SURVEY OF THE COASTAL ENVIRONMENT OF BABELTHAUP AND KOROR AND IMPLICATIONS FOR IT OF PROPOSED COASTAL ZONE DEVELOPMENTS

A Cooperative Study By

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SUMMARY

All the major developments being considered are planned for the coasts or, in the case of the airport and roads, inland on the large islands of Babelthaup and Koror with the potential of affecting the coasts. The coastal communities examined were generally similar to each other because they were all fringing the major island masses. Excepting the octocorals in the Toachel Mid off Ngesaol, the communities were not found to have unique or endangered species. (It is possible that the Ngeremeduu estuary [western Babelthaup] and the bay enclosed by the Ngiwal causeway [eastern Babelthaup] are important for dugongs and crocodiles, but these species were not actually seen in this study.)

The main characteristic of the areas being considered for development is that they are presently being harvested for seafoods by Palauans. Several of the areas, especially Ngesaol, Ngaraard, Melekeok, and the north coast of Koror between T-Dock and the causeway, are important because they are productive and accessible to the local people. They provide a source of seafood that can be collected by wading close to home by Palauans that do not have vehicles or boats. The plans for development must include a consideration of the food supply for local residents. Each area contributes its own particular foods from the sea. The effects of development on the supply of nonpurchased food to the Palauans should be assessed for each area for which development is being planned.

The productivity of the areas and the abundant juvenile fishes observed indicates that these areas may also be important as nursery areas that supply fishes and invertebrates to neighboring habitats. For example, the juvenile fishes among the prop-roots of mangroves may migrate to nearby reef habitats. This relationship, and its potential influence on reef fisheries, has not been demonstrated quantitatively. The effects of dredging, filling and removal of mangroves on the fisheries of nearby habitats should be assessed as part of the development plan.

Few cases of ciguatera have been reported from Belau to date. It has been hypothesized that ciguatera appears where there is disturbance to the benthic community by dredging, blasting, etc. With this in mind, it is recommended that a careful record be started in order to keep track of any patterns in the occurrence of ciguatera now that development of coastal regions of Belau is about to increase dramatically.

Economic and engineering considerations may occasionally take priority over matters of the presence of unique or endangered habitats or species, the influences of alteration of the one habitat on neighboring habitats, or the welfare of the local residents. However, the sites of some of these developments being planned for Palau are most unusual in that it seems that economic and engineering considerations are also

overshadowed. Fifty million dollars is being spent in dredging the reef-flat at Ngesaol to open a marina and to use as fill to reclaim some of the mangrove area, while there are a number of sites around Babelthaup that require much less investment for preparation for building. Furthermore, these other sites would probably be more appealing to the tourist than Ngesaol which has a view of the underside of the Koror-Babelthaup Bridge. Some of these other sites may not be as important in supplying seafood for the local residents.

It has been suggested that land tenure is a consideration that overrides economic, engineering, sociological, and ecological considerations (see also the discussion in Section IV on Ngatpang). It appears that the investors prefer to spend millions in dredging and filling, thereby creating new land, rather than to lease land. It could be that it is worth millions of dollars to have a more secure claim to the property. A second way in which land-ownership could overshadow economic, engineering, and ecological considerations occurs when the land-owner wishes to sell. In this case, political pressure could be used to override other considerations in order to sell or develop the particular choice of property. We should carefully weigh the economic, engineering and ecological advantages of selecting sites which are esthetically pleasing and compatible with development, i.e., locations in which the construction could blend into the environment with a minimum of habitat destruction.

I. Resort/Marina Development Southeast of the Koror-Babelthaup Bridge (Ngesaol)

This area is characterized by an especially productive soft-substratum community between a dense stand of mangroves shoreward and a diverse and unusual coral-reef community seaward along the wall of the Toachel Mid (channel). The shallow soft-bottom community near shore at the Koror-Babelthaup Bridge is the site which sustains the greatest harvest of edible bivalves of all of Belau (Senator Minami Ueki, pers. comm., via Nancy Convard). Crabs, holothurians, and fishes are also gathered here. The coral-reef community along the Toachel Mid is very diverse and contains some unusual species of octocorals.

I.a Mangroves

Mangroves form a band ranging from 250 to 500 m thick along the shoreline. Large schools or "clouds" of very small juvenile fish were observed among the prop-roots. Small carangids ("jacks") and gerrids ("mojarras") frequented the edges of the mangroves. Large Siganus lineatus (lined rabbitfish) were common. The abundance of juvenile fishes indicated that the mangroves are serving as a refuge for some edible fishes during the early stages of growth. Mangroves also function as a buffer to the coral reefs against salinity changes and sedimentation. If the removal of mangroves is being considered, the effects on the recruitment of edible fishes to neighboring coral reefs and

the direct effects on the coral-reef community of increased sedimentation and salinity fluctuations should be assessed.

I.b *Enhalus acoroides* meadow

The major portion of the shallow littoral zone at this site consists of a soft-bottom community dominated by the seagrass *Enhalus acoroides*. This is the habitat most heavily harvested by the Palauans for clams and holothuroids. Siganids (rabbitfish), small snappers and other fishes are commonly taken here. Shells of edible infaunal bivalves were abundant on the soft substratum and the edible *Arca* spp. were commonly attached to solid substrata. Since this area near the south end of the Koror-Babelthaup Bridge is reputed to be the area from which the most clams are harvested by Palauans, the importance of this site as a source of food for the Palauans and the availability of alternative sites with similar potential should be investigated before the habitat is seriously altered.

Holothurians of several species (e.g., *Stichopus variegatus*, *Holothuria atra*, *H. leucospilota*, *H. edulis*, and *Bohadschia marmorata*) were common in the *Enhalus* meadow. The juveniles of *S. variegatus* were more common close to the mangroves, while the the adults were more common toward the channel.

Within the nearly continuous stand of *Enhalus acoroides*, which extended about 250 to 400 m from the mangroves to where the corals became predominant near the channel, there were scattered small clumps of corals and relatively dense stands of *Halimeda macroloba*. Some of the clumps of corals were based on a mound of *Porites* spp. and others were an aggregation of branching corals (mostly *Porites cylindrica*, *Montipora digitata*, and *Acropora* spp.). A few microatolls of *Porites* spp. were scattered about. Faviid corals, especially *Goniastrea* spp., and *Pocillopora damicornis* were also common.

Along a gradient within the seagrass meadow from the mangroves to the Toachel Mid (channel), the seagrass *Halodule uninervis* became more commonly interspersed among the *Enhalus*. Patches of the finger-like coral *Montipora digitata* also became more frequent and extensive, and the solitary coral *Heliofungia actiniformis* became common. Territories of the damselfish *Dischistodus perspicillatus* were prevalent near corals in the seagrass towards the channel end of the gradient. The bivalve *Tridacna crocea*, the benthic jellyfish *Cassiopeia* sp., and the large starfish *Protoreaster nodosus* were conspicuous invertebrates in this area. The more conspicuous algae were *Halimeda macroloba*, *H. opuntia*, *Padina* sp. and *Caulerpa* sp.

The biological complexity of the community in the *Enhalus acoroides* meadow at this site was striking. The plants were frequently being overgrown by animals that were functioning as plants with plant cells in their tissues. Several species of colonial ascidians contained the unicellular plant *Prochloron* (a

prokaryote which contains the photosynthetic pigment chlorophyll a) in their tissues. The Prochloron-ascidian Lissoclinum voeltzkowi was frequently found overgrowing Enhalus acoroides and Halimeda macroloba. Didemnun molle was also found on E. acoroides. Diplosoma virens occasionally coated the pneumatophores of the mangroves. The most common sponge (Dysidea herbacea) in the Enhalus acoroides meadow at this site contained photosynthetic cyanobacteria in its tissue.

I.c Reef-crest pavement

The microatolls of flattened massive Porites colonies also become more prevalent along the gradient between the mangroves and the channel. At the shallowest portion of the littoral zone just before the edge of the channel, the crest of the coral reef consists of a nearly solid pavement of Porites microatolls, with dead coral covered with filamentous algae on the upper horizontal surfaces and with living Porites tissue on the vertical surfaces. The green finger-like alga Neomeris annulata was common in this zone. The small, pink colonial ascidian Didemnum nekozita was abundant.

I.d Coral community

At the edge of the Toachel Mid (channel), extensive patches of the finger-shaped corals Porites cylindrica, Montipora digitata, and Pocillopora damicornis and large mounds of Porites are dominant. The number of species of corals increases greatly after the first couple of meters depth. Pachyseris speciosa, Porites (Synaraea) rus, Montipora trabeculata, M. fragilis, Echinopora sp., Goniopora sp., Millepora spp., Anacropora spinosa, Acropora echinara, and a variety of Acropora spp., faviids, mussids, and fungiids were prevalent.

The coral community on the wall of the Toachel Mid has the characteristics of coral communities in areas protected from strong wave impact, but influenced by strong currents. In particular, crinoids, octocorals, antipatharians, sponges and planktivorous pomacentrid fishes were predominant. The octocorals were extraordinarily diverse, with both gorgonaceans and alcyonaceans represented by a variety of species. One large, fan-shaped, anaxonian gorgonacean had no central supportive axis in its branches. None of us had seen such an animal on Pacific coral reefs, although it resembled Iciligorgia of the Atlantic. Some of the "sea-fans" appeared to be hydroids (cf. Solanderia) rather than gorgonians. This coral-reef community deserves extensive documentation and study, considering the diversity and unusual species found along the Toachel Mid.

In summary, several aspects of the site (Ngesaol) southeast of the Koror-Babeldaob Bridge should be investigated before the habitat is seriously altered. To extent do the Palauans rely on this particular Enhalus acoroides meadow for foods? Are other sites accessible to which the local residents could obtain

bivalves and other resources for local consumption? How would the removal or substantial reduction of the mangroves affect recruitment of fishes to neighboring habitats? How would the reduction of mangroves affect sedimentation and environmental stability (e.g., salinity fluctuations) on the littoral habitats? Are the unusual species in the coral-reef community along the Toachel Mid unique to this site?

II. "New City" Development on the North Coast of Koror Between the T-Dock and the Causeway

A self-contained "New City" has been contemplated for construction on landfill on the reef-flat along the north coast of Koror between T-Dock and the causeway to Arakabesan Island. This reef-flat is an extensive seagrass meadow on fine sediment extending between mangroves along the shore to a coral reef along the seaward margin. This area is presently harvested extensively for seafood by those residents of Koror who do not have boats or vehicles that would allow them access to more distant areas. Several species of holothurians, bivalves, and fishes are harvested from this reef-flat. The bivalves Tridacna crocea and Arca sp. are gleaned from patches of solid substrata. Siganids (rabbitfish) and "sardines", as well as a variety of other small fishes, are collected for food.

In order to create a substratum on which a "new city" could be constructed, motus (emerged land on the reef-flat) will be formed by depositing fill dredged from adjacent areas. This will result in major changes in the habitat. Three matters should be investigated in the planning of this enterprise. First, extensive dredging and filling will alter the entire coastal system in terms of current patterns and sedimentation. The secondary impacts on the community on the north coast of Koror must be accommodated. Second, civil engineering matters such as sewage disposal, freshwater supply, substatum and foundation erosion, etc., must be thoroughly assessed. Third, extensive dredging and filling will probably decrease the supply of seafoods to residents of Koror which do not have boats or vehicles to harvest the resources of other reefs. The economic and social aspects of this change in accessible supply of seafood should be assessed.

Most of the area of the littoral zone between T-Dock and the Causeway to Arakabesan was covered by a meadow of the seagrass Enhalus acoroides. The seagrass Thalassia hemprichii was also common. There were a few microatolls of Porites sp. scattered about. The more common organisms in this meadow included the holothuroids Holothuria atra and H. edulis, the large asteroid Protoreaster nodosus, the ascidians Didemnum molle and Lissoclinum patella, sponges, and the macroalgae Halimeda macroloba, H. opuntia, Caulerpa, and Padina.

An area of largely bare sand came between the seagrass meadow and the coral community, as the seagrass became

increasingly sparse and before the corals became common. Isolated clusters of Porites (Synaraea) rus, Porites cylindrica, Pocillopora damicornis, and large areas of Anacropora spinosa were scattered about. A few microatolls of Porites were also found.

The reef community came in two major parts, a reef crest and forereef slope and then a barrier reef, with a channel in between. The microatolls on the sand flat between the seagrass meadow and the reef became more densely distributed towards the outer edge of the bay, and eventually fused together to form a pavement at the crest of the forereef slope. Three species of Porites, P. cylindrica, P. lutea, and P. (Synaraea) rus, were the predominant species on all parts of the reef: on the reef crest, the forereef slope, and on the lee, the top and the forereef portions of the barrier reef. Although a variety of other species were present, these 3 species were by for the most abundant.

III. Ngeremeduu, Below the Proposed New Airport

Ngeremeduu is the largest estuarine area in Belau, and probably in all of Micronesia. Two of the largest rivers in Micronesia drain into Ngeremeduu. Tabecheding drains into the south end of the estuary and Nkebeduul drains into the north. The east side of Ngeremeduu, above which the new airport has been proposed to be built, is bordered by an extensive stand of mangrove. The proposed airport is designed for two runways, each large enough for Boeing 747s. These runways, in addition to the driveways, roads, parking areas and buildings of the airport, will constitute a large surface area that will not absorb water. The mangroves bordering Ngeremeduu are capable of intercepting and trapping sediments, as well as damping the amplitude of salinity changes. If the plans for the construction of the airport include erosion-control and the construction of ponding basins to trap sediments, if the mangroves bordering the Ngeremeduu are not molested, and if there are no extraordinarily heavy rains, the Ngeremeduu will probably withstand the effects of the construction.

Without erosion-control measures, however, heavy rains could cause a strong pulse of sediment from runoff to reach the coral reefs immediately outside Ngeremeduu. This is because Ngeremeduu is a well-stratified estuary (Table 1). Much of the sediment would be held in the surface water which would flow from the river. The sediment-rich freshwaters would be retained above the seawater while flowing across the estuary, and would then flow as a sediment plume out to the reefs where the freshwater would be mixed and dispersed by wave action and the sediment would be deposited. The mangrove traps the sediments in slow-flowing waters during dry weather or after small storms, but sediments in 4-hour storms would be moved rapidly by the rivers.

The surface area of nonabsorbant cement and asphalt at the

airport will create a large volume of water drainage during heavy rains. Without erosion-control construction, this water will drain into the rivers. The volume of outflow of the rivers and the stratification of the estuarine waters will cause extensive outflow of sediments. Erosion-control must be an integral part of the construction plans for the airport.

Ngeremeduu is a major source of mangrove crabs (Scylla serrata) which are caught in traps by Palauans and sold in the market in Koror. Most of the trapping is done by residents of Ngereklmadel and Ngerebkus.

Fishes are also caught for food in the estuary. It is possible that this habitat is important for the now scarce crocodiles, but they were not seen.

Within Ngeremeduu estuary, juvenile fishes were observed among the prop-roots and rock oysters were seen attached to the prop-roots. Halimeda and Neomeris were the more common macroalgae within the estuary. At the inner end of the channel leading out of the estuary towards the outer coast, large rock oysters dominated the hard substrata. Padina was the most common macroalgae.

Edible rock oysters were the dominant occupant of the hard substrata all along the channel leading out to the reefs from Ngeremeduu. This channel also had the richest plankton (Table 2). Rock oysters are not a favored food of Palauans, but they might be marketable. The plankton-rich channel, through which the nutrient-rich waters pass out of the Ngeremeduu estuary, is a natural situation in which suspeension-feeders such as oysters could be produced and harvested easily by merely providing substrata such as suspended platforms.

IV. Ngatpang, New Fisheries Warf

The main concern at this site is water circulation. First, there must be good water exchange at any fisheries warf. Even if there is no fish-processing facility, there will still be scraps of fish, bait, gasoline and oil from rinsing of the decks of the boats. If any fish-processing takes place, there will be even more need for water exchange.

Second, because of the potential importance of mangroves as nurseries for fishes that migrate to surrounding reef areas, the fisheries warf should be constructed so as to allow exchange between the mangroves and the ocean. The site of the Ngatpang pier can be spotted from a distance because of the dead mangroves along the shore. These mangroves were apparently killed by stagnant "black water" conditions which followed the enclosure of the waters into ponds. Culverts might be placed through the walls of the ponds so as to allow water exchange. If culverts are constructed, they should be large enough so that the bottom of the culverts are at the bottom of the ponds. This is so stagnate anoxic water does not remain at the bottom of the ponds

below the level of the bottom of the culverts.

The reef-flat at the site of the Ngatpang warf is important for the local population as a place to collect seafood. This is a favorite place to collect the small holothuroid called Erumrum in Palauan. Juvenile Stichopus variegatus, juvenile Bohadschia sp., H. nobilis, and Actinopyga sp. (brown with banding) were also common. Juvenile Linckia laevigata are rarely observed on coral reefs, but they were seen here. Three large Acanthaster planci (rrusech) were seen on the rocks at the base of the jetty.

The bivalves Tridacna maxima, T. crocea, and infaunal clams were also common and collected as food. Mangrove crabs were also collected as food from this site.

Fishing at this site is generally for the numerous small fishes. A large school of thousands of clupeids "sardines" were observed on every visit to this site. Schools of small lutjanids (snappers), mullids (goatfishes), caesionids (fusiliers), carangids (jacks), and Siganus argenteus (forktail rabbitfish) were also prevalent.

Patches of freshwater were common over the reef-flat. The benthic community on the reef-flat was dominated by the seagrass Enhalus acoroides. The seagrasses Halodule uninervis and Thalassia hemprichii were also prevalent. Microatolls of Porites sp. were scattered about. Porites cylindrica and Psammocora sp. were also prevalent.

The water was turbid and there was a lot of siltation in the channel into which the warf protruded. The upper reef slope of the reef across the channel from the end of the warf was dominated by Porites cylindrica, P. (Synarea) rus, P. lutea, and Anacropora spinosa along the upper reef slope. Fungiid corals and Tridacna crocea were common. The seagrasses Enhalus acoroides and Thalassia hemprichii were prevalent on most of the reef-flat; Halodule uninervis and Halophila ovalis were common in patches. Patches of the alga Sargassum and patches of the corals Montipora digitata and Acropora were prominant. Porites lutea was also prevalent. Tridacna crocea, Holothuria atra, Linckia laevigata, Cypraea tigris and sponges were the conspicuous macroinvertebrates. The common macroalgae were Padina, Caulerpa, Dictyota and Schizothrix.

On the seaward side of the reef across the channel from the warf, the microatolls of Porites became more abundant and gradually blended into a pavement. At the top of the seaward slope, the predominant corals were Porites cylindrica, P. (Synaraea) rus, P. lutea, and the alcyonacean Sinularia. Tridacna crocea, Hippopus hippopus, and Holothuria nobilis were conspicuous macroinvertebrates.

The coral community on the main section of the seaward reef slope was more diverse than the reef slope in the turbid channel.

The predominant corals were Porites cylindrica, Porites lutea, Porites (Synaraea) rus, Pocillopora damicornis, Pachyseris speciosa, Turbinaria sp., Seriatopora sp., Echinopora lamellosa, Millepora sp., and numerous Acropora spp. Tubastraea micrantha and Distichopora violacea were conspicuous. The antipatharian Cirrhipathes anguina, Junceela sp. and a variety of other gorgonaceans, and Sarcophyton sp. and other alcyonaceans were also common.

Crinoids were common. The bivalves Tridacna maxima, T. squamosa, T. crocea, and Arca sp. were also common. Other conspicuous macroinvertebrates included Panulirus sp., Bohadschia graeffei, Linckia laevigata, and Acanthaster planci.

The point of the reef which forms the end of the channel leading into the warf appeared to support the greatest concentration of fish. Large Lethrinus spp., Plectorhinchus sp., Monotaxis grandoculis, and carangids, and numerous clupeids and caesionids were present within the small area at the point. A green sea turtle was also observed.

It is not obvious why Ngatpang rather than Ngermetengel has been suggested as the site at which the fisheries warf is to be built. It would seem that Ngermetengel is easier access for boats, being directly in from West Pass with a less complex series of reefs through which to navigate. A comparative study should be made of the exchange and circulation of water at each site, since these are of importance to the operation of a fisheries warf. Logistics and access to the fishing warf from land would appear to have a better infrastructure at Ngermetengel than at Ngatpang where the construction of a fisheries warf may have to be accompanied with road construction and improvement. It is possible that aspects of land-tenure may have consideration that overrides matters of economics, engineering, navigation, ecology, accessibility or convenience to the user.

V. Ngermetengel

Although the area was silty and the water was turbid at this site, the biological community was rich and productive. A school of thousands of relatively large clupeids was encountered at the edge of the mangroves. Halimeda macroloba was prevalent between the mangroves and the seagrass. Enhalus acoroides was the predominant species on the reef-flat. Patches of Halimeda macroloba, H. opuntia, and Padina, and colonies of Porites cylindrica, Porites lobata, Pavona frondifera, Pocillopora damicornis, Acropora spp., and Goniastrea sp. and other faviids were scattered about in the Enhalus meadow. The more massive colonies of Porites were occupied by the bivalve Pedum spondyloideum.

At the outer edge of the reef-flat, corals became more abundant and replaced the seagrass. The coral community was dominated by Porites cylindrica, Millepora dichotoma, Anacropora

spinosa and Turbinaria sp. Mounds of massive Porites sp. were also common. The coral cover was essential complete.

A number of the colonies of Porites (Synaraea) rus were heavily infested with hundreds of small brown flatworms.

VI. Ngaraard, New Commercial Port

This is the site from which more Tridacna crocea and T. maxima are collected than anywhere else for market. Mangrove crabs (Scylla serrata) and rabbitfish (siganids) are collected. There is also a lot of general fishing. Infaunal clams are also collected here.

This area is very silty out to at least 300 m from the pier. The area was dredged around 1979 according to Sebastian Shiro. The Toach ra Klebeang (canal from Klebeang?) emptying into this area might be suggested as the source of siltation, but the coral community appears to have been affected by siltation only during the past few years, perhaps by the side-effects of dredging. The evidence of a recent change in environmental conditions in the coral community is that the corals are mostly large; there is little recruitment. Sediment is especially detrimental to tiny recently metamorphosed corals. The abundance of large corals indicates that there was most probably better recruitment in the past. Furthermore, although the skeletons of the colonies are large, the percent of each of the colonies that are alive appears to be smaller than is typical of other localities. The cover of the substratum by large coral skeletons indicates that the coral community was in better condition in the past. It should be determined whether the annual catch of clams, crabs, and fishes has declined since the dredging.

An unusual aspect of this area is the sparcity, nearly complete absence, of seagrasses. Perhaps this is because of sedimentation?

VII. Melekeok, New Capital

The marine communities directly off the town of Melekeok appeared to be in excellent health. We were particularly interested in examining this area because there were no mangroves along the shore and the town had been there for many years. We wished to observe how a community under these conditions differed from those in more usual situations.

People were out gleaning the reef community while we were there. Mangrove crabs (Scylla serrata), the bivalves Hippopus hippopus, Tridacna maxima, T. squamosa, the urchin (Tripneustes gratilla) and all kinds of fishes are collected there.

The major difference between the reef-flat community off the town of Melekeok (no mangroves along the shore) and most other communities on the fringing reef-flats on the coasts of

Babelthaup is the larger grain size of the substratum. Under both conditions, the reef-flat community appears to be influenced as much by substratum grain-size as by mangroves.

VIII. Melekeok, Fisheries Warf

There was a distinct zone of silt that extended out about 25 m onto the reef-flat seaward of the dredged area. A siltation screen would be effective if placed between the dredged area and the rest of the reef community. Within the dredged area, in very turbid water, schools of recently metamorphosed juvenile fishes, a school of large Monodactylus argenteus, and a large swimming blue crab Portunus pelagicus were seen.

Beyond the zone of siltation, the benthic community was characterized by a meadow composed of a variety of seagrasses: Enhalus acoroides, Thalassia hemprichii, Halodule uninervis, Syringodium and Halophila ovalis. Halimeda macroloba, H. opuntia, and Caulerpa were the most conspicuous macroalgae. The productivity was so great that excess oygen was being given off as bubbles throughout the seagrass meadow.

The colonial ascidians, Lissoclinum voetzkowi and L. patella, with symbiotic plant cells (Prochloron sp.), were abundant on the reef-flat, overgrowing the seagrass and macroalgae. Sponges were also prevalent.

Juvenile Linckia laevigata were found. In combination with observations of juveniles at other sites, this indicates that there had been an unusally strong recruitment of this asteroid species on all sides of Babelthaup about a year ago.

Stichopus variegatus, Holothuria atra, and H. leucospilota were common.

IX. Ngchesar, Dredge Site for Road Material on Southeast Babelthaup

Little care was being taken to reduce the effects of the dredging operation at this site. No sediment screen or siltation curtain was being used. A gasoline slick of about 2000 m^2 (about 30 X 70 m), from a leaking drum laying on its side near heavy equipment on shore, coated the nearshore water. Moses Ramarui, Project Director, Ngchesar State Government, commented that it is of little practical use to suggest that a sediment screen or siltation curtain be installed unless we also suggest where to find the funds to obtain the necessary equipment and materials. The dredging project has the budget and technical skills to operate the heavy equipment, but neither funds nor technical skills for constructing sediment screens were provided. Effective siltation curtains can be constructed out of palm fronds, but they periodically need to be refurbished.

A spotted eagle ray (Aetobatis narinari) was seen at the

dredge site. According to Sebastian Shiro, eagle rays often gather around new dredge sites.

The zonation of the marine communities on the reef-flat at Ngchesar was typical of the habitat. A meadow of Enhalus acoroides dominated the reef-flat from shore to about 250 m offshore where the microatolls of Porites become do abundant that they fuse into a pavement near the reef crest. The top of the reef slope is dominated by the stony corals Porites cylindrica, P. (Synaraea) rus, and P. lutea, and by the alcyonaeans Sinularia spp. and Sarcophyton spp.

There appeared to be an extraordinary number of juvenile fishes on the forereef slope and juvenile Linckia laevigata on the reef-flat. It would be interesting to investigate whether the current patterns or reef topography might facilitate larval recruitment.

Colonies of Pocillopora damicornis, Porites cylindrica and Porites lutea were scattered among the Enhalus. Microatolls of Porites lutea were scattered throughout the Enhalus meadow, becoming more frequent along a gradient on the reef-flat from shore to the ocean. Dense patches of Halimeda macroloba, H. opuntia, and Sinularia sp. were found in the Enhalus meadow. Dense populations of the ascidian Lissoclinum voeltzkowi were overgrowing Enhalus in patches. Conspicuous macroinvertebrates included Stichopus variegatus, Holothuria nobilis, H. atra, H. leucospilota, Bohadschia marmorata, Linckia laevigata, Lambis sp., and sponges. Padina was common.

On the pavement formed by fused microatolls of Porites lutea at the reef crest, the common corals included Pocillopora damicornis, P. verrucosa, Goniastrea sp., Psammocora sp., and Fungia sp. The alcyonacean Sinularia was also prevalent. The most abundant algae were Halimeda opuntia and H. incrassata.

The forereef slope coral-reef community was characteristic of coral communities not subjected to strong currents, i.e., there were few crinoids and few gorgonaceans, but sponges were prevalent. Acropora echinata, Merulina sp., Pavona clavus, and Millepora sp. were common corals. The holothuroids Holothuria atra and Bohadschia argus, and the bivalves Tridacna crocea and Pedum spondyloideum were prevalent.

X. Ngiwal, Causeway

The causeway built in the 1930s has broken in several places, allowing some exchange of water between the enclosed bay and the outside. If a new causeway is constructed to allow vehicles to pass across the bay, large culverts should be included in the design to allow water exchange. The bay inside the causeway is dominated by the seagrass Enhalus acoroides. Crocodiles and dugongs, both endangered species, are alleged to occur in this bay, although we did not find any in our brief

visit. The presence of these species should be assessed and taken into consideration when designing development plans.

Outside the causeway, the reef-flat is dominated by the seagrass Enhalus acoroides, the cyanobacteria Schizothrix sp., the holothuroid Holothuria atra, and mounds of sand constructed by the crustacean Callianassa sp. Juvenile H. atra were common, as were juvenile fishes. Mounds of Porites sp. became prevalent towards the seaward edge of the reef crest. Right at the reef crest, the coral community was characterized as being subjected to a lot of sand-scour.

Although the seagrass Enhalus acoroides was predominant, representatives of at least 5 other genera of seagrasses were also found mixed together within the Enhalus acoroides: Thalassia hemprichii, Cymodocea rotundata, Halodule uninervis, Syringodium isoetifolium, and Halophila ovalis. Representatives of all 6 genera of seagrasses were all abundant in close proximity with each other.

XI. Ollei

This area is on the northwest tip of Babelthaup, and is identified by a large cement structure (a remnant of a former pier) on the outer edge of the reef-flat. The shore at this location is a rocky coast without mangroves. Silt extends about 100 m out from the shoreline. The marine communities on the reef-flat are generally similar to those along Babelthaup where mangroves line the shore. This area is generally fished by the local people for a variety of small reef fishes such as small snappers.

XII. Oil Refinery Dock, Ngchemiangel

The substratum in this area is very silty, consisting of a black, fluid mud. No fishes were observed among the roots of the mangrove trees. Blue crab (Portunus pelagicus), mangrove crab (Scylla serrata), holothuroids, oysters and sardines are taken here by local people.

Two surveys were made, one about 100 m east of the oil refinery dock, the other about 100 m west. The seagrass Enhalus acoroides was predominant along both transects. Scattered colonies of the corals Porites sp. and Goniastrea sp. and patches of the algae Sargassum sp. and Padina sp. were also common along both transects. Microatolls of Porites sp. and patches of Porites cylindrica occurred offshore (depth 2-3 m) along both transects. On the eastern (landward) transect, mounds formed by the crustacean Callianassa were abundant in the sand, sponges coated occasional rocks, and patches of Halimeda macroloba were conspicuous.

On the western (seaward) transect, the water was more clear and the biota was more diverse. Patches of the coral Montipora digitata were predominant, and Porites cylindrica, Porites lutea, Goniastrea sp., Fungia sp., and Montipora sp. were all common. The alcyonacean Sinularia sp. was predominant. Sponges encrusted exposed rocks, the pink colonial ascidian Didemnum nekozita was common on the microatolls, and the Procloron-associated ascidian Lissoclinum voeltzkowi commonly encrusted seagrass and algae. The common macroalgae were Sargassum, Turbinaria, Neomeris, Caulerpa, and Padina. The conspicuous macroinvertebrates were Holothuria atra and Culcita novaeguineae.

XIII. Imul, Jetty South of the Oil Refinery

This area is allegedly being dredged for road fill. This seems strange since the substratum appears to be a clay-like material. The marine community is relatively dull, with mostly bare clay-mud substratum close to shore, grading into a fine sandy substratum offshore. The local people use this area for collecting blue crab (Portunus pelagicus) and for general fishing.

Two surveys were made, one about 100 m east of the jetty and the other 100 m west. All along the eastern (landward) transect, the seagrass Enhalus acoroides was the predominant organism. Inshore were occasional patches of Halimeda macroloba. Enhalus acoroides was often covered densely with the colonial ascidian Lissoclinum voeltzkowi. Rock oysters and sponges covered isolated rocks protruding from the silty substrata. Leafy sponges containing cyanobacteria were also common. Further out from shore were a few colonies of Goniastrea sp. and microatolls of Porites sp. Most of the clay-mud substratum inshore and the sandy substratum offshore was bare, despite the occasional occurrence of the biota mentioned.

The western (seaward) transect had even more bare substrata and fewer biota than did the eastern transect. Enhalus acoroides was still the most common organism throughout. Inshore, the seagrass Thalassia hemprichii, then the seagrass Halodule uninervis, finally offshore microatolls and mounds of Porites sp. were, respectively, the second most common species. No other species were common.

XIV. West Bay of Arakabesan, Pacific Resort

The University of Guam Marine Laboratory conducted a quantitative survey of this site in November 1977, before the Pacific Resort was built. A brief reconnaissance 12 years later did not indicate any substantial changes in the coral-reef community. It would be most informative to undertake a quantitative assessment of the changes that have occurred over the past 12 years.

XV. South Tip of Malakal, Sewer Outfall

The reef at the southern tip of Malakal Island was quantitatively surveyed in January 1976, before the sewer outfall was constructed. At that time, the coral community observed by snorkeling around the southern tip of the reef included at least 163 species. This is about 2½ times the species list for hermatypic corals in the entire Atlantic Ocean. The octocorals were also found to be extraordinarily diverse at this site.

Nearly fourteen years later, and after the sewer outfall has been operating for more than a decade, the coral community appears unchanged, except for a band about 5 m to either side of the sewer pipe. Bordering the sewer pipe, the substratum had been excavated and so there is a band of rubble rather than solid pavement. The rubble is invaded mainly by relatively small colonies of Porites. The largest colonies were about 16 cm in diameter. The corals within 5 m of the sewer pipe appear healthy, but young. It may be difficult for corals to become established on rubble which is periodically rolled around by heavy wave action. It may be taking a while for the corals to survive long enough to grow to a size at which the can begin to reconsolidate the substratum.

On the solid substrata more than 5 m from the pipe, the coral-reef community appears very similar to what it looked like in 1976 before the sewer outfall was constructed. The predominant corals on the upper reef slope were Porites cylindrica (called P. andrewsi in 1976), Porites lutea, and Porites (Synaraea) rus (called P.[S.] iwayamaensis in 1976) as in 1976. Alcyonaceans, e.g., Sinularia sp. were also prevalent as in 1976.

In deeper waters, the octocorals were extraordinarily diverse and abundant. Large patches of ellisellids, plexaurids, gorgonacean sea fans, Sinularia and Junceela were still present near the outfall. Several large, arborescent Tubastraea micrantha seemed to be the same individual colonies as remembered from 1976. Heliofungia actiniformis was common.

Some colonies of Porites were infested by dense populations of small brown flatworms. This was also observed at several locations around Babelthaup and so there is no reason to conclude the infestation is related to the sewer outfall.

Of course the above observations are subjective impressions. It would be most informative to devote about a week to repeating a quantitative survey of the southern tip of Malakal to determine if there have been any substantial changes in the community beyond 5 m from the pipe. However, even if significant changes in the coral-reef community were documented, it would be difficult to attribute them to the effects of the sewage outflow. They may be a result of natural variability of the reef community with time. Nevertheless, it would be most interesting to analyze

the changes that have occurred in the coral-reef community over the past 14 years. There are few places on Pacific coral reefs, and none other in Palau, at which baseline data are available to allow such a quantitative assessment of changes in the reef community over a 14-year period.

Fig. 1 Location of the study sites.

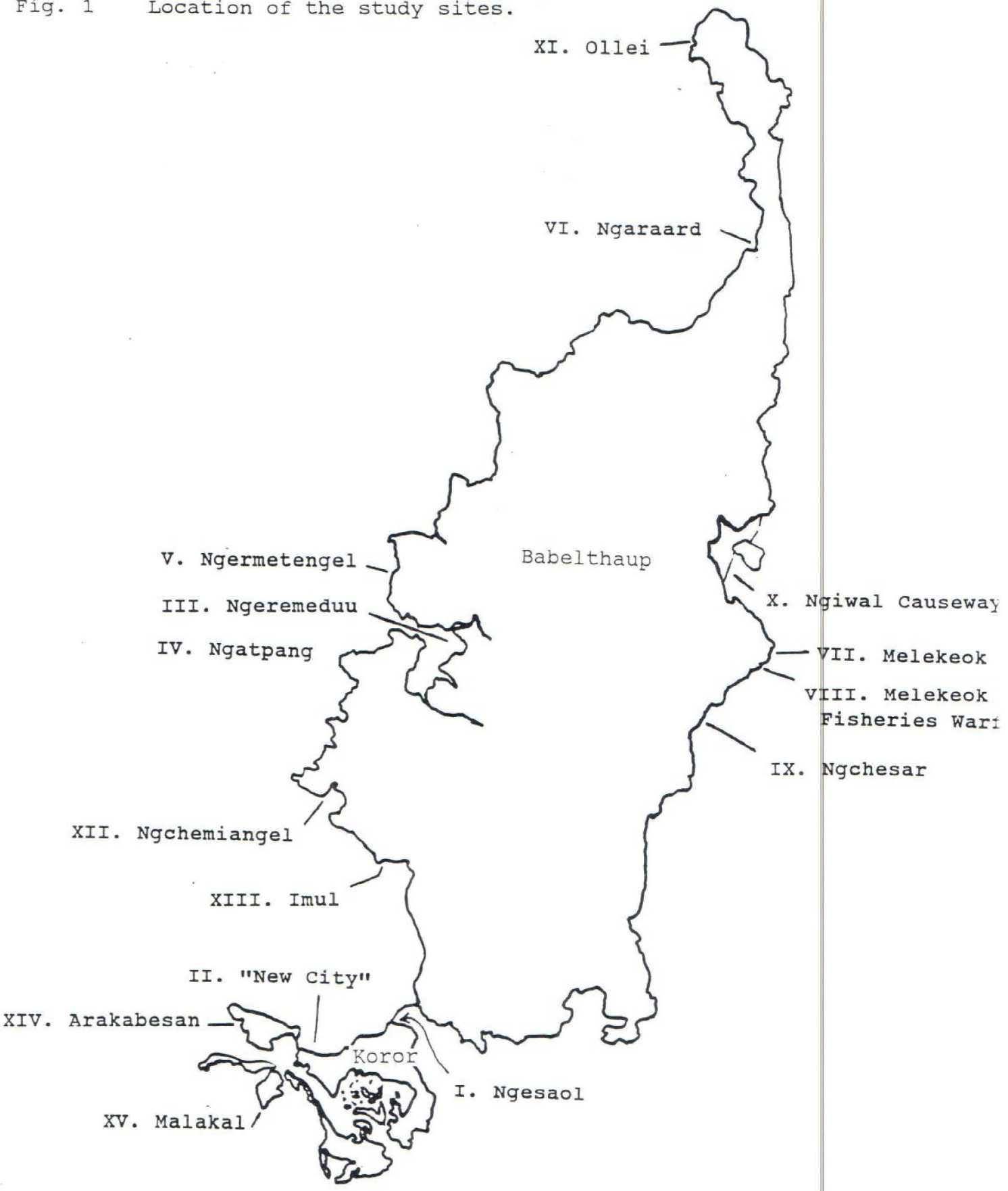

Fig. 2 Location of the sites of the water samples (Table 1) and plankton tows (Table 2) in Ngeremeduu estuary, Babelthaup, and on the reefs outside.

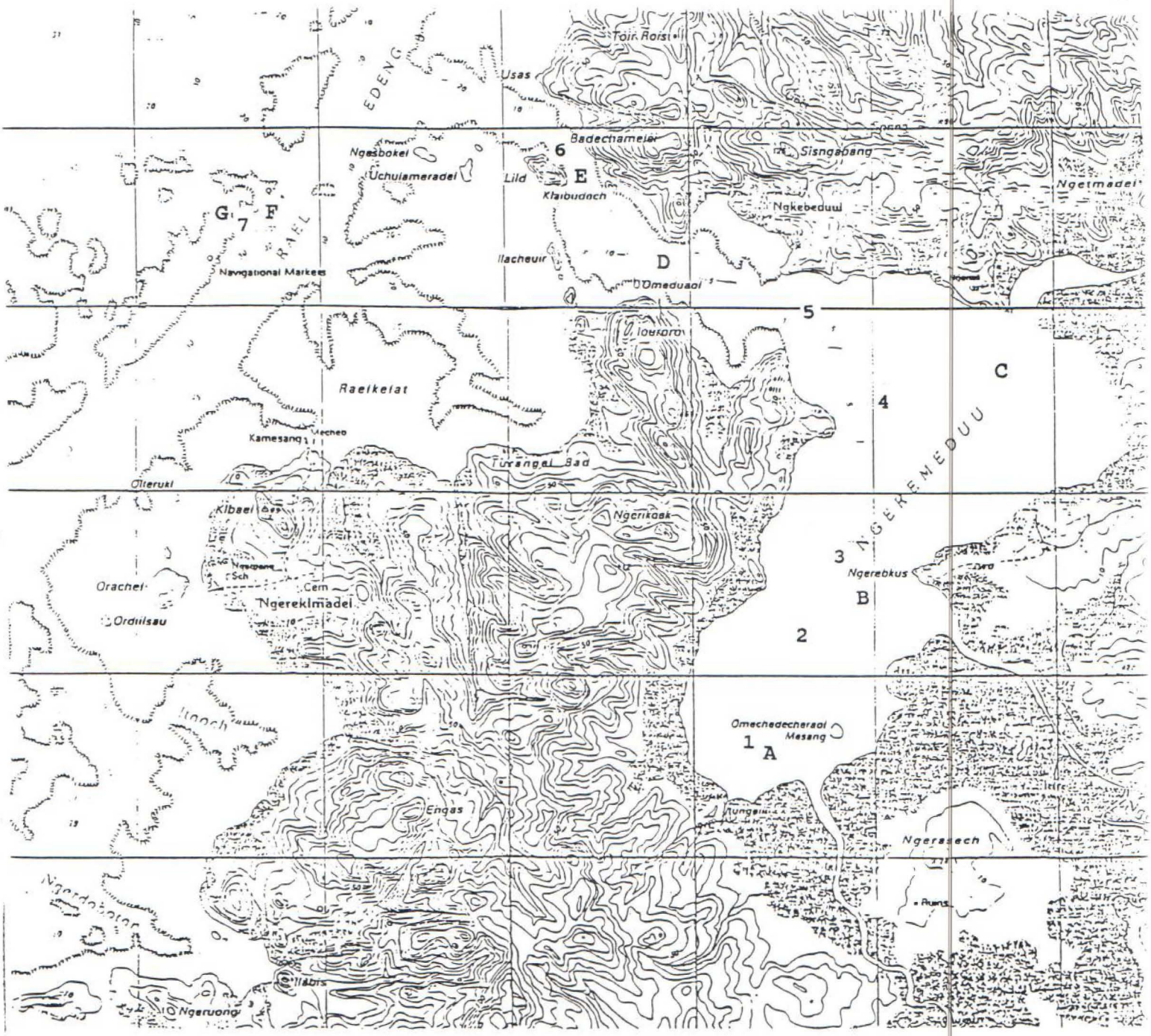

Table 1. Salinity measurements in Ngeremeduu estuary, 15 August 1989, water temperature was 25°C. The sites are indicated by number on the map of Ngeremeduu.

Location	Depth	Salinity (%.)
1	surface	30
	0.7 m	30
2	surface	31
	1.2 m	34.5
3	surface	31.2
	3 m	32.8
4	surface	30.0
	3 m	32.6
5	surface	31.2
	3 m	32.2
6	surface	32.8
	3 m	33.4
7	surface	34.8
	3 m	34.6

Table 2. Prevalent components of the zooplankton within Ngeremeduu, in the channel leading out, and near coral reefs along the coast outside Ngeremeduu. Locations of stations are indicated alphabetically on the map of Ngeremeduu. The predominant (+++) and common (++) components are indicated by plus signs.

Site	Habitat		Prevalent zooplankton
A, B, C	Estuary	+++	(organic detritus, small particles of wood, filaments of algae and seagrass were predominant)
		++	fish eggs
			larval fish
		++	crustacean larvae
			zoea
			megalops (some quite large)
			nauplii
		++	copepods
			euphausiid
			shrimp larvae
			polychaete larvae
			bivalve larvae
			chaetognath
			hydromedusae
			anthomedusae
			sea mites
D, E	Channel	+++	fish eggs
		+++	larval fish (generally further developed than in A, B, and C)
		+++	crustacean larvae
		+++	zoea
			megalops
		++	nauplii
		+++	copepods (calanoid)
			mysids
			shrimp larvae
			amphipods
			chaetognaths
			hydromedusae
			anthomedusae
			(acroporid?) coral planula
F, G	Patch reefs		(small particles of plant material were common, but not as abundant as A, B, and C)
		++	fish eggs
		++	parrotfish (scarid) eggs
			larval fish
			crustacean larvae
			zoea
			nauplii
			shrimp larvae

amphipod
veliger
late trochophore (Trochus)
anthomedusa
Cassiopeia