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Old and New Observations on Coastal Changes of Jakarta Bay: An Example of Trends in Urban Stress on Coastal Environments

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ABSTRACT

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Since the author surveyed the coastal environment of Jakarta Bay in the 1950s, rapid urbanization has affected both the alluvial plain that borders the bay and the coral reefs in it. The urban stress factors are diverse and include baywater pollution, the use of beach sand and coral debris for construction, the implementation of major engineering works (harbour extension, storage lake), intensified fishing and tourism and, within the Jakarta connurbation, groundwater extraction resulting in land subsidence of as much as 4–5 cm/year. Natural stress factors also have occurred and relate to an anomalous behavior of the InterTropical Convergence Zone (ITCZ), resulting in very low precipitation and relatively strong northerly and easterly winds during the 1960s and 1970s. The coastal environment was unable to absorb the combined stress factors and substantial change and deterioration thus resulted. The causative factors are weighed and an outlook for the future is given.

ADDITIONAL INDEX WORDS: *Coastal development, groundwater withdrawal, land subsidize, erosion, Intertropical Convergence Zone, water pollution.*

INTRODUCTION

The alluvial plain bordering Jakarta Bay started to grow seaward approximately 5,000 years ago at the foot of the Pleistocene fluviovolcanic Bogor fan. Fluvial deposition, repeated changes in position of river courses, delta formation, and intermittent build-up of cheniers along parts of the coastline occurred simultaneously with a 5-m sealevel drop.

The present location of the bay can be partly explained from the radial (divergent) drainage pattern on the fan that favoured fluvial deposition to the west and east at the expense of the sedimentation directly north of it. This is where present-day Jakarta is situated. Much more important in this context, however, is the presence of an almost northward stretching structural ridge in the west where Miocene rocks outcrop or occur at shallow depth under the Holocene deposits of the Cisadane River. The eastern shore of the bay is formed by the large delta of the Citarum River (Figure 1) which is quite unaffected by the fan.

Coastal accretion and abrasion since the turn of the century was studied by the author in the early 1950s, using aerial photographs and old and new topographic maps (VERSTAPPEN, 1953). In this context, the turbidity conditions of the baywater were also recorded using a Secchi's disc during the dry (NE), wet (SW) and transitional monsoon periods. The coral cays in the bay were also subject of study. Their changes with time were studied using 1:20,000 topographic maps dating from 1874/1901, 1:5,000 maps from 1927 prepared by UMBGROVE (1928) and maps at the same scale prepared under supervision of the author in 1950/51. The changes in the coral cays can be accounted for by recorded climatic fluctuations. Fluctuations in the average seasonal position of the InterTropical Convergence Zone (ITCZ) result in changing relative intensities of the dry and wet monsoons which in turn result in precipitation fluctuations and in frequency and force changes of the winds from the eight main

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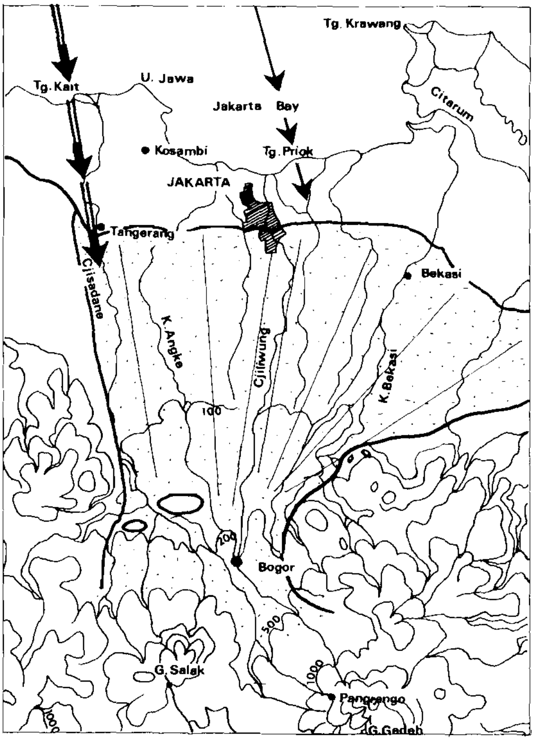

Figure 1. Jakarta Bay and surroundings; scale 1:1,000,000.

directions. The changing wind regime is important in explaining the changes of the coral cays since they govern the wave and current patterns around them (VERSTAPPEN, 1954).

The research undertaken in the early 1980s aimed at assessing how the environment has responded to the heavy stress of rapid urbanization and industrialization during the last three decades, when the population increased from approximately 1 million to 6 million. This urbanization has resulted in excavation of building materials (mainly beach sand and coral debris), pollution of the baywater, land subsidence caused by groundwater extraction, etc. The human factors were unprecedented, but the climatic factors were rather extreme as well. The period includes the years of the ill-famed Sahelian drought which, in the humid tropical realm, are also characterized by a climatic fluctuation of rather unusual amplitude.

The data on which this study was based consist of meteorological data, 1982 false colour aerial photographs of the coastal zone and a cluster of coral cays in the western side of the bay, black-&-white aerial photographs of some of the islands, selected field observations of the alluvial plain and terrestrial mapping of a number of coral cays in 1983/1985. The results are given below.

THE URBAN STRESS FACTORS

The urban stress factors are diverse. At least eight major and minor factors can be listed and grouped under three headings.

Generalized Factors Affecting Large Parts of the Bay or the Hinterland

Water pollution in the bay is attributed to the growing Jakarta connurbation and the shipping activities associated with its harbour Tanjung Priok. This has been seriously studied by the National Oceanographic Institute (L.O.N.) using measurements carried out by the author in the early 1950s as representing the "clean, pre-pollution" situation (A. SOEGIARTO, 1975, 1976; BIRD and ONGKOSONGO, 1980). The biotope distribution in the bay has been studied by HEHUWAT (1977). The increasing pollution of the baywater, especially near Jakarta and Tg. Priok, has a strong negative effect on coral growth and thus on the evolution of the bay's coral reefs and cays. Pollution is in part related to oil spilled by ships and in part to urban waste. The recent coral debris ridges around the cays show a high proportion of floating plastics.

Land subsidence is caused by the extraction of groundwater. The rapid growth of the Jakarta connurbation has resulted in a sharp rise in both domestic and industrial water requirements. Most of this water is derived from the four major aquifers of the Jakarta artesian basin. They occur at less than 60 m, 6–150 m, 150–225 m and more than 225 m depth respectively, and plunge northward (SOEKARDI & HADIWIDJOJO, 1979). The pumping of large quantities of groundwater has resulted in land subsidence, the magnitude and spatial distribution of which is still largely unknown. An indication of the importance of this phenomenon is the 50 cm subsidence of the ground surrounding the Sarinah Department Store in Jalan Thamrin during a 12-year period, or approximately 4 cm/yr. Study of the spatial dis-

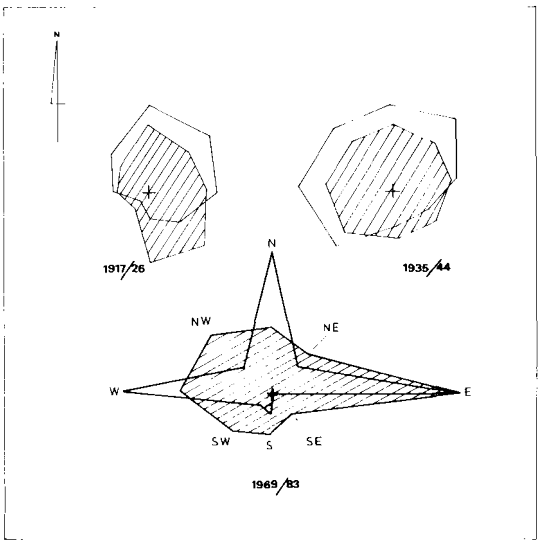

Figure 2. Fluctuations in annual precipitation (dashed line) and number of rainy days (full line) in Jakarta since about 1880 (11-years running averages).

tribution is hampered by the absence of repeated precise levelling. Observations can be made only at buildings with deep pile foundations and at artesian wells that gradually "rise" above the sinking ground. Houses without deep foundations subside at the same rates as the ground surface and become more susceptible to inundation, without visible traces of the amount of subsidence. Since especially the northern part of Jakarta that borders the bay is only a few metres above mean sea level, it is obvious that abrasion of the coast and invasion by the sea are realistic dangers. The extracted groundwater is, at least in the northern parts of the town, in part replaced by saline water and the subsidence is thus reduced to some extent. There are now regulations that reduce the extraction of groundwater to the deeper aquifers or prohibit it altogether, to avoid further salinization of the aquifers. The subsidence-salinization dilemma is of great concern to the responsible authorities.

Engineering Works Affecting Certain Areas

Three groups of activities have to be considered in this context:

(1) The excavation of sand for construction from beaches and nearby beach ridges bordering the bay. Excavation is concentrated in the Cilincing area to the east of Tg. Priok. Strong abrasion, first mentioned by PARDJAMAN (1977), and saline water intrusion have taken place and will be discussed below. Excavation of beach sand may also have contributed to the coastal abrasion of the coast at the NW of the bay.

Sand is also excavated from inland beach ridges, but this has only limited direct adverse effects. These ridges are of the chenier type and form shallow sandy lenses in the otherwise clayey material of the plain. Excavation thus does not affect the salinization of aquifers. Only the shallow groundwater in the cheniers will disappear, but the small quantities of water concerned, though important in a rural context, would hardly be of importance in a densely populated, urbanized area. The excavated areas become more susceptible to flooding.

(2) The excavation of coral sand and shingle for construction from the reefs and cays. Mining of coral boulders and the extrication of the shingle accumulated in ridges at the windward side of the reefs obviously have an adverse impact on the islands. Mining the boulders destroys the living reef. Lowering the reef flat, by mining the coral, results in increased wave activity and consequently in abrasion of the islands. Where the shingle ridges have disappeared, the waves are dissipated on the primary shores of the cays. The excavation of coral sand from the cays adds to the abrasion, even if the mined material comes from accumulations on the relatively protected leeward side of the coral cays. If the climatic conditions were constant, which obviously they are not, this sand would have reached its ultimate position and could not contribute anymore to the defense of the cay against abrasion. Since the windward side of the cays changes with the climatic fluctuations, however, this sand in fact is the very material that could contribute to the (partial) reconstruction of the island once the dominant wind direction changes.

The construction of the Jatiluhur reservoir lake in the Citarum River results in less sediment transport downstream. This may reduce the seaward growth at the outfalls which are

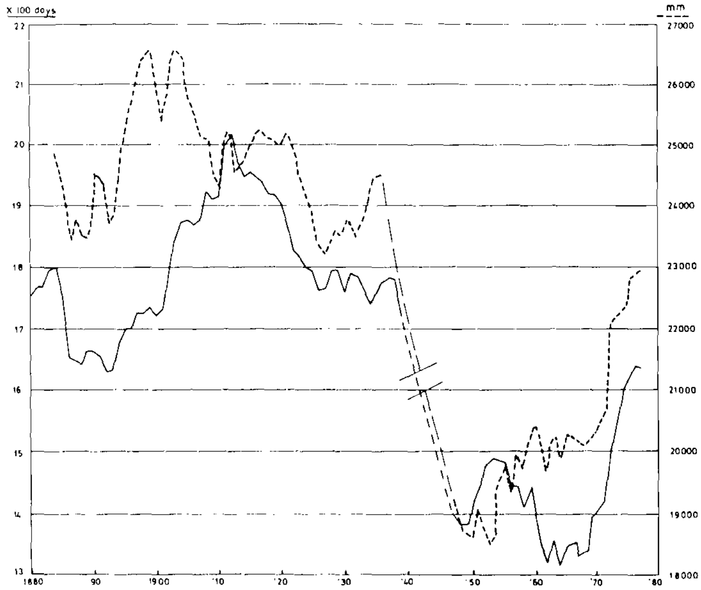

Figure 3. Wind force times frequency (FxV) in Jakarta 1969/1983 (3-years running averages). Average monthly winds are indicated by full line and monthly maxima by hachures. The wind roses for 1917/1926 and 1935/1944, based on daily observations, are added for comparison.

located to the east of the bay. It will, however, hardly affect the transport of material along the coast of the bay by beach drifting: the river carries mainly material in suspension, most of which is deposited in the NE part of the bay in the form of clayey bottom sets. The baywater near the delta will receive less suspended material from the Citarum in the future. It is rather too early for a definite assessment of the new situation because the material inevitably added to the sediment load of the river during the construction of the dam may for some years still affect its downstream course.

(3) The harbour extension of Tg. Priok implemented in the 1960s. The most important aspect in the present context is that a new pier has been constructed perpendicular to the coast, east of an existing pier. Wave energy, guided and accelerated by this structure, may result in more abrasion immediately to the east, in much the same way as previously occurred to the east of the old pier near the former yacht club. The effect seems to be rather limited, however, and much more abrasion occurs farther to the east because of the excavation of beach sands. One should realize, however, that very little material is accreting on the bay shores and that even minor impediments to longshore movement of sediment may adversely effect the existing equilibrium.

Other (Minor) Factors

(1) The introduction of new fishing methods. In recent years, many bamboo fishing rakes, the so-called "Bagang", have been erected on the reef flats and in the adjacent parts of the bay. Large numbers of bamboo poles and coconut palm stems are present on the shores of many cays. Dragging them across the reef flats results in the destruction of the reefs. Since many Bagang are situated on parts of the reef flat previously occupied by a sand cay, they cannot be considered as a main factor of the destruction of the reefs. They do interfere with new coral growth, however, and thus increase the force of the wave attack on the sand cays.

(2) Tourism on the reefs and cays. The proximity of a large urban population has triggered the development of tourism on some of the coral cays. Although most tourists do little harm, their large numbers can easily lead to a decline of the vegetation, not to mention the adverse impact caused by shell collectors, etc.

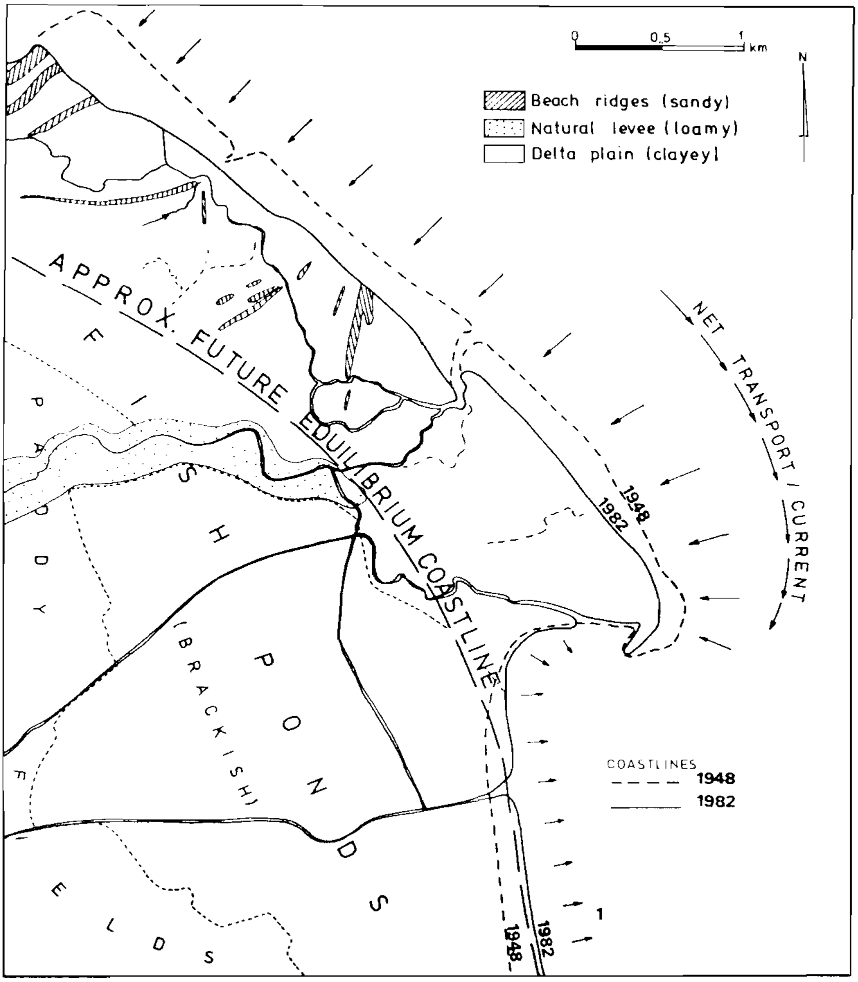

Figure 4. Strongly increased rate of abrasion at the NW side of Jakarta Bay. Sources: aerial photographs of 1948 and 1982.

The Natural Factors

In contrast to the various urban stress factors, the natural factors relate to a single cause: a climatic fluctuation resulting in strong wave energy from the north and east.

The area studied is situated in the SE Asian monsoonal area where the seasonal latitudinal shifts of the ITCZ create a wet season (or west monsoon), with dominance of (south-) westerly winds, and a dry season (or east monsoon) with dominant (north-) easterly winds. These two seasons occur approximately in the months October-March and April-September respectively, and are separated by relatively short transition periods.

Notable variations in the seasonal displacement of the ITCZ have been observed in Indonesia over the years (SCHMIDT & SCHMIDT-TEN HOOPEN, 1951). They are related mainly to the development of the anticyclonal area over (central) Asia which, if of unusual strength, moves the ITCZ farther southward than usual. Since most of the rains are associated with the ITCZ, such anomalies result in marked fluctuations in annual precipitation. Important differences in the wind regime are also associated with these fluctuations of the ITCZ. This phenomenon has been investigated by VERSTAPPEN (1953, 1954), who studied the relationships between wind frequency, velocity and direction, and the development of the lowland

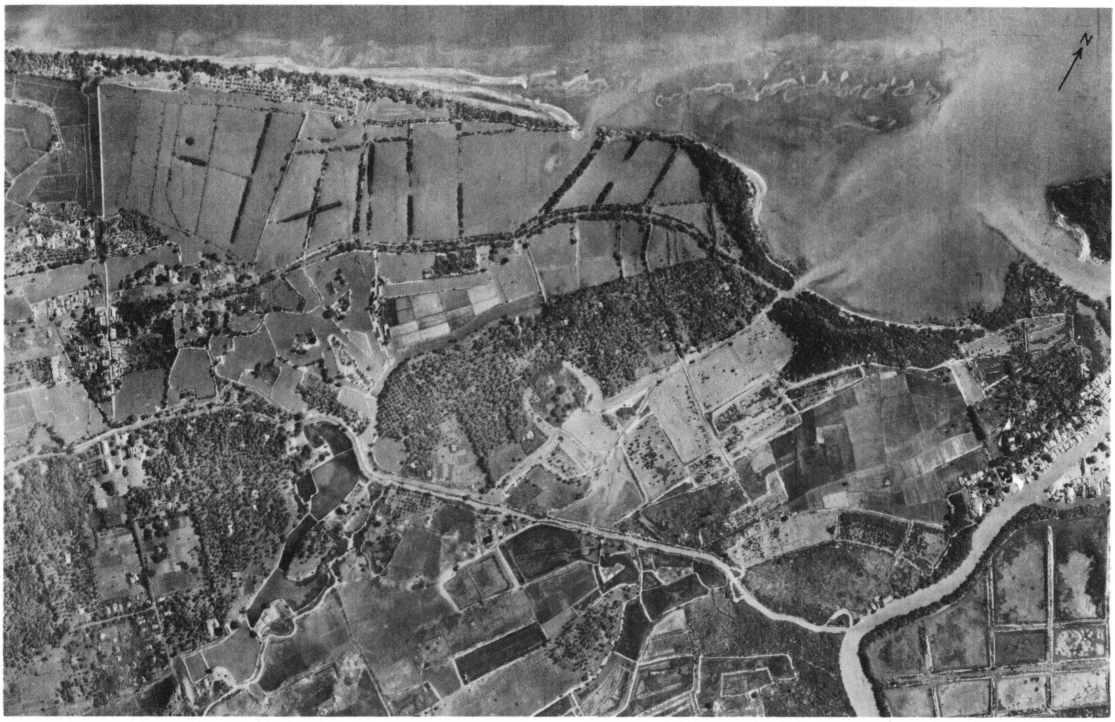

Figure 5. Vertical aerial photograph, scale 1:12,500, of the Cilincing area, east of Tg. Priok picturing the situation of 1948. Compare with Figure 7.

coast, including coral cays, bordering on the Jakarta Bay.

Running 11-year averages were collected of annual rainfall and rainy-day frequency, calculated over the period 1944–1983. The results were combined with the earlier data of SCHMIDT & SCHMIDT-TEN HOOPEN. The graph of Figure 2 shows the fluctuations that have occurred since 1880. It is obvious that the rainfall since 1945, and especially in the 1960's and 1970's, reached an all-time low. This points to a strongly developed east monsoon and a weak west monsoon. The precipitation rose substantially again during the early 1980s.

In this connection, data on the frequency of the eight main wind directions and wind velocity at the Jakarta observatory were collected. The product of frequency (F) and velocity (V), considered as a measure of the total effect of wind and waves, is presented in Figure 3 for the period 1969–1984. The wind data for the years 1917–1926 and 1935–1944 are added for comparison (source: VERSTAPPEN, 1953). The 1969–1984 data relate to the frequency of the monthly data on average (thick line) and maximum (hachures) wind velocity, whereas the older data are based on the daily wind observations and thus are more detailed. Notwithstanding this inconsistency, it is obvious that the wind regime in the latter period deviates substantially from that prevailing in the two preceding periods. The strong dominance of the east monsoon in the 1970s, as compared to the two earlier periods, is reflected in the strong and frequent easterly winds and the high frequency of the average north and east winds. The weakness of the west monsoon is illustrated by the near-absence of winds from southerly directions.

Strong wind and wave attacks on the coasts exposed to north and east winds and on the north and east sides of the coral cays, with accretion (sand accumulation) along the south shores, seems a plausible consequence of this anomalous wind regime of the period 1960–1980. This climatic fluctuation is a natural fac-

Figure 6. The same area as pictured in Figure 7 as it was in 1982, scale 1:12,500 (enlarged from a 1:30,000 aerial photograph). The 1948 coastline is added for comparison. Note the strong abrasion (up to 750 m) and the urbanization.

tor of environmental change which is superimposed on the environmental deterioration caused by urbanization stress during this period. It would be interesting to explore how the rainfall deficiency that occurred in this equatorial area correlates with the Sahelian drought that occurred during approximately the same period. A correlation would not be surprising, notwithstanding the great distance between these two areas, since fluctuations of the ITCZ affect both areas. It appears that the ITCZ occupied a position more southerly than usual in this period, as a result of which Jakarta Bay stayed largely at the northern "dry" side of it.

Effects of the Environmental Stress Factors on the Shores of the Bay

Accretion along the eastern shores of the bay, and particularly at the Bekasi and Citarum outfalls, has been claimed by PARDJAMAN (1977) on the basis of a comparison of nautical charts dating from 1951 and 1976. A Landsat (1976) analysis carried out by KARDONO & WISNUSUDIBYO (1980), including a comparison with a 1883 map, also indicates growth of the Citarum delta during that period. The northern coast of the delta has to some extent been straightened since 1951 because of the strong northerly wind during this period. The other outfalls are rather protected from the NE monsoon and stronger wave attacks there can be expected during years when westerly winds are more dominant.

The situation at the NW side of the bay is completely different. Near Cape Pasir, there is a slowly abrading old part of the Cisadane delta that formed before the river took its present, more northerly course. The coast of the old delta extends in a NW-SE direction and is thus fully exposed to the east monsoon. As a result, abrasion drastically increased here during the period 1948–1982, causing a land loss of 1.5

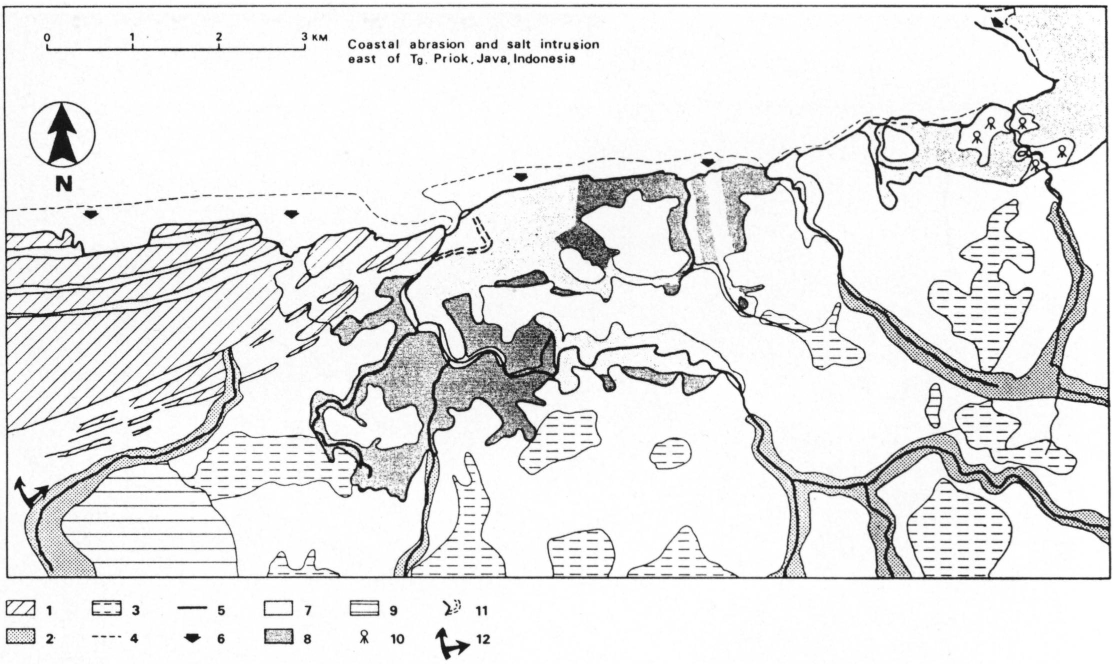

Figure 7. Map of coastal abrasion and salt intrusion, east of Tg. Priok. Legend: (1) beach ridges; (2) natural levees; (3) deepest back swamps, in part with cat clays; (4) coastline of 1948; (5) coastline of 1982; (6) abrasion/accretion; (7) brackish (fishpond) areas in 1948; (8) same in 1982; (9) artificial fill of backswamp; (10) mangrove; (11) present and former creeks; (12) man-made river diversion dating from the 5th century AD.

km^2 (an average of 250 m over a distance of 6 km). Since a narrow sandy beach ridge was present along this abrading coast, extraction of beach sand may well have been a contributing factor. The ridge has disappeared and the fish ponds, which were protected by it, have been abandoned. These conditions will continue until a smoothly rounded coastline has been formed that is more or less in equilibrium with the various exogenous forces (see Figure 4).

The most dramatic environmental deterioration of the coastal zone has occurred a few kilometres to the east of the harbour of Tg. Priok, near Cilincing. The main cause of the coastal abrasion in this case is beyond doubt the excavation of sand for construction from both the beach and beach ridges. The strong northerly winds have, of course, aggravated the impact of these activities. PARDJAMAN (1977) claims an abrasion of 600 m during the period 1951–1975, whereas the annual abrasion used to be less than 1 m. By 1982, the abrasion totalled 750 m. The aerial photographs of Figures 5 and 6 illustrate the situation in 1948 and 1982, respectively. A surface area of 2.25 km^2 has been lost along this part of the coast. In 1948, the environment was still semi-natural and the population was sparse. In 1982, the area formed part of the greater Jakarta urban area and thousands of people lived in increasingly congested quarters. The continuous abrasion aggravates the situation. The area is composed of a series of parallel beach ridges with intervening swales; every time a beach ridge disappears, the swale behind is inundated. The coastal protection works consist of only bamboo poles. Since wave energy is not dissipated, sand behind the poles is removed, making this construction utterly inadequate. Many people have already been resettled in other near-coastal areas farther to the west. Another result of the abrasion is that saline water intrudes much farther inland than previously. A total of 3 km^2 of paddy fields had to be transformed into brackish-water fish ponds. The map in Figure 7 illustrates the situation. There are no (automatic)

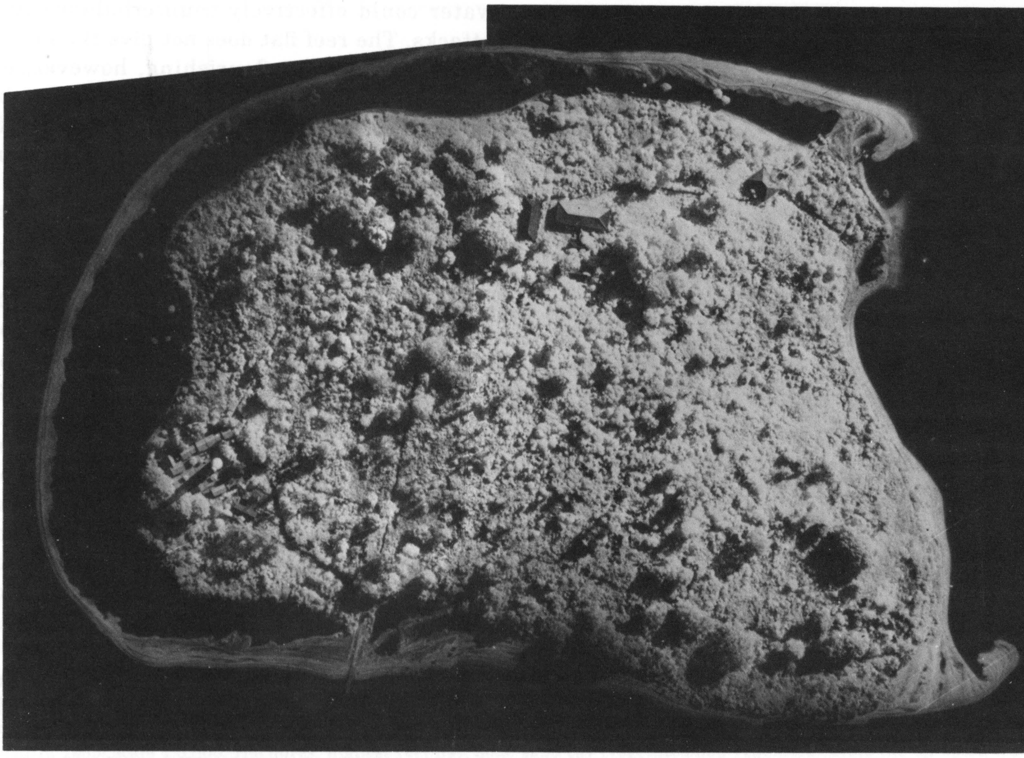

Figure 8. Aerial photograph (1980) of the coral island of Damar besar, scale 1:5,000 (reduced from original aerial photograph).

movable barriers in the creeks to limit the intrusion of saline water.

To the west of Tg. Priok, an artificial recreational beach has been created. Some abrasion takes place, as is evident from the construction and present seaward position of a seawall composed of blocks. In fact, hardly any natural deposition is expected along this stretch of the beach, which makes it rather vulnerable. This applies to the whole south-central coast of Jakarta Bay. Subsidence caused by groundwater extraction may introduce future abrasion. If the subsidence cannot be brought under control, the probability of flooding will increase, especially during years of strong west (wet) monsoons. Invasion of the sea in northern areas of the town can also be expected during years of strong east (dry) monsoons. The invasion of the sea can, of course, be prevented by artificial fills along the shores, but the built-up areas to the landward will then form closed depressions with, again, increased flood susceptibility.

The Effect of the Environmental Stress Factors on the Coral Reefs and Cays

The coral reefs and cays in the bay have been strongly affected by human and natural factors. A number of them were surveyed in 1983/84 and compared with the 1950/51 situation to assess their changes in the light of the environmental changes that have occurred in the last three decades. Recent, very detailed aerial photographs (1:2,500) were available of two islands (Damar besar and Birdadari/Sakit); for the others, only 1:30,000 false colour airphotos from 1982 could be used. Because of their scale, the survey of the latter was based mainly on terrestrial survey using a geological compass and a pedometer.

It appears that the evolution of the sand cays varies with their situation in the bay. The following can be distinguished: (1) reefs in the outermost, northern parts of the bay; (2) reefs in the shallow waters near the western shores of

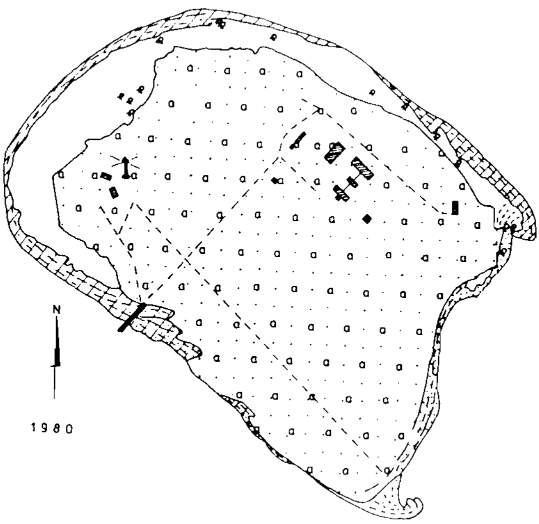

Figure 9. Map of Damar besar island (1980), scale 1:10,000. Shingle ridges are indicated by hachures; the sand cay by dots (*cf.* Figure 8).

the bay; and, (3) reefs in the south-central parts of the bay closest to Jakarta. The island Damar besar, by far the largest cay in the bay, is representative of the first group. It is pictured on the aerial photograph of 1980 (Figure 8), which served as the basis for the 1:10,000 map shown in Figure 9.

Comparison of the maps of 1950 and 1984 shows that the sand cay did not decrease in size during this period. The low, interrupted shingle ridge featured on the 1950 map (and incipiently already in 1927) to the west of the sand cay was not only built up substantially but was also pushed landward. It loops around the whole north coast to the NE side of the island and it also extends to the southwest where it terminates at a small jetty SE of the lighthouse. At this location, the material becomes more sandy. Accumulation of sand occurred particularly at the SE tip of the island and to a lesser extent along the east coast where shingle ridges are lacking. Only minor changes have occurred in the position of the shingle ridge in the three years elapsed between the aerial photograph and the author's visit in 1984. Some abrasion of the south coast to the east of the jetty points to stronger southerly winds in the early 1980s. Evidently this most seaward island is attacked by wind and surf from almost all directions. Coral growth in the relatively lightly polluted water could effectively counterbalance these attacks. The reef flat does not give the impression of being very flourishing, however, and damaging factors such as dragging bamboo across the reef and mining coral sand at the SE tip contribute to the disturbance of the natural equilibria.

The island of Air besar (Figure 10), situated farther to the southwest, forms a transition to the "unhealthy" reefs and cays of the bay. The decrease in the size of the cay is minor, but the shingle ridge featured on the 1950 map along the northern side of the island was pushed towards the northern shore. The lagoon separating it from the sand cay in 1950 thus disappeared. Abrasion of the north and northeast coast of the cay, as evidenced by numerous uprooted trees, is facilitated by the comparatively narrow and not very shallow reef flat that does not adequately dissipate the energy of the waves before they reach the cay. Sand accumulation at the southern leeward side shows as a distinct bulge of the cay on an airphoto of 1982. It appears, from a visit in 1985, that part of this recent sand accumulation was abraded during the period 1982–1985 as a result of stronger southerly winds. The north side of both reefs has clearly been under severe wave attack during the last three decades but the shingle ridge of the larger one, Damar besar, appears to have adequately protected the cay. A narrow moat still exists there, whereas the moat of Air besar has disappeared. The formation of a new, protecting shingle ridge there seems doubtful in view of the poor condition of the living reef. The island may well have reached a critical stage in its development. Relics of a former reef flat approximately 1 m above the present one indicate the stability of the cay during several thousands of years.

A third island belonging to this group, Damar kecil or Monyet, is privately owned and cannot be visited. The impression gained from a distance is that, although the north coast is abrading and unprotected by a shingle ridge, the island has not decreased much in size. No bamboo poles could be seen on its shores. The change in the islands of this group appears to be still dominated largely by the natural processes of winds and waves and their long-term fluctuations.

The differences in development among the

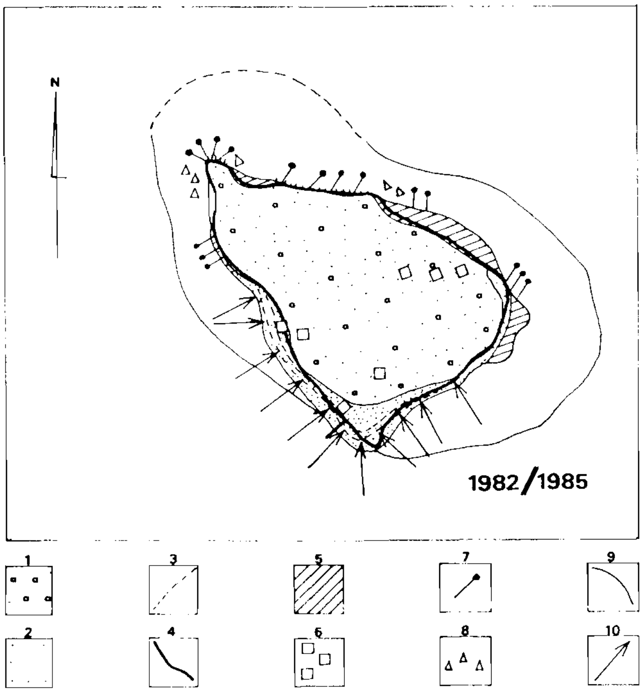

Figure 10. The island of Air besar according to an aerial photograph dating from 1982 with indication of changes observed during a visit in 1985, scale 1:5,000. Hachures: highest reef flat; dots: sand cay (vegetated/non-vegetated). Note the uprooted trees, the abrasion cliff in the NW and the growth ridges of the cay in the SE. Note the abrasion 1982/1985 in the SE. Key: (1) sand cay, vegetated; (2) same, non-vegetated; (3) growth ridges; (4) coastline 1985; (5) highest reef flat; (6) houses; (7) uprooted trees; (8) abrasion cliff; (9) coastline 1982; (10) abrasion 1982–1985.

islands of this group are related to differences in size and shape of the reefs. Where the reef flats are broad, relatively high and rough, the force of the waves is more efficiently dissipated before they reach the cays.

The islands of the second group form a cluster of four in the comparatively quiet water near the western shores of the bay. They have for a long time been subjected to human influences: East India Company fortresses were built on each of them. Two islands have been quarantine stations for many years and are stable. The two other islands are more dynamic and are dealt with in this paper: i.e. the island of Birdadari (formerly known as Sakit) and the smaller island of Kelor. These two islands are largely protected from southwesterly and westerly winds by the nearby shores of the bay, and a broad reef flat offers protection from the northeasterlies.

Birdadari/Sakit has a fairly roundish shape and a broad reef flat protects it on the north, northwest and western sides. It has been rather stable since the turn of the century, as is illustrated by Figure 11 showing the superimposed coastlines of 1901, 1927, 1950 and 1982. Stability during a much longer period is likely. The sands of the cay are cemented along the east coast and this beach rock acts as a natural seawall. The cay furthermore reaches a greater height than observed elsewhere in the bay and its soil development is more advanced. Three recent airphotos, dating from the mid-1970s to 1982, illustrate how slight erosion took place in the north. This is more than balanced by recent sand accretion along the south and southwest coast. Several small groines were constructed in recent years but it is doubtful whether these have much to do with the accretion in the south: this is a common recent trend on all islands as a consequence of the near absence of southerly winds in the period 1950–1980. There are not

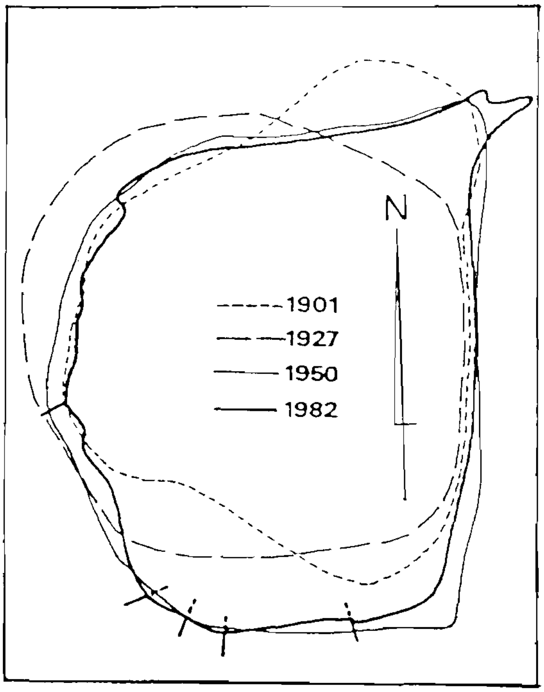

Figure 11. Birdadari/Sakit island, superimposed coastlines of 1901, 1927, 1950, and 1982, scale 1:5,000. The relative stability of the sand cay is obvious.

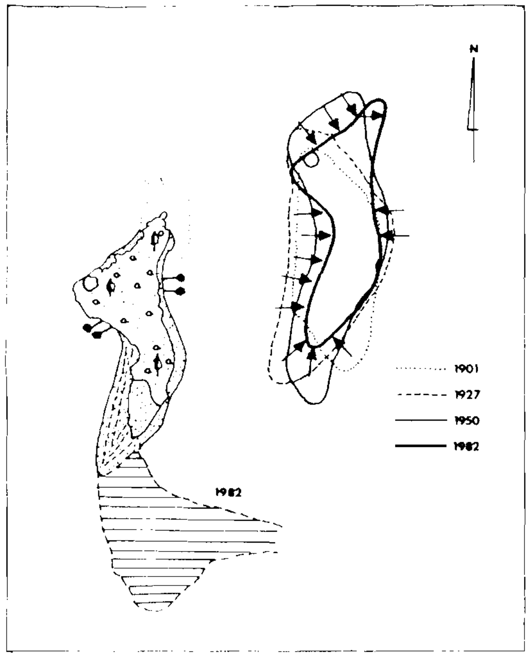

Figure 12. Kelor island. Superimposed coastlines of 1901, 1927, 1950, and 1982 (top right). Dominant abrasion is obvious, as indicated by the arrows. Bottom left: the remainder of the island in 1982. Abrasion occurs all around the island. The southern part is devoid of vegetation. Scale 1:5,000.

many bamboo poles on the beaches and damage caused by tourism so far seem to be limited.

The nearby Kelor island is a small and narrow cay, extending in a north-south direction. Its reef flat is less well developed and generally deeper than that of Birdadari/Sakit. The island has been abrading slowly since the beginning of this century. This is especially noteworthy in the east, as is evident from Figure 12 showing the superimposed coastlines of 1901, 1927, 1950 and 1982. In the period 1950–1982, the abrasion intensified and as a consequence the island's size reduced from 17,000 m^2 to 11,000 m^2. What is left is thinly vegetated, with the southern part almost barren. It is low and lacks the natural protection of beach rock. The cay is in imminent danger of disappearing altogether. Since the other three islands of the cluster have specific uses and are built-up, Kelor island has a concentration of coral mining and extensive fishing, as a result of which the reef is almost completely destroyed. It is no longer inhabited.

The deterioration during the last three decades of the two coral cays of the third group, located in the most polluted part of the bay, has been disastrous. Nirwana, formerly known as Nyamuk besar, was among the most beautiful islands in 1950, measuring 57,000 m^2. It was reduced to a mere 4,100 m^2 by 1984, thus losing 93% of its surface area. The vegetation of what remains is in ruin. Tourism, introduced in the 1960s, had to be moved to Birdadari because of the rapid abrasion of the cay. Figure 13 illustrates the situations of 1950 and 1984. Superimposion of the two maps is impossible in the absence of reference points, but what remained in 1984 is in the south-central part of the 1950 map. Abrasion is still going on and many fallen trees occur all around the cay. A striking feature is a large, southward pointing sand "tail" caused by the beach drift of the northerly winds. In 1927 the cay was protected on the north by a shingle ridge. By 1950, the ridge had been pushed toward the cay, which resulted in the direct attack of the waves when the years of strong northerly winds began. Since the reef

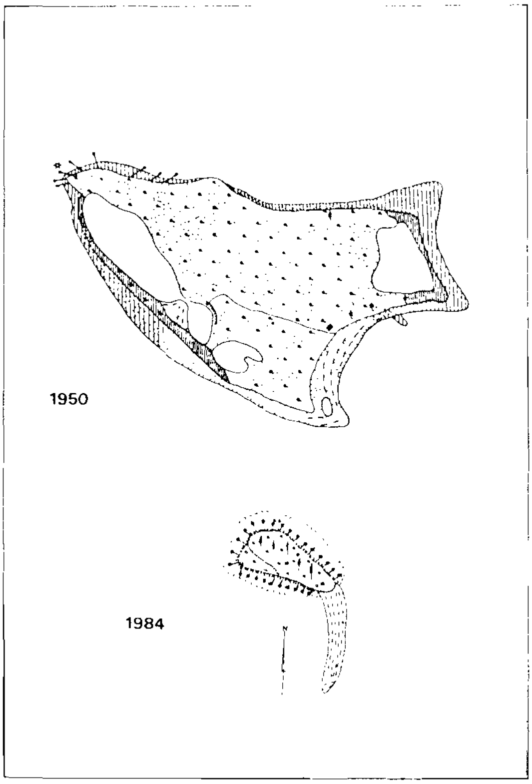

Figure 13. The sand cay of Nyamuk besar as it appeared in 1950 and 1984: the island has almost completely disappeared.

has been nearly destroyed because of pollution, no new shingle ridge has formed which could help prevent the disappearance of the cay. Also, the proximity of the cay to Jakarta made it an easy target for both coral mining and sand extraction. Numerous bamboo poles, needed for the construction of Bagang fisher rakes around the island, are also piled up on the cay. Although these hardly help in producing a healthy reef, they are not a cause of the island's decline: much of it had already been destroyed when the author visited the island in 1975, even though few Bagang could be seen.

Another small and deteriorated cay, Nyamuk kecil, is located farther south. Figure 14 shows the cay as it was in 1950 and 1984. It measured 15,000 m^2 in 1950 and 5,700 m^2 in 1984, representing a loss of approximately 62%. Another conspicuous southward-pointing sand "tail" can be observed, certainly caused by the strong northerly winds of recent years. To protect a

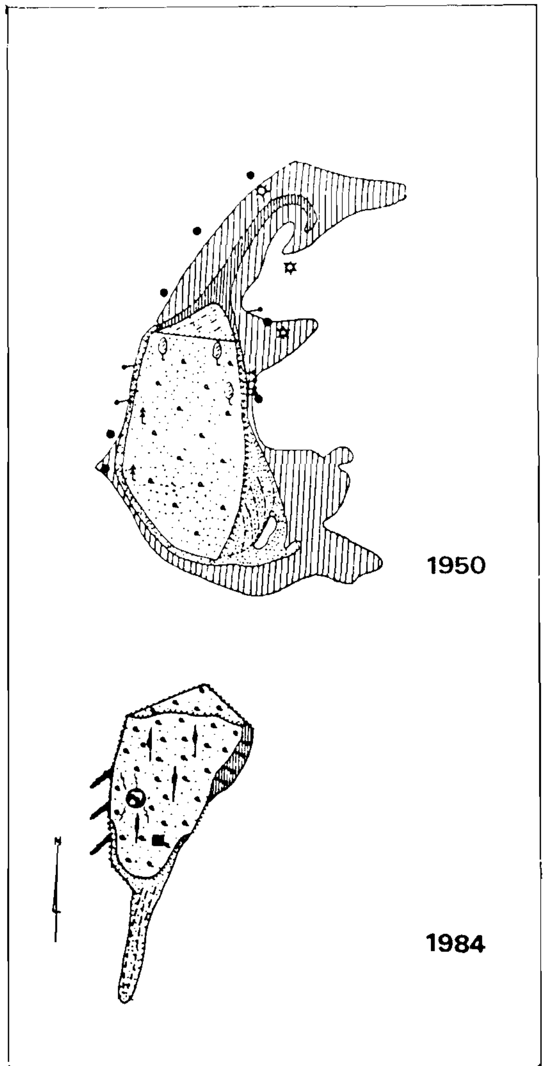

Figure 14. The sand cay of Nyamuk kecil as it appeared in 1950 and 1984: also this cay has shrunk considerably. Concrete "drums" are erected all along the north and west shores in an attempt to stop abrasion. In addition three groines have been built in the west.

navigational beacon on the cay, a concrete seawall was built in 1978 along the entire northern and western sides of the island. It consists of a series of concrete "petrol drums" placed on a flat foundation. In addition, three short groines were built near the beacon. Abrasion is now limited to the NE side where several trees have been toppled on the beach/reef flat. Because the adjacent concrete drums are separated by a few inches, only a part of the wave energy is dissipated and sand is being removed from behind the drums. The defense is thus not fully effective and several drums are already tilting seaward. The seawall, being much higher than actually required, has decreased the scenic value of the island. The reef of Nyamuk kecil is largely dead because of water pollution and coral mining. Spontaneous recuperation of the cay thus cannot be expected.

The islands of this third group are thus clearly in a state of catastrophic decline, the main cause being water pollution. This has happened in the past to the Father-Smith reef situated still closer to the coast. In 1824, this was a vegetated island, but it is now reduced to a submerged reef. A similar fate befell the Schiedam reef, situated in the west of the bay, which in 1753 was a wooded island (UMBGROVE, 1947).

CONCLUSIONS

It is evident that the coastal environment (including the bay and the coral cays) has been unable to withstand the stress of the last three decades of urbanization in combination with somewhat unusual wind and wave patterns. Considerable abrasion and further environmental deterioration have thus resulted. The leading causative factors are the: pollution of the baywater and subsequent dying-off of the coral polyps, use of beach sand and coral shingle/boulders for construction purposes, and excessive groundwater extraction with subsequent land subsidence.

There is an obvious need for an ecology-based management of the coastal zone. Among the main managerial aspects, the following are especially urgent: monitoring all changes of the coastal environment; developing adequate structures for combatting further coastal abrasion; selecting appropriate sites for movable gates to stop saline water intrusion; studying the areal distribution of flooding and reducing flood susceptibility, particularly of built-up areas; countering land subsidence, *e.g.* by replenishing the aquifers with fresh water (without polluting the drinking water!); developing ways of protecting the recreation potential of the coral cays, *e.g.* by constructing effective low seawalls, creating artificial shingle ridges near the reef edge, or "roughening" the reef flats: and controlling use of the fragile coastal environment (baywater pollution, coral mining, sand excavation, etc.). A masterplan has to be devised to reconcile the heavy resource demands (construction, recreation, etc.) of Jakarta with the limitations of the dynamic range that characterizes the coastal ecosystem.

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□ RESUMEN □

Desde que el autor visotó la costa de la Bahía de Yakarta en la década de los 50, hasta nuestros dias, se ha desarrollado una rápida urbanizacion de las llanuras aluviales y los bordes de la Bahía, incluido los arrecifes coralinos.

Las acciones urbanas son diversas e incluyen, contaminación del aqua, la utilización de la arena de la playa y derrubio de coral para la construcción, uso de grandes áreas para asentamientos industriales, pesca intensiva; turismo y bombeo de aquas subterráneas dando como resultado la subsidencia de 4.5 cm por año. Un efecto acumulado resulta del comportamiento anómalo de la Zona de Convergencia Intertropical (ITCZ), con precipitaciones escasas y vientos del Nordeste y Este relativamente fuertes durante las décadas 60 y 70. La costa no ha podido sequir estos cambios sustanciales por lo que se ha deteriorado. Mediante una ponderación de los factores que han cuasado el deterioro se hace una previsión de futuro.—*Department of Water Sciences, University of Santander, Santander, Spain.*

□ RÉSUMÉ □

Depuis les années 1950, la plaine alluviale bordant la baie et les récifs corraliens s'est rapidement urbanisée. Les contraintes urbaines sont multiples: pollution de l'eau de mer, utilisation du sable de plage at des débris coralliens pour la construction, mise en oeuvre de grands travaux (extension du port, lac de retenue), pêche intensive, tourisme et, au sein de la connurbation de Jakarta, pompage de la nappe phréatique provoquant une subsidence de 4–5 cm/an. Les contraintes naturelles ont aussi joué: de 1960 à 1970, il y a eu un comportement anormal de la zone de convergence intertropicale, caractérisé par de faibles précipitations et des forts vents du Nord et de l'Est. L'environement littoral est incabaple d'absorber ces contraintes combinées, si bien que des modifications importantes et une deterioration du milieu en découle. L'impact des facteurs de cette évolution est pesé pour une prospective.—*Catherine Bressolier, EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Der Autor hat die Küstenentwicklung der Bucht von Djakarta seit 1950 kontinuierlich verfolgt und festgestellt, daß die aktuelle Urbanisation neben den Aufschüttungsebenen an den Seiten der Bucht auch die Korallenriffe beeinflußt hat. Die urbanen Streßfaktoren sind vielfältig: Wasserverschmutzung, Entnahme von Strandsand und Korallenschutt für Bauzwecke, Errichtung großer Bauwerke (z.B. Hafenerweiterung), intensiver Fischfang, wachsender Tourismus und eine verstärkte Grundwassenentnahme im Bereich des Stadtgebietes, die zu Landabsenkungen (4–5 cm/a) geführt hat. Natürliche Streßfaktoren traten in Form des anomalen Verhaltens der innertropischen Konvergenzzone (ITC) auf, welches einen sehr niedrigen Niederschlag und relativ starke nördliche und östliche Winde während der 60er und 70er Jahre zur Folge hatte. Der Lebensraum Küste war nicht in der Lage die Kombination anthropogener und natürlicher Streßfaktoren zu absorbieren, welches eine substantielle Veränderung bzw. Verschlechterung der Verhältnisse zur Folge hatte. Der Autor versucht, die verschiedenen Faktoren gegeneinander abzuwägen und Prognosen für die Zukunft zu geben.—*Ulrich Radtke, Geographisches Institut, Universität Düsseldorf, F. R. G.*