. Pictures of the village's houses appear in Sarfert's 1919 Sudsee Expedition volume.]

18. Ko-C7-1, Sipyen. Alignments, narrow platform and paving. Function and age uncertain.

19. Ko-C7-7, Sipyen. Enclosures and paving = permanent dwelling. A.D. 900s-1200s to pre-1840.

20. Ko-C7-2, Sipyen. Rectangular alignment & paving = permanent dwelling. A.D. 1000s-1400s.

21. KO-C7-3, Sipyen. Enclosure, 2 platform-terraces, 2 pavings with subsurface remains = permanent dwelling. Pre-A.D. 1410-1640 to 1800s.

22. Ko-C7-5, Sipyen. Rectangular alignment & enclosure with earlier buried remains = permanent dwelling. A.D. 1400-1630 to 1840.

23. Ko-C7-6, Sipyen. Deposits on islet in mangroves. Age and function unclear.

24. Ko-C13-7, Newot fal. General revetment area, with earlier buried feature = likely permanent dwelling. Abandoned by 1840.

25. Ko-C13-2, Newot. Enclosure, with earlier buried enclosures = permanent dwelling. A.D. 1490-1730 to 1840.

26. Ko-C13-1, Newot. Platform-terrace with earlier buried feature = permanent dwelling. A.D. 1235-1415 to 1840.

MAP 10

27. As under Map 9.

28. Ko-C13-3, Newot. Enclosure and adjacent oven deposits and platform-terrace = permanent dwelling. A.D. 1320-1840.

29. Ko-C13-4, Newot. Platform = charcoal kiln. Japanese period, 20th Century.

30. Ko-C13-5, Newot. Enclosure = permanent dwelling, with earlier buried cultural remains. A.D. 1050-1265 to 1840.

31. Ko-C13-6, Newot. Rectangular alignment = permanent dwelling, with earlier, buried remains. A.D. 1350-1495 to 1840, hiatus between occupations.

32. Ko-C13-8, Newot. Rectangular alignment = permanent dwelling, with earlier buried remains. A.D. 1200-1405 to 1840.

33. Ko-C8-14, Nefalil fal. Two rectangular alignments = permanent dwelling. A.D. 1525-1810.

34. Ko-C8-50. Enclosure = permanent dwelling. Earlier buried charcoal lens = A.D. 1025-1320.

35. Ko-C8-4, Nefalil. At least 1 platform = permanent dwelling. Age unknown.

36. Ko-C8-15, Nefalil. Deposits on Finlosr Islet (basalt outcrop) on edge of mangroves. Function and age uncertain.

37. Ko-C8-2. Three sand islets in mangroves with enclosures and other features and with subsurface deposits = permanent dwellings. A.D. 1400-1515 to 1800s.

38. Ko-C8-51, Nefalil. Enclosure and rectangular alignment = permanent dwelling. A.D. 65-580.

39. Ko-C8-3, Nefalil. Enclosure and paving with earlier buried features = permanent dwelling. A.D. 1340-1485 to 1820-1840.

40. Ko-C8-5, Nefalil. Paving and rectangular alignment = permanent dwelling. A.D. 1790-1840. Buried oven further down = A.D. 645-915.

41. Ko-C8-9, Nefalil. Enclosure = permanent dwelling. Undated.

42. Ko-C8-10. Platform and possibly other features permanent dwelling. Undated.

43. Ko-C8-1, Nefalil. Major complex of 14 enclosures and 7 other major architectural units = permanent dwellings. Shore portions of site date back to A.D. 600-870. Most of site is partial artificial landfill along the shore, dating A.D. 1400-1800. Virtually abandoned by A.D. 1860s-1880s.

44. Ko-C8-6, Nefalil. Enclosure = permanent dwelling. Abandoned by A.D. 1840.

45. Ko-C8-7, Nefalil. Sand islet in mangroves with deposits. Permanent dwelling area likely. Age unknown.

46. Ko-C8-13, Nefalil. At least 1 platform = permanent dwelling. Undated.

47. Ko-C8-12, Nefalil. Terrace with platform and paving = permanent dwelling. Undated.

48. Ko-C8-18. Remains of undertain type, function and age.

49. Ko-C9-7, Isra. Enclosure = permanent dwelling. Undated.

[Sites in upper valleys of Nefalil fal and Selmeoa and on flat lower ridges in Nefalil.]

MAP 11

50. Ko-C9-1, Isra fal. Enclosure = permanent dwelling. Undated.

51. Ko-C9-22, Isra. Mangrove islet with cultural deposits. Function and age uncertain.

52. Ko-C9-2, Isra. Enclosure = permanent dwelling. Undated.

53. Ko-C9-20, Isra. Enclosure = permanent dwelling. Undated.

54. Ko-C9-21, Isra. Enclosure = permanent dwelling. Undated.

55. Ko-C9-8, Isra. Enclosure = permanent dwelling. Undated.

56. Ko-C9-10, Isra. Two enclosures = permanent dwelling. Dated back to A.D. 1405-1665.

57. Ko-C9-18, Isra. Paving = permanent dwelling. Undated.

58. Ko-C9-16, Isra. Paving = permanent dwelling. Undated.

59. Ko-C9-17, Isra. Paving = permanent dwelling. Undated.

60. Ko-C9-15, Isra. Enclosure = permanent dwelling. Undated.

61. Ko-C9-14, Isra. Enclosure = permanent dwelling. Undated.

62. Ko-C9-12, Isra. Enclosure and pavings = permanent dwelling. Undated.

63. Ko-C9-13, Isra. Paving = permanent dwelling. A.D. 1410-1635.

64. Ko-C9-11, Isra. Enclosure = permanent dwelling. Undated.

65. Ko-C10-5, Tafwon fal. Wall. Function and age uncertain.

66. Ko-C10-3, Tafwon. Two enclosures and subsurface deposits = permanent dwelling. A.D. 1500s-1800s.

67. Ko-C10-4, Tafwon. Enclosure = permanent dwelling. Undated.

68. Ko-C10-6, Tafwon. Enclosure and platform = permanent dwelling. Dated back to A.D. 1200s-1300s.

69. Ko-C10-1, Tafwon. Enclosure = permanent dwellino. Undated.

70. Ko-C10-2, Tafwon. Wall and paving. Function and age uncertain.

71. Ko-C10-7, Tafwon. Paving = permanent dwelling. Undated.

72. Ko-C10-8, Tafwon. Enclosure = permanent dwelling. Undated.

73. Ko-C11-1, Falwe fal. Four enclosures = permanent dwellings. Undated.

74. Ko-C11-2, Falwe. Enclosure = permanent dwelling. Undated.

75. Ko-C11-6, Falwe. Walls and paving. Function and age uncertain.

76. Ko-C11-7, Falwe. Enclosure = permanent dwelling. Undated.

77. Ko-C11-3, Falwe. Mangrove islet with 4 enclosures and 2 pavings and subsurface deposits = permanent dwellings. A.D. 1600s-1900s.

78. Ko-C11-4, Falwe. Paving = permanent dwelling. Undated.

79. Ko-C11-5, Falwe. Paving = permanent dwelling. Undated.

MAPS 12-13

80. Ko-C12-1, Yemulil fal. Rectangular alignment and paving. Permanent dwellings, undated.

81. Ko-C12-2, Yemulil. Rectangular alignment. Function and age uncertain.

82. Ko-C12-4, Yemulil. Paving = permanent dwelling. Undated.

83. Ko-C12-5, Yemulil. Platform = permanent dwelling. Undated.

84. Ko-C12-3, Yemulil. Four enclosures = permanent dwellings. Undated.

85. Ko-D17-2, Lukunlulem fal. Enclosure = permanent dwelling. Undated.

86. Ko-D17-3, Lukunlulem. Enclosure & columnar basalt cliff = permanent dwelling and possible quarry. Undated.

87. Ko-D17-4, Lukunlulem. Enclosure and platform = permanent dwellings. Undated.

88. Ko-D17-1, Lukunlulem. Major complex of ca. 9 Enclosures, with subsurface deposits = permanent dwellings. Extensively studied [ ]. Initial occupation A.D. 435-630. Bulk of the site dates A.D. 1400s-1700s.

89. Ko-D17-5, Lukunlulem. Alignment with paving. Function and age uncertain.

90. Ko-D1-1, Koasr fal. Cave = temporary shelter. Undated.

91. Ko-D1-2, Koasr. Two pavings = permanent dwellings. Undated.

92. Ko-D1-3, Koasr. Enclosure = permanent dwelling. Undated.

93. Ko-D1-4, Koasr. Enclosure = permanent dwelling. Undated.

94. Ko-D1-5, Koasr. Paving = permanent dwelling. Undated.

95. Ko-D1-6, Koasr. Enclosure and paving = permanent dwellings. Undated.

96. Ko-D1-7, Koasr. Platform. Function and age uncertain.

97. Ko-D2-2, Leap fal. Enclosure = permanent dwelling. Undated.

98. Koasr Coastal Site, Koasr fal. Complex of multiple, abutted, low-walled enclosures = permanent dwellings. Undated.

MAPS 13-14

99. Ko-D2-4, Leap. Enclosure = permanent dwelling. Undated.

100. Ko-D2-5, Leap. Enclosure = permanent dwelling. Undated.

101. Ko-D2-6, Leap.

102. Ko-D2-7, Leap.

103. Ko-D2-1, Leap. Leap Coastal Site. Prehistoric and historic site with subsurface deposits in sand = permanent dwellings. Prehistoric portions largely gone today due to erosion of shoreline.

104. Srukames Islet, Leap. Structural remains present. Function and age uncertain. May have been part of Ko-D2-1 prior to the erosion of that site.

105. Ko-D3-3, Mwot fal. Large boulder outcrops on point = possible prehistoric quarry for Lelu Ruins.

106. Ko-D3-2, Mwot. Boat landing for Mwot School. Saka (kava) pounding stones present, indicating prehistoric or early historic permanent dwelling or landing area.

107. Ko-D3-1, Mwot.

108. Ko-D3-4, Mwot. Mwot Mission School. Includes foundations of school buildings, cemetery, etc. American Board of Commissioners for Foreign Missions (Congregational missionary society based in Boston and Hawaii) and later Kosrae Congregational Churches school from late 1800s until 1964. This school served Kosrae, the Gilberts, and the Marshall islands.

109. Mwot. Coral walkway from shore to Mwot school buildings. Part of Mwot Mission School complex.

110. Mwot. Platform = boat landing for school, but also has prehistoric/early historic artifacts indicating an earlier permanent dwelling function.

111. Mwot. Coral walkway up other ridge to school buildings.

112. Ko-D5-7, Wiya fal. Enclosure = permanent dwelling. Undated.

113. Ko-D4-1, Lenwot. Coastal strand at outer edge of mangroves with complex of alignments and walls. Function and age unknown.

MAP 15

114. Ko-D6-5, Yela fal. Stone-lined pit = charcoal kiln. Japanese period, 20th Century.

115. Ko-D6-4, Yela. Food pounding stone and alignments = permanent dwelling(s). Undated.

116. Ko-D6-1, Yela. Sand islet on outer edge of mangroves, south side of Yela Stream. Pavings and alignments. Function and age uncertain.

117. Ko-D6-2, Yela. Alluvial islet in mangroves with 3 enclosures = permanent dwellings. Undated.

118. Ko-D6-3, Yela. Enclousre = permanent dwelling. Undated.

119. Ko-D6-8. Sand islet on outer endge of mangroves, north side of Yela Stream. Complex of platforms, pavings, and walls. Likely permanent dwellings. Undated.

120. Ko-D6-9, Yela. Islet in mangrove swamp with platform = permanent dwelling(s). Undated.

121. Ko-D6-10, Yela. Enclosure = permanent dwelling. Undated.

122. Ko-D6-11, Yela. Platform = permanent dwelling. Undated.

123. Ko-D7-1, Yal fal. Platform = permanent dwelling. Undated.

124. Ko-D7-2, Yal. Complex of 3+ enclosures at interface coastal plain and mangroves = permanent dwellings. Undated.

125. Ko-D7-3, Yal. Complex of 8+ enclosures at interface coastal plain and mangroves = permanent dwellings. Undated. Likely to be a continuation of D7-2. Together they form a major complex like Ko-C8-1 in Nefalil, Ko-D17-1 in Lukunlulem, and Ko-D11-1 in Loal.

MAP 16

126. Ko-D8-1, Las fal. Platform = permanent dwelling. Undated.

127. Ko-D8-2, Las. Platform = permanent dwelling. Undated.

128. Ko-D8-3, Las. Enclosures = permanent dwelling. Undated.

129. Ko-D8-5, Las. Complex of platforms and alignments = permanent dwellings. Undated.

130. Ko-D8-4, Las. Platform = permanent dwelling. Undated.

131. Ko-D9-1, Finolof fal. Platform with walls = permanent dwelling. Undated.

133. Ko-D9-2, Finolof. Platform = permanent dwelling. Undated.

134. Ko-D9-3, Finolof. Enclosure = permanent dwelling. Undated.

135. Ko-D9-4, Finolof. Complex of platforms and enclosures = permanent dwellings. Undated.

136. Ko-D9-5, Finolof. Platform = permanent dwelling. Undated.

137. Ko-D9-6, Finolof. Platform = permanent dwelling. Undated.

138. Mutunyal Islet. Possibly artificial islet. Camp location for 1824 Duperrey and 1827 Lutke expeditions, the first to reach Kosrae.

[Sites found along the edge of the freshwater marsh in the Melo area of Okat fal. The rest of Okat has yet to be completely surveyed by archaeologists.]

MAP 17

139. Ko-D11-1, Loal fal. Loal Coastal Site. Major complex of 14+ enclosures = permanent dwellings. Undated. This was the village visited most frequently by the Duperrey and Lutke expeditions.

140. Ko-D12-1, Tepat fal. Putuk Hamlet Ruins. 12 enclosures & landfill terraces on edge of mangroves. Dated to A.D. 1700s-1800s. Largely destroyed by airport road construction.

141-145. Ko-D12-2 through -6, Tepat. Sites off map. Three house sites of 1-3 architectural features, 1 possible cemetery platform, and one sacred place with an upright stone. Two sites dated, indicating Tepat's occupation from A.D. 580-800 through the 1800s.

MAP 18

146. Tafunsak-Mutunte-Finfoko Area. Confirmed subsurface deposits at Finfoko (Ko-D14-1) in sand -- similar to Wiya Coastal Site. Likely to be continuous deposits from Finfoko through Mutunte and Tafunsak. Area of permanent housing at European Contact. No dates.

1. & 2. As in Map 1.

APPENDIX F

WATER USE CLASSIFICATION

Trust Territory of the Pacific Islands (TTPI) classification of coastal water uses (from Part 5 of Title 63, Chapter 13, Subchapter VII, as amended 31 March 1986).

PART 5 WATER USE CLASSIFICATION

(A) Classification of Coastal Water Uses

Coastal waters are classified in accordance with uses to be protected in each class as follows:

(1) Class AA Waters

The uses to be protected in this class of waters are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and other aesthetic enjoyment.

It is the objective of this class of waters that they remain in as nearly their natural, pristine state as possible with an absolute minimum of pollution from any source. To the extent possible, the wilderness character of such areas shall be protected. No zone of mixing will be permitted in these waters.

The classification of any water area as Class AA shall not preclude other uses of such waters compatible with these objectives and in conformance with the standards applicable to them.

(2) Class A Waters

The uses to be protected in this class of waters are recreational (including fishing, swimming, bathing, and other water-contact sports), aesthetic enjoyment, and the support and propagation of aquatic life.

It is the objective for this class of waters that their use for recreational purposes and aesthetic enjoyment not be limited in any way. Such waters shall be kept clean of any trash, solid materials or oil, and shall not act as receiving waters for any effluent which has not received the best degree of treatment or control practicable under existing technological and economic conditions and compatible with the standards established for this class.

(3) Class B Waters

The uses to be protected in this class of waters are small boat harbors, commercial and industrial shipping, bait fishing, compatible recreation, the support and propagation of aquatic life, and aesthetic enjoyment.

It is the objective for this class of waters that discharge of any pollutant be controlled to the maximum degree possible and that sewage and industrial effluents receive the best degree of treatment practicable under existing technological and economic conditions and compatible with the standards established for this class.

The Class B designation shall apply only to a limited area next to boat docking facilities in bays and harbors. The rest of the water area in such bay or harbor shall be Class A unless given some other specific designation.