

Alleng, G. P. (1998). "Historical development of the Port Royal mangrove wetland, Jamaica." Journal of Coastal Research 14(3): 951-959.

Studies on the historical development of mangrove wetlands are rare in contrast to the vast array of information on the geological development of these systems. Historical development of the Port Royal mangal was investigated so as improve understanding of recent changes occurring in relation to the increasing threat of sea level rise to their existence. The historical development of the Port Royal mangal, Jamaica, began with the first documented spatial record for the area in 1692 and traced to 1991 using historical maps and aerial photographs. The mangrove system is a fringe mangrove community type, composed of primarily *Rhizophora mangle* L. located along the northern shore of the Palisadoes, which is a composite tombolo on the south coast of Jamaica. A general trend was determined for the morphology of the mangal which showed relative stability, displaying little significant variation in its areal extent over a period of 300 years. The horizontal extension by colonizing mangroves has not been significant, with forested areas being restricted to sharply defined geomorphological units, probably because of the response of the system to a combination of factors. These include: i. a small tidal range; ii. geomorphology of the system; iii, a lack of large sediment inputs and iv. episodic events such as hurricanes. This stability of the Port Royal mangrove system is atypical of the understanding of development of these wetlands, which has been accepted to be a constant state of migration or movement. The stable trend of this mangrove system has implications with regard to its response to occurrences such as sea-level rise. Coastal wetlands of this type will probably experience complete collapse when sea levels begin to rise.

Bacon, P. R. (1994). "Template For Evaluation of Impacts of Sea-Level Rise On Caribbean Coastal Wetlands." Ecological Engineering 3(2): 171-186.

Published predictions of the impacts of sea level rise on mangroves are too simplistic, due to the assumption that ecosystem structure and plant zonation are uniform. Field survey and analysis of over 200 coastal wetland sites in the Insular Caribbean suggests the likelihood of very variable system responses, because of the wide range of wetland types and geomorphic settings. A template is presented for use in predicting site-specific responses to sea level change in mangrove and associated coastal wetlands. Significant predictors are site physiography and relation to neighbouring coastal systems, plus the immediate hinterland and recent changes to wetlands resulting from human intervention. Impacts on mangroves may include some losses,

but inland migration, change in species dominance, and increase in area are more likely in the short term, depending on the range of site characteristics. This is supported by review of palaeoecological studies on wetland development in the region. The use of the template in coastal area planning and engineering is discussed.

Beaman, R., P. Larcombe, et al. (1994). "New Evidence For the Holocene Sea-Level High From the Inner Shelf, Central Great-Barrier-Reef, Australia." Journal of Sedimentary Research Section a-Sedimentary Petrology and Processes **64**(4): 881-885.

Radiocarbon dates from fossil oyster beds of intertidal origin on Magnetic Island, north Queensland indicate that the local Holocene maximum of relative sea level was attained no later than 5660 +/- 50 B.P. (conventional uncorrected age) and remained at 1.6-1.7 m above modern levels until 4040 +/- 50 B.P. Given the tectonic stability of the area, this implies that eustatic sea level remained at its Holocene peak for at least ca. 1600 yr. The new high-precision sea-level data indicate sea levels 1-5 m higher than those of the same age inferred from buried mangrove deposits on the inner shelf in north Queensland. Uncertainties in deriving relative sea level from such mangrove deposits may be a significant source of error in worldwide attempts to distinguish the eustatic and crustal warping components of relative sea-level change, especially in the tropics.

Behling, H. (1996). "First report on new evidence for the occurrence of Podocarpus and possible human presence at the mouth of the Amazon during the Late-glacial." Vegetation History and Archaeobotany **5**(3): 241-246.

Palynological studies on late Quaternary lake sediments from the region of the Amazon estuary, 100 km north-east of Belem, Para State, Brazil, enable reconstruction of lowland Amazonian rain forest during the Late-glacial and Holocene periods. Late-glacial forests included populations of Podocarpus which suggests a distinct climatic cooling. Ilex was abundant in the early Holocene. Records of the mangrove taxon, Rhizophora, indicate rapid Atlantic sea-level rise in the beginning of the Holocene. High charcoal representation may reflect the first arrival of Amerindians in the Amazon coastal area, probably about 10 800 B.P.

Belperio, A. P. (1993). "Land Subsidence and Sea-Level Rise in the Port-Adelaide Estuary - Implications For Monitoring the Greenhouse-Effect." Australian Journal of Earth Sciences **40**(4): 359-368.

The historic tide gauge records from Port Adelaide and Outer Harbour are one of the more important datasets from

the Australian region purporting to show a significant rate of local sea level rise. However, geological evidence including radiocarbon dated palaeosea level indicators, indicates that most of this rise is due to subsidence of the land. The subsidence is significant but localized, and can be largely attributed to human activities associated with port development, reclamation and industrialization- Two principal contributing factors are reclamation of Holocene wetlands and groundwater extraction from deeper Tertiary aquifers. Wetland reclamation has caused surficial soil compaction as a result of artificial lowering of the water table, oxidation of peat and pyrite, and leaching of the substrate by soil acidification. Surficial subsidence at rates of up to 10 mm/year has occurred in reclaimed mangrove woodlands as a result of these processes. Extraction of groundwater from deeper aquifers over the past 50 years has created a potentiometric cone of depression in excess of 20 m beneath the Port Adelaide estuary. Land subsidence estimated at 2.8 mm/year is associated with the central zone of depressed groundwater levels. The tide gauge data from Port Adelaide and Outer Harbour have been used in global sea level rise calculations without adequate local neotectonic correction. Although outside the zone of greatest land subsidence, three-quarters of the secular rise in mean sea level of 2.5 2.9 mm/year indicated by the tide gauge records can be attributed to land level changes. Hence the local sea level trend is a rise of approximately 0.7 mm/year. As many of the world's historic tide gauge sites are expected to be affected by similar anthropogenic effects, it is imperative that local neotectonic corrections be applied to all tide gauge data before drawing any conclusions regarding global or local eustatic sea level change.

Blasco, F., P. Saenger, et al. (1996). "Mangroves as indicators of coastal change." Catena 27(3-4): 167-178.

In view of the unique biological characteristics of mangroves, it is interesting to assess the extent to which these ecosystems can be used as indicators of coastal change or sea-level rise. From recent studies of mangrove mortality at several locations (including Guiana, Gambia, Cote d'Ivoire, Kenya, India and Bangladesh), it appears that these coastal ecosystems are so specialized that any minor variation in their hydrological or tidal regimes causes noticeable mortality. Each species of mangrove (but particularly those belonging to the genera *Rhizophora*, *Bruguiera*, *Sonneratia*, *Heritiera* and *Nypa*) occurs in ecological conditions that approach its limit of tolerance with regard to salinity of the water and soil, as well as the inundation regime. If the duration of daily immersion were to be modified by tectonic, sedimentological or hydrological events, the species either readjusts to the new

conditions or succumbs to unsuitable conditions. Consequently, the use of remote sensing data for mangrove ecosystems offers excellent potential as a tool for monitoring coastal change.

Bryant, E. A., R. W. Young, et al. (1992). "Evidence For Pleistocene and Holocene Raised Marine Deposits, Sandon Point, New-South-Wales." Australian Journal of Earth Sciences **39**(4): 481-493.

In New South Wales there has been an elusive search for coastal deposits that might substantiate an elevated Holocene sea-level. Chronostratigraphic evidence is presented for estuarine and beach deposits raised more than 1 and 2 m respectively above Australian Height Datum around Sandon Point, New South Wales, between 6900 and 1520 BP. The chronology is based upon C-14 dating of shell and in situ mangrove stumps, and upon thermoluminescence dating of quartz sand. These elevations concur with other results determined along the east coast of Australia and in the south Pacific. Moreover the Holocene beach sediments lie above Pleistocene aeolian sand dating between 25 300 and 32 700 BP and estuarine mud which must be at least Last Interglacial in age. The latter units also be more than 2 m above Australian Height Datum. Fossil coral found along the adjacent coast plus the elevation and orientation of the raised marine deposits imply that ocean temperature was warmer around 2800 BP by up to 2-degrees-C, that sea-levels from 6000 to 1500 BP were over 1 m higher than present, and that a benign northeast swell may have dominated in the mid-Holocene. The marine deposits show little indication that they were deposited by storms but the role of tsunami in their formation cannot be ignored.

Callaway, J. C., R. D. DeLaune, et al. (1997). "Sediment accretion rates from four coastal wetlands along the Gulf of Mexico." Journal of Coastal Research **13**(1): 181-191.

Our study of sediment accretion rates from four low tidal-range sites along the Gulf of Mexico does not support previous hypotheses concerning the relationship between tidal range and vertical accretion rates. The addition of our data to an earlier data set decreased the correlation between these variables, and all but one of our low-tidal range sites had positive accretion rates, contradicting previous studies which have predicted that low tidal-range sites would have negative net accretion rates. Additionally, in transects across the marsh, accretion rates decreased from low- to high-marsh stations; however, this appeared to be caused by changes in rates of organic matter accumulation, not mineral matter accumulation, as has been proposed in previous studies. Vertical accretion rates were more strongly correlated with organic matter accumulation

rates than mineral matter accumulation rates, confirming previous studies which indicated the important role of sediment organic matter in determining sediment structure. These results do not imply that mineral matter is unimportant in maintaining the elevation of the marsh; mineral matter input affects organic matter production and sediment bulk density. There was little correlation between mineral and organic matter accumulation rates, with average organic matter accumulation rates for each site having little variation compared to the variation in mineral matter accumulation rates. This result supports a previous hypothesis that there may be a limit to annual rates of organic matter accumulation. Finally, the study indicates that the negative net accretion rates documented in Louisiana are not typical of other Gulf coast wetlands.

Carter, R. M., D. P. Johnson, et al. (1993). "Episodic Postglacial Sea-Level Rise and the Sedimentary Evolution of a Tropical Continental Embayment (Cleveland Bay, Great-Barrier-Reef Shelf, Australia)." Australian Journal of Earth Sciences 40(3): 229-255.

Cleveland Bay is a 400 km² landlocked tropical embayment located at 19-degrees-S and 146-degrees 55'E. The bay is protected from the dominant southeasterly tradewind by Cape Cleveland, but lies open to northerly and northeasterly weather and to the effects of occasional tropical cyclones. Water-motion within the bay is dominated by the effects of refracted southeasterly-generated waves (mostly 0.5-1.2 m high, 4-6 s period) and by semi-diurnal tidal currents, which reach speeds of 15-30 cm/s during spring tides. Residual circulation within the bay is anticlockwise and results in preferential sediment accumulation on the eastern side. The bay contains three main Holocene stratigraphic units (A-C) which rest on weathered Late Pleistocene clay. The Pleistocene land surface is planar, dips seawards at 0.8 m/km and is incised by a major complex of fluvial and tidal channels. Seismic unit C encompasses cross-bedded or draped fill of the channel system. Seismic unit B, occurring laterally to C, comprises massive grey mud with mangrove roots, is up to 4 m thick, ranges in radiocarbon age from 8 (depth 15 m, outer bay) to 7 ka BP (depth 5 m, adjacent to the coastline) and accumulated at vertical rates up to 680 cm/ka. Unit A is the main Holocene bay-fill, comprising transgressive beach sand at the base which passes up into bioturbated offshore muddy sand. The unit A prism is the offshore continuation of the coastal chenier plain and represents rapid transgression in the Early mid Holocene followed by coastal and bay progradation since 6.5 ka BP at horizontal rates of 0.5-1.0 km/ka and vertical rates up to 100 cm/ka. Surficial sediment distribution within the bay has been markedly affected by

the dumping of harbour and shipping channel dredge spoil. The predumping sediment distribution comprised a coastal platform of beach sand and subtidal silty sand, passing offshore into bioturbated muddy sand with scattered shells; minor bioclastic detritus accumulates adjacent to fringing reefs on Magnetic Is. The Pleistocene land surface is exposed on the sea floor adjacent to the shipping channel in the western bay, and at depths > 20 m seawards of the shore-connected Holocene sediment prism. The combined sedimentary evidence is consistent with pauses or slowdowns in the post-glacial sea-level rise at 28 m at 10 ka BP (shoreline S3) and 10 m at 8 ka BP (shoreline S2).

Cederlof, U., L. Rydberg, et al. (1995). "Tidal exchange in a warm tropical lagoon: Chwaka Bay, Zanzibar." Ambio **24**(7-8): 458-464.

Measurements of sea levels, velocities and temperatures, are used to study water exchange and heat flux in Chwaka Bay, a shallow tidal marsh on the East African coast. The bay has an area, ranging from 50 km² at high water spring (HWS) to 20 km² at low water spring (LWS). It is characterized by vast muddy sand flats, partly covered by sea grass. The tide is semidiurnal with a spring tidal range of 3.2 m. The southwestern creek, surrounded by mangrove vegetation, shows a tidal asymmetry with a combination of long ebb periods and high ebb velocities. The water and heat exchange with the ocean is calculated from simultaneous sea level and temperature data. Although the average temperature within the bay is higher than oceanic temperature, there is an average import of heat from the ocean of approx. 50 W m⁻². Thus, the sum of longwave back radiation, evaporation and sensible heat flux exceeds the net incoming shortwave solar radiation. This negative heat balance is interpreted as a result of reflexion of shortwave radiation at the bottom. The result is supported by a set of figures, featuring the temperature as a function of time of day and time after high tide, which can be used as a guideline for comfortable bathing. Although the bay is almost drained during low tide, and the average residence time is estimated to between 1/2-1 day, the residence times for the waters in the inner parts of the bay are substantially longer.

Chappell, J. (1993). "Contrasting Holocene Sedimentary Geologies of Lower Daly River, Northern Australia, and Lower Sepik-Ramu, Papua-New-Guinea." Sedimentary Geology **83**(3-4): 339-358.

The estuarine plain of the macrotidal Daly River, in monsoonal northern Australia, is underlain by extensive mid-Holocene mangrove swamp sediments which accumulated during the last stages of Post-glacial sea-level rise. Sediment yield from the catchment is too low to account for the

volume which accumulated during sea-level rise, and onshore transport is invoked. This is supported by radiocarbon ages and facies analysis of the transgressive sediment tract beneath the maximum flooding surface (MFS), and of the tract of vertical sedimentation which extends from the MFS to the surface of estuarine/fluviol transition (the EFT). The EFT occurred about 5000 to 6000 BP throughout the estuarine plain. A contrasting situation exists in the lowland Holocene basin of the microtidal Sepik and Ramu rivers in Papua New Guinea, which derive sediment from highly tectonic catchments. A tectonic basin, which was a shallow brackish inland sea after Post-glacial transgression, is separated by a low divide from a deltaic plain. Progradation of the deltaic plain commenced about 3500 BP after regressive sedimentation eclipsed the inland sea in the tectonic basin. Contrasting organic facies, mangrove in the Daly and freshwater swamp deposits in the Sepik-Ramu, highlight differences between facies models of the two systems. Differences between fluvio-tidal regimes are reflected by the EFT, which is synchronous in the Daly and diachronous in the Sepik-Ramu, and possibly by the MFS which is diachronous in the Daly and may be synchronous in the Sepik-Ramu.

Clark, M. W. (1998). "Management implications of metal transfer pathways from a refuse tip to mangrove sediments." Science of the Total Environment **222**(1-2): 17-34.

Mangroves have often been thought of as wasteland, and because of this attitude, many mangrove forests have been used as sites for refuse tips, sewage outfalls and as illegal dumping grounds. The transfer of metals from a refuse tip to mangrove sediments is investigated and four pathways of heavy metal migration are identified. These are direct seepage across the tip-cell floor to groundwater, tidal over-topping of the bund wall and capillary suction of leachates to groundwaters, direct seepage through the cell wall of leachates to surficial sediments, and surface runoff during rainfall events. Metal input by surficial runoff indicates that significant quantities of metals have been transferred to the mangroves via this mechanism. However, metal transfer via surface runoff is probably small in comparison to the other three mechanisms discussed. The variable nature of the transfer mechanisms operating, the variability in sediment texture both vertically and laterally, and the number of transfer pathways makes potential management of the site difficult. Any management plan for this site must consider both the feedback mechanisms that operate, and that the whole sediment column is involved in metal transfer. (C) 1998 Elsevier Science B.V. All rights reserved.

Clark, M. W., D. McConchie, et al. (1998). "Redox

stratification and heavy metal partitioning in Avicennia-dominated mangrove sediments: a geochemical model." Chemical Geology **149**(3-4): 147-171.

Mangrove forest sediments can provide a sink for trace metals because the mangroves create a baffle that promotes the accumulation of fine-grained organic matter-rich sediment, which is usually sulphidic due to the presence of sulphate-reducing bacteria. Direct adsorption, complexing with organic matter, and the formation of insoluble sulphides all contribute to the trapping of metals. The concentration and chemical speciation of the metals are influenced by the distribution of geochemically distinct horizons within the sediment. In horizons with a pH > 7 and an Eh < - 150 mV (reduction horizons), metals are largely present as sulphide-bound species, whereas in horizons with a pH < 7 and an Eh > + 100 mV (oxidation horizons), most metals are present as exchangeable or oxide-bound species. In most cores, two oxidation and two reduction horizons can be recognised, but dark mottles of low Eh (< - 150 mV) sediment can be found in the oxidation horizons, and orange-brown halos of high Eh (> + 100 mV) sediment can be found around mangrove roots and burrows in the reduction horizons. The depth to each horizon, differs between cores and can change in response to seasonal shifts in the position of the water table. A model is presented that accounts for the development of the oxidation and reduction horizons within the Avicennia-dominated mangrove forest sediment and describes the major controls on metal cycling within the sediment. (C) 1998 Elsevier Science B.V. All rights reserved.

Clarke, P. J. and P. J. Myerscough (1993). "The Intertidal Distribution of the Gray Mangrove (*Avicennia Marina*) in Southeastern Australia - the Effects of Physical Conditions, Interspecific Competition, and Predation On Propagule Establishment and Survival." Australian Journal of Ecology **18**(3): 307-315.

The upper and lower limits of the distribution of mature *Avicennia marina* lie between mean high water and mean sea level in open estuaries in southeastern Australia. Newly established seedlings are highly variable in abundance, but are rarely found in the saltmarsh or on mudflats. Their distribution is unlikely to be limited by dispersal because propagules disperse into the saltmarsh and to intertidal mudflats, but their establishment may be limited by physicochemical conditions, interspecific competition and predation. The model that physicochemical conditions control the intertidal limits of establishment of seedlings was accepted for propagules stranding in the saltmarsh but rejected for those stranding on mudflats. No seedlings established on saltmarsh sediments but similar numbers of

seedlings established within light gaps in adult mangrove stands and on intertidal mudflats. The model that interspecific interaction with freeliving macroalgae (*Hormosira banksii*) re-duces the establishment of seedlings on mudflats covered with macroalgae or in stands with a ground cover of macroalgae was accepted. Under controlled conditions five times as many propagules established on cleared ground compared with ground covered with macroalgae. Predators also reduce seedling establishment, but the model that they preferentially act on propagules stranding on the mudflat was rejected. The low number of seedlings found on mudflats without macroalgae appears to relate to wave and current effects on establishment and the effects of waterlogging or fouling on survival.

Cronin, T. M., L. M. Bybell, et al. (1991). "Neogene Biostratigraphy and Paleoenvironments of Enewetak Atoll, Equatorial Pacific-Ocean." Marine Micropaleontology **18**(1-2): 101-114.

Micropaleontologic analyses of Neogene sediments from Enewetak Atoll, Marshall Islands, provide data on the age of lagoonal deposits, stratigraphic disconformities and the paleoenvironmental and subsidence history of the atoll. Benthic foraminifers, planktic foraminifers, calcareous nannofossils and ostracodes were studied from six boreholes, the deepest penetrating 1605 feet below the lagoon floor into upper Oligocene strata. The Oligocene-Miocene boundary occurs at about 1200 ft below the lagoon floor. The early and middle Miocene is characterized by brief periods of deposition and numerous hiatuses. Ostracodes and benthic foraminifers indicate a shallow-marine reefal environment with occasional brackish water conditions. Upper Miocene and lower Pliocene deposits placed in calcareous nannofossil Zones NN9-15 and in planktic foraminifer Zones N 16-19 contain species-rich benthic microfaunas which indicate alternating reefal and brackish water mangrove environments. The upper Pliocene contains at least two major depositional hiatuses that coincide with a major faunal turnover in benthic foraminiferal and ostracode assemblages. The Quaternary is characterized by benthic microfaunas similar to those of modern atoll lagoons and is punctuated by at least 11 disconformities which signify periods of low sea level. Atoll subsidence rates during the last 10 Ma averaged 30 to 40 m /m.y.

Crowley, G. M. and M. K. Gagan (1995). "Holocene evolution of coastal wetlands in wet-tropical northeastern Australia." Holocene **5**(4): 385-399.

Pollen in sediments drilled from the Innisfail coastal plain, northeast Queensland, Australia, was examined to reconstruct the evolution of Holocene wetlands in a wet-

tropical environment. In contrast to monsoonal Australia, stable environmental conditions created by year-round rainfall and low tidal range caused abrupt, unidirectional transitions in wetland zonation as marine influence changed. This has enabled a detailed reconstruction of the marine transgression and subsequent progradation. Mangroves colonized in response to marine transgression at c. 7400 BP, as riverine mangroves of low salt tolerance migrated up the Mulgrave River. These were replaced around 7000 BP by extensive *Rhizophora*-dominated mangroves, coinciding with the development of a *Rhizophora*-dominated community in Wyvuri embayment. Mangroves reached their greatest extent as sea-level rise slowed towards 6000 BP, with a stillstand indicated by a brief return to terrestrial conditions at one site. High freshwater input depressed salt intrusion in the upper reaches of the Mulgrave estuary and prevented the development of hypersalinity in the upper tidal zone. Drainage conditions then controlled whether mangroves were succeeded by freshwater swamp or swamp-forest.

Crowley, G. M. (1996). "Late quaternary mangrove distribution in northern Australia." Australian Systematic Botany 9(2): 219-225.

Although mangroves have long graced the north Australian coastline, stable sea levels required for the formation of extensive mangrove swamp forests have occurred only intermittently over the late Quaternary. Most ancestral mangrove swamps are likely to have been formed below present sea level. The only well-preserved deposits that have been described, developed on the present continental surface as sea level reached its present position in the early Holocene. Gradual upstream shifting of mangrove communities from about 8400 BP is recorded in sediments from the wet tropics, followed by the establishment of extensive *Rhizophora* forests over the newly drowned estuaries. More extensive *Rhizophora* swamps developed in the monsoon tropics where an earlier transitional phase has not been preserved. These 'big swamps' infilled over the next 1500-4500 years as sediments accumulated above the now stable sea level. The present mangrove estate, though more restricted, is fairly stable, with maintenance of mangrove forests in protected prograding bays and in estuaries kept open by adequate river flow. In the short term, mangroves may be threatened by human influences, but any change in climate leading to a gradual change in sea level should again provide conditions for expansion of mangrove habitats across northern Australia.

Dupont, L. M. and M. Weinelt (1996). "Vegetation history of the savanna corridor between the Guinean and the Congolian rain forest during the last 150,000 years." Vegetation

History and Archaeobotany 5(4): 273-292.

Pollen and spores from a deep-sea core located west of the Niger Delta record an uninterrupted area of lowland rain forest in West Africa from Guinea to Cameroon during the last Interglacial and the early Holocene. During other periods of the last 150 ka, a savanna corridor between the western - Guinean - and the eastern - Congolian - part of the African lowland rain forest existed. This so-called Dahomey Gap had its largest extension during Glacial Stages 6, 4, 3, and 2. Reduced surface salinity in the eastern Gulf of Guinea as recorded by dinoflagellate cysts indicates sufficient precipitation for extensive forest growth during Stages 5 and 1. The large modern extension of dry forest and savanna in West Africa cannot be solely explained by climatic factors. Mangrove expansion in and west of the Niger Delta was largest during the phases of sea-level rise of Stages 5 and 1. During Stages 6, 4, 3, and 2, shelf areas were exposed and the area of the mangrove swamps was minimal.

Edet, J. J. and E. E. Nyong (1993). "Depositional-Environments, Sea-Level History and Paleobiogeography of the Late Campanian Maastrichtian On the Calabar Flank, Se Nigeria." Palaeogeography Palaeoclimatology Palaeoecology 102(1-2): 161-175.

Campanian-Maastrichtian palaeoenvironments and sea-level history on the Calabar Flank are interpreted by recognising palynofacies based on statistical and morphological variations in organic-walled microplankton, mainly dinoflagellates and miospores. A holomarine palynofacies defining an inner-neritic depositional environment is characterised by > 80% dinoflagellates, mainly spiniferate cysts with short, simple to complexly hooked or barbed processes. Fluvio-marine palynofacies corresponding to a littoral setting shows close abundance percentages of dinoflagellates and miospore elements. Both spiniferate and peridinioid cysts with short, long and simple processes occur abundantly and the miospore elements are dominated by mangrove-type species. A non-marine palynofacies representing a fresh-water environment is dominated by miospores of hinterland affinities. Few peridinioid cysts with long processes are present. Sedimentation and palynofacies disposition was mainly controlled by eustatic sea level fluctuations. Resolution of palynofacies, in relation to outcrop data, presents two depositional cycles, each exhibiting transgressive, highstand and lowstand systems tract deposits. The boundary between the two cycles is marked by an abrupt change from non-marine to holomarine palynofacies. These cycles, dated as late Campanian-mid Maastrichtian and late Maastrichtian, relate favourably with the 75 Ma and 71 Ma depositional

sequences recorded on the Global Cycle Chart.

Ellison, J. C. (1989). "Pollen Analysis of Mangrove Sediments As a Sea-Level Indicator - Assessment From Tongatapu, Tonga." Palaeogeography Palaeoclimatology Palaeoecology **74**(3-4): 327-341.

Ellison, J. C. and D. R. Stoddart (1991). "Mangrove Ecosystem Collapse During Predicted Sea-Level Rise - Holocene Analogs and Implications." Journal of Coastal Research **7**(1): 151-165.

Review of the stratigraphic record of mangrove ecosystems during sea-level changes of the Holocene shows that low islands will be particularly vulnerable to the loss of mangrove ecosystems during the rises of relative sea-level projected for the next 50 years. Mangrove ecosystems in these locations could keep up with a sea-level rise of up to 8-9 cm/100 years, but at rates of over 12 cm/100 years could not persist. This is due to low rates of sediment accumulation, with limited sources from outside the mangrove zone, such as from rivers or soil erosion sources. Other factors contributing to mangrove persistence are the primary production rate of forests, shoreline erosion due to deeper and more turbulent water and the frequency and intensity of tropical storms.

Ellison, J. C. (1993). "Mangrove Retreat With Rising Sea-Level, Bermuda." Estuarine Coastal and Shelf Science **37**(1): 75-87.

Ellison, A. M. and E. J. Farnsworth (1996). "Anthropogenic disturbance of Caribbean mangrove ecosystems: Past impacts, present trends, and future predictions." Biotropica **28**(4): 549-565.

We review historical, current, and projected future impacts of four classes of anthropogenic disturbance-extraction, pollution, reclamation, and changing climate-on Caribbean mangrove ecosystems (mangal). These disturbances occur, respectively, at increasing spatial and temporal scales, and require increasing recovery time. Small-scale selective extraction has little system-wide effect, but regeneration is slow even on single hectare clear-cuts due to rapid soil acidification. Petroleum is the primary pollutant of Caribbean mangal, and results in tree defoliation, stand death, and loss of associated sessile and mobile animal species. Hydrocarbons persist in mangrove sediments for decades, and are correlated with increasing seedling mutation rates. Chemical, industrial, and urban wastes are associated with increased heavy metal content of seedlings, stand die-back, reduced system-wide species richness, and higher incidence of *Vibrio* spp. (shellfish

poisoning). Mangal has been reclaimed for urbanization, industrialization, and increasingly, for tourism. Overall, the region is losing mangrove forests at approximate to 1 percent per yr, although the rate is much faster on the Caribbean mainland (approximate to 1.7% yr(-1)) than it is on the islands (approximate to 0.2% yr(-1)). The region's fisheries are declining at a similar rate, as most commercial shellfish and finfish use mangal for nurseries and/or refugia. Few Caribbean states have legislation or enforcement capabilities to protect or manage mangal, although at least 11 international treaties and conventions could be applied to conserve or sustainably use these forests. These treaties may protect riverine and basin mangal, but are likely to be moot with respect to fringing mangal, which may vanish as a consequence of global climate change. Growth enhancements of mangroves resulting from increasing atmospheric CO₂ probably will not compensate for negative effects of concomitant rises in regional sea level.

Ellison, J. C. (1996). "Pollen evidence of Late Holocene mangrove development in Bermuda." Global Ecology and Biogeography Letters 5(6): 315-326.

Bermuda is the northern latitudinal limit for mangroves, but communities are diverse and productive. Two pollen diagrams from the largest mangrove area show vegetation changes over the last 5000 years. From 5000 to 2100 years ago this was a marsh wetland, and pollen evidence is also shown of the dryland endemic forest before colonisation of Bermuda. Establishment of mangroves has only occurred in the last 3000 years, when sea-level rise slowed from 26 to 7 cm/100 years. Flotation experiments indicate that propagules could readily colonize from the Caribbean, and evidence both of cooler climate during the glacial and that none of Bermuda's many endemics utilize a mangrove habitat suggests that mangroves have had discontinuous presence in Bermuda through the Late Pleistocene. This study shows that mangrove ranges may be more plastic than was previously thought, subject to availability of habitats rather than dispersal capability.

Ellison, A. M. and E. J. Farnsworth (1996). "Spatial and temporal variability in growth of *Rhizophora* mangrove saplings on coral cays: Links with variation in insolation, herbivory, and local sedimentation rate." Journal of Ecology 84(5): 717-731.

1 We used demographic growth analysis to quantify seasonal and annual patterns of shoot and root module production by *Rhizophora* mangrove saplings growing on three coral cays in Belize, Central America. We investigated scaling relationships among root and shoot modules, leaf life-span, effects of herbivores on module and whole plant

growth, and differences in growth under different sedimentation regimes. 2 Production of new shoots and aerial roots occurred seasonally. Annual peaks in solar insolation occurred in May; relative rates of change in numbers of shoot meristems and leaves, and stem length peaked one month following. Relative rate of change in numbers of aerial roots peaked one month following this shoot flush, and roots elongated primarily during the dry season. 3 Increased water depth was positively correlated with the ratio of root length to shoot length in saplings. Mean shoot growth rate was significantly lower at cays exhibiting relatively low sedimentation rates, as well as at similar locales within cays. 4 Average leaf life-span was 9 months. During an outbreak of the mangrove skipper *Phocides pigmalion*, insect herbivores shortened leaf life-span by increasing leaf abscission rate. Insect folivores reduced above-ground net primary production available for export to adjacent marine ecosystems by 5-20%. Up to seven-fold increases in percentage of roots bored by isopods occurred concomitantly with annual peaks in new root production. Relative elongation rate of roots decreased five-fold following isopod attack. However, whilst both insects and isopods tracked production of and consumed new modules, neither consumer contributed significantly to variance in whole-plant growth. 5 Demographic growth analysis is a powerful tool with which to predict dynamic responses of module production and whole-plant growth in response to local environmental conditions. Our analyses illustrate that growth of mangroves are sensitive to seasonal patterns of insolation, to decreasing sedimentation and to increasing water depth. Given that growth of mangrove saplings on coral cays declines significantly with sedimentation rate, persistence of these forests is unlikely if sea level in the Caribbean increases as predicted.

Ellison, A. M. and E. J. Farnsworth (1997). "Simulated sea level change alters anatomy, physiology, growth, and reproduction of red mangrove (*Rhizophora mangle* L.)." Oecologia **112**(4): 435-446.

Tropical coastal forests - mangroves - will be one of the first ecosystems to be affected by altered sea levels accompanying global climate change. Responses of mangrove forests to changing sea levels depend on reactions of individual plants, yet such responses have not been addressed experimentally. We report data from a long-term greenhouse study that assessed physiological and individual growth responses of the dominant neotropical mangrove, *Rhizophora mangle*, to levels of inundation expected to occur in the Caribbean within 50-100 years. In this study, we grew potted plants in tanks with simulated semidiurnal (twice daily) high tides that approximated current conditions (MW

plants), a 16-cm increase in sea level (LW plants), and a 16-cm decrease in sea level (HW plants). The experiment lasted 2 years, beginning with mangrove seedlings and terminating after plants began to reproduce. Environmental (air temperature, relative humidity, photosynthetically active radiation) and edaphic conditions (pH, redox, soil sulfide) approximated field conditions in Belize, the source locale for the seedlings. HW plants were shorter and narrower, and produced fewer branches and leaves, responses correlated with the development of acid-sulfide soils in their pots. LW plants initially grew more rapidly than MW plants. However, the growth of LW plants slowed dramatically once they reached the sapling stage, and by the end of the experiment, MW plants were 10-20% larger in all measured growth parameters. Plants did not exhibit differences in allometric growth as a function of inundation. Anatomical characteristics of leaves did not differ among treatments. Both foliar C:N and root porosity decreased from LW through MW to HW. Relative to LW and HW plants, MW plants had 1-7% fewer stomata/mm², 6-21% greater maximum photosynthetic rates, 3-23% greater absolute relative growth rates (RGRs), and a 30% higher RCR for a given increase in net assimilation rate. Reduced growth of *R. mangle* under realistic conditions approximating future inundation depths likely will temper projected increased growth of this species under concomitant increases in the atmospheric concentration of CO₂.

Eong, O. J. (1993). "Mangroves - a Carbon Source and Sink." Chemosphere 27(6): 1097-1107.

The mangrove ecosystem in many wet tropical areas represents one of the most, if not the most productive of natural ecosystems. The question that has occupied the minds of many mangrove scientists is "What is the fate of this high productivity"? More recently this question has gained added relevance as a result of the increase in global carbon dioxide concentration. Are mangroves sinks of atmospheric carbon? We try to answer these questions using 15 years of data from the Matang Mangrove Forest Reserve and the Sungai Merbok Forest Reserve, in Peninsular Malaysia. We take a quick look at the palaeo-geological evidence on sea level changes in the Straits of Malacca during the recent past (Holocene) to give us a better perspective of the Matang and Merbok mangroves and emphasise the dynamics and ephemeral characteristics of the mangrove ecosystem. The pristine forest of Matang has a mean nett annual above-ground productivity of 18 t dry organic matter ha⁻¹ yr⁻¹ whereas the same forest managed on a sustained yield basis is a good 20% more productive. If harvested timber is used as fuel wood then much of what is fixed is released back into the atmosphere. On the other hand, if harvested timber is used

as pilings then significant amounts of mangrove carbon are locked away. We estimate that for the mangroves of Matang some 1.5 tC ha⁻¹ yr⁻¹ is buried each year over the past 8,000 years or so. The impact of man (since the beginning of this century) has resulted in an initial increased release of carbon into the atmosphere (in the first half of this century) as a result of the use of mangrove timber as fuel-wood but sustained yield management has ensured a carbon balance between what is fixed as timber and what is burned. The present management system (which produces significant amounts of slash and stumps) may result in increased amounts of burial (i.e. more than the 1.5 tC ha⁻¹ yr⁻¹). To demonstrate that the terms 'source' and 'sink' are relative terms, we show that mangroves may (at the same time as being a sink for atmospheric carbon) also be a source of carbon in that they may out-well significant amounts of carbon to adjacent coastal ecosystems and thus play a vital role in coastal fisheries production. Conversion of mangrove to aquaculture ponds could result in the release (from about 1,000 years accumulated mangrove sediments) of some 75 t C ha⁻¹ yr⁻¹ to the atmosphere over a 10-year period. This is 50 times the sequestering rate.

Ewel, K. C., R. R. Twilley, et al. (1998). "Different kinds of mangrove forests provide different goods and services." Global Ecology and Biogeography Letters 7(1): 83-94.

The goods and services that mangrove forests provide to society are widely understood but may be too generally stated to serve as useful guidelines in decision-making. Understanding the differences between fringe, riverine, and basin forests map help to focus these guidelines and to determine the best use of a particular forest. Fringe mangroves are important primarily for shoreline protection. Riverine forests, which are likely to be the most productive of the three types of forests, are particularly important to animal and plant productivity, perhaps because of high nutrient concentrations associated with sediment trapping. Basin forests serve as nutrient sinks for both natural and anthropogenically enhanced ecosystem processes and are often important sources of wood products. Exploitation of a forest for one particular reason may make it incapable of providing other goods and services.

Farnsworth, E. J., A. M. Ellison, et al. (1996). "Elevated CO₂ alters anatomy, physiology, growth, and reproduction of red mangrove (*Rhizophora mangle* L)." Oecologia 108(4): 599-609.

Mangroves, woody halophytes restricted to protected tropical coasts, form some of the most productive ecosystems in the world, but their capacity to act as a carbon source or sink under climate change is unknown. Their ability to

adjust growth or to function as potential carbon sinks under conditions of rising atmospheric CO₂ during global change may affect global carbon cycling, but as yet has not been investigated experimentally. Halophyte responses to CO₂ doubling may be constrained by the need to use carbon conservatively under water-limited conditions, but data are lacking to issue general predictions. We describe the growth, architecture, biomass allocation, anatomy, and photosynthetic physiology of the predominant neotropical mangrove tree, *Rhizophora mangle* L., grown solitarily in ambient (350 $\mu\text{l}(-1)$) and double-ambient (700 $\mu\text{l}(-1)$) CO₂ concentrations for over 1 year. Mangrove seedlings exhibited significantly increased biomass, total stem length, branching activity, and total leaf area in elevated CO₂. Enhanced total plant biomass under high CO₂ was associated with higher root:shoot ratios, relative growth rates, and net assimilation rates, but few allometric shifts were attributable to CO₂ treatment independent of plant size. Maximal photosynthetic rates were enhanced among high-CO₂ plants while stomatal conductances were lower, but the magnitude of the treatment difference declined over time, and high-CO₂ seedlings showed a lower P-max at 700 $\mu\text{l}(-1)$ CO₂ than low-CO₂ plants transferred to 700 $\mu\text{l}(-1)$ CO₂: possible evidence of downregulation. The relative thicknesses of leaf cell layers were not affected by treatment. Stomatal density decreased as epidermal cells enlarged in elevated CO₂. Foliar chlorophyll, nitrogen, and sodium concentrations were lower in high CO₂. Mangroves grown in high CO₂ were reproductive after only 1 year of growth (fully 2 years before they typically reproduce in the field), produced aerial roots, and showed extensive lignification of the main stem; hence, elevated CO₂ appeared to accelerate maturation as well as growth. Data from this long-term study suggest that certain mangrove growth characters will change flexibly as atmospheric CO₂ increases, and accord with responses previously shown in *Rhizophora apiculata*. Such results must be integrated with data from sea-level rise studies to yield predictions of mangrove performance under changing climate.

Field, C. D. (1995). "Impact of Expected Climate-Change On Mangroves." *Hydrobiologia* 295(1-3): 75-81.

There is a consensus of scientific opinion that the activities of man will cause a significant change in the global climate over the next hundred years. The rising level of carbon dioxide and other industrial gases in the atmosphere may lead to global warming with an accompanying rise in sea-level. Mangrove ecosystems grow in the intertidal zones in tropical and sub-tropical regions and are likely to be early indicators of the effects of climate change. The best estimates of predicted climate change in

the literature are presented. It is suggested that a rise in mean sea-level may be the most important factor influencing the future distribution of mangroves but that the effect will vary dramatically depending on the local rate of sea-level rise and the availability of sediment to support reestablishment of the mangroves. The predicted rise in mean air temperature will probably be of little consequence to the development of mangroves in general but it may mean that the presence of mangroves will move further north and south, though this will depend on a number of additional factors. The effect of enhanced atmospheric CO₂ on the growth of mangroves is unknown at this time but that there is some evidence that not all species of mangroves will respond similarly. The socio-economic impacts of the effects of climate change on mangrove ecosystems may include increased risk of flooding, increased erosion of coast lines, saline intrusion and increased storm surges.

Fujimoto, K. and T. Miyagi (1993). "Development Process of Tidal-Flat Type Mangrove Habitats and Their Zonation in the Pacific-Ocean - a Geomorphological Study." Vegetatio **106**(2): 137-146.

Using the sites of Pagbilao, the Philippines and Pohnpei Island, the Federated States of Micronesia, zonation and development process of mangrove habitats on tidal flats situated in the geomorphic environment excluding estuary, delta, and lagoon or backmarsh behind barrier or beach ridge were discussed from the viewpoint of geomorphology. Zonations of the mangrove forests were observed from seaward to landward in both areas. Most of the zones correspond with the variations of the ground level or deposit. Mangrove peat which has a thickness of about 2 meters was deposited in the main part of the mangrove habitats in both areas. On the other hand, some large *Sonneratia alba* were observed in the *Rhizophora apiculata* habitat on Pohnpei Island. The authors presumed that some of the large *S. alba* have survived by regeneration from fallen stems since the mangrove forest developed on the present site. The maximum depth of the mangrove peat layer reaches 1.7 meter below the present sea level in Pagbilao and over 2.5 meters at Pohnpei Island. The bottom of the mangrove peat was dated at about 2,000 y.B.P. in both areas by the radiocarbon method. The mangrove peat depositional areas have not been moved during the last 2,000 years. Therefore, the mangrove forests seem to have grown in the present sites since 2,000 y.B.P. and accumulated peat in connection with the subsequent sea-level rise.

Fujimoto, K., R. Tabuchi, et al. (1995). "Site environments and stand structure of the mangrove forests on Pohnpei Island, Micronesia." Jarq-Japan Agricultural Research Quarterly **29**(4): 275-284.

In order to obtain fundamental data for the prediction of stand productivity and sustainable management, two permanent plots, 1 ha each, were established in two types of mangrove habitats, i.e. estuary and coral reef types, on Pohnpei Island, Micronesia. This paper analyzes the stand structure and the site environments and their relationships. The number of trees in the estuary type was less than half of that in the coral reef type and tree size in the former was larger than in the latter. These differences were attributed to the difference in the age between the forests which was estimated from the thickness of the mangrove peat layers. Distribution of *Rhizophora apiculata* and *Xylocarpus granatum* trees may possibly be related to the submergence frequency which affects the soil water content and soil water EC. Large *Sonneratia alba* trees were widely scattered in both plots. These trees were assumed to have survived by vegetative reproduction in spite of the changes in site environments that have occurred since the mangrove forests were developed at their present site. There were few *Bruguiera gymnorrhiza* and *X. granatum* trees with a diameter between 10 and 25 cm in the estuary type. This fact suggests that some environmental changes which disturbed the establishment of *B. gymnorrhiza* and *X. granatum* trees, such as a relative rise in sea level, occurred during a certain period of time.

Gagan, M. K., D. P. Johnson, et al. (1994). "Sea-Level Control of Stacked Late Quaternary Coastal Sequences, Central Great-Barrier-Reef." Sedimentology **41**(2): 329-351.

Lithofacies analysis, pollen assemblages and radiocarbon age dates of 20 stratigraphic drill holes are used to develop an evolutionary history for late Quaternary sedimentation in two coastal embayments landward of the central Great Barrier Reef. Different physiographic settings of the embayments result in two contrasting styles of sedimentary sequence: (a) an exposed, moderate energy, beach barrier-lagoon system (Wyvuri Embayment) and (b) a protected, low energy, muddy inlet fill sequence (Mutcherro Inlet). Despite sharp contrast in sequence style, similar depositional cycles occur in both embayments in response to late Quaternary sea level fluctuations including: (1) a last interglacial highstand (+2 m; c. 125 000 yr BP) beach barrier (Wyvuri); (2) an early to mid-Holocene (8000-6100 yr BP) transgressive beach barrier-lagoon (Wyvuri) and estuarine infill (Mutcherro); and (3) mid-Holocene to present highstand beach barrier (Wyvuri) and estuarine (Mutcherro) progradation. Preservation of such cycles in the stratigraphic record would produce a series of vertically stacked and offset linear barrier sands surrounded by lagoonal mud and fine grained shoreface sediment juxtaposed to muddy, estuarine infills. Sea level elevations are well

recorded by the upward transition from Rhizophora-dominated intertidal mangrove mud to freshwater swamps (clearly identified by pollen analysis) and by the basal contacts of beach barrier sediments which sharply overlie the upper shoreface. Transgressive sedimentation is interrupted in both embayments by a constructional beach barrier (Wyvuri) and abbreviated progradation (Mutchero) corresponding to a 5 m pause in relative sea level rise at c. 6800 yr BP. Sea level control of fine scale coastal sedimentation patterns is beginning to be widely recognized and provides an accurate analogue for stacked ancient sequences.

Gischler, E. and A. J. Lomando (1997). "Holocene cemented beach deposits in Belize." Sedimentary Geology **110**(3-4): 277-297.

Two types of cemented beach deposits occur on reef islands off the coast of Belize. These are (1) intertidal beachrock that is dominantly cemented by marine aragonite and high-magnesium- calcite cements, and (2) supratidal cayrock that is cemented mainly by vadose low-magnesium-calcite cements. Besides differences in position relative to present sea level and resulting early diagenetic features, beachrock and cayrock can be distinguished on the basis of differences in composition, texture, geographical position, and age. Whereas the composition of beachrock is similar to that of the adjacent marginal reef sediments, cayrock is enriched in benthic foraminifera. Intertidal beachrock is moderately to well sorted and well cemented, while supratidal cayrock is very well sorted, poorly cemented and friable. Beachrock occurs preferentially on windward beaches of sand-shingle cays on the middle and southern barrier reefs and on the isolated platforms Glovers and Lighthouse Reefs. Cayrock only occurs on larger mangrove-sand cays of the isolated platforms Tumeffe Islands, Lighthouse Reef, and the northern barrier reef. C-14-dating of ten whole-rock and mollusk shell samples produced calibrated dates between AD 345 and AD 1435 for beachrock and between BC 1085 and AD 1190 for cayrock. The large-scale distribution of beachrock in Belize supports the contention that physical processes such as water agitation rather than biological processes control beachrock formation and distribution. Only on windward sides of cays that are close to the reef crest, where large amounts of seawater flush the beaches, considerable amounts of cements can be precipitated to produce beachrock. Cayrock forms due to cementation in the vadose zone and is only preserved on larger, stable mangrove-sand cays.

Gischler, E. and J. H. Hudson (1998). "Holocene development of three isolated carbonate platforms, Belize, central America." Marine Geology **144**(4): 333-347.

Locally operating factors such as topography of the reef basement and exposure to waves and currents rather than regionally effective factors such as the post-glacial sea level rise in the western Atlantic explain the different Holocene developments of the three isolated carbonate platforms Glovers Reef, Lighthouse Reef, and Turneffe Islands offshore Belize. A series of NNE-striking tilted fault-blocks at the passive continental margin forms the deep basement of the Belize reefs. Glovers and Lighthouse Reefs are located on the same fault-block, while Turneffe Islands is situated west of Lighthouse Reef on an adjacent fault-block. The three platforms are surrounded by deep water and have surface-breaking reef rims. Significant differences exist between platform interiors. Glovers Reef has only 0.2% of land and an 18 m deep, well-circulated lagoon with over 800 patch reefs. Lighthouse Reef has 3% of land and a well-circulated lagoon area. Patch reefs are aligned along a NNE-striking trend that separates a shallow western (3 m) and a deeper eastern (8 m) lagoon. Turneffe Islands has 22% of land that is mainly red mangrove. Interior lagoons are up to 8 m deep and most have restricted circulation and no patch reefs. Surface sediments are rich in organic matter. In contrast, the northernmost part of Turneffe Islands has no extensive mangrove development and the well-circulated lagoon area has abundant patch reefs. Holocene reef development was investigated by means of 9 rotary core holes that all reached Pleistocene reef limestones, and by radiometric dating of corals. Maximal Holocene reef thickness reaches 11.7 m on Glovers Reef, 7.9 m on Lighthouse Reef, and 3.8 m on Turneffe Islands. Factors that controlled Holocene reef development include the following. (1) Holocene sea level. The margin of Glovers Reef was flooded by the rising Holocene sea ca. 7500 YBP, that of Lighthouse Reef ca. 6500 YBP, and that of Turneffe Islands between 5400 and 4750 YBP. All investigated Holocene reefs belong to the keep-up type, even though the three platforms were flooded successively and, hence, the reefs had to keep pace with different rates of sea level rise. (2) Pre-Holocene topography. Pleistocene elevation and relief are different on the three platforms. This is the consequence of both tectonics and karst. Different elevations caused successive reef initiation and they also resulted in differences in lagoon depths. Variations in Pleistocene topography also explain the different facies distribution patterns on the windward platforms that are located on the same fault-block. On Lighthouse Reef tectonic structures are clearly visible such as the linear patch reef trend that is aligned along a Pleistocene fault. On Glovers Reef only short linear trends of patch reefs can be detected because the Pleistocene tectonic structures are presumably masked by the higher Holocene thickness. The lower

Pleistocene elevation on Glovers Reef is probably a consequence of both a southward tectonic tilt, and stronger karstification towards the south related to higher rainfall. (3) Exposure to waves and currents. Glovers Reef, Lighthouse Reef, and the northernmost part of Turneffe Islands receive the maximum wave force as they are open to the Caribbean Sea. Adjacent lagoons are well-circulated and have luxuriant patch reef growth and no extensive mangrove development. By contrast, most of Turneffe Islands is protected from the open Caribbean Sea by Lighthouse Reef to the east and is only exposed to reduced wave forces, allowing extensive mangrove growth in these protected areas. (C) 1998 Elsevier Science B.V.

Gonzalez, H. and M. Ramirez (1995). "The Effect of Nickel Mining and Metallurgical Activities On the Distribution of Heavy-Metals in Levisa Bay, Cuba." Journal of Geochemical Exploration **52**(1-2): 183-192.

The distribution of Ni, Co, Fe, Mn, Cu, Pb and Zn was investigated in surface and core sediment samples and in the leaves of the red mangrove (*Rhizophora mangle*) from Levisa Bay, an area affected by nickel mining and metallurgical activities. The results revealed that these activities have seriously polluted the sediments, especially by Ni, Fe, Co and Mn, with concentrations decreasing with increasing distance from discharge sources. The concentrations of Fe (0.64-22.66%) and Co, Mn and Ni (7.7-324, 125-2957 and 69-4764 µg/g, respectively) were up to two orders of magnitude greater than those of non-polluted coastal areas in Cuba. *Rhizophora mangle* was shown to be a useful bioindicator of heavy metal pollution in the studied ecosystem.

Hayward, B. W., H. R. Grenfell, et al. (1997). "Foraminiferal associations in the upper Waitemata Harbour, Auckland, New Zealand." Journal of the Royal Society of New Zealand **27**(1): 21-51.

Census data on 68 benthic foraminiferal tests in 56 seafloor sediment samples from the upper Waitemata Harbour, Auckland, New Zealand (36 degrees 50' S, 174 degrees 40' E) are analysed by Cluster Analysis. The faunal samples, taken from extreme high tide to 8 m depth, and from strongly brackish to normal marine salinities, are grouped into 7 associations. Characterising species of each association are found by calculating Association Scores for each species, based on its mean abundance, relative abundance, fidelity, persistence, and dominance within each association. The foraminiferal associations are: JE, *Jadammina macrescens*-*Elphidium excavatum* f. *clavata* - high tidal, sandy mud, in salt meadow and dwarf mangrove swamp, with near normal marine salinity; Tn, *Trochammina inflata* - around mean high water springs in salt marsh and salt meadow, with variable

salinity; M, *Miliammina fusca* - subtidal channels and intertidal mud banks, mangrove swamp, and salt marsh with reduced salinity; H, *Haplophragmoides wilberti* - above mean high water, in salt meadow and salt marsh, with slightly reduced salinity; Tr, *Trochammina salsa* intertidal sandy mud banks at head of estuary, with lowest salinity; AM, *Ammonia beccarii*-*Miliammina fusca* - intertidal and shallow subtidal mud flats and channels, with near normal marine to slightly reduced salinity; A, *Ammonia beccarii* - intertidal and subtidal (to 8 m+ depth) muddy sand, with near normal marine to slightly reduced salinity. In the cluster analysis dendrogram of samples, the first-order division produces a three-way split of (1) near-normal marine salinity agglutinated associations (JE,Tn); (2) low-salinity, agglutinated associations (M,H,Tr); and (3) near-normal marine salinity, calcareous associations (AM,A). The dominant foraminiferal species are grouped by cluster analysis into five species associations; these correlate closely with the sample associations. There is an overall trend of increasing species diversity from brackish to saline and from intertidal to subtidal. This study supports earlier conclusions that salinity and tidal exposure are the two most influential factors in determining foraminiferal distribution patterns in sheltered tidal harbours and estuaries. A common species in the near-normal salinity subtidal channels, *Siphogenerina striata*, may have been introduced into the harbour with foreign shipping.

Homji, V. M. M. (1995). "Curbing coastal erosion - Example of Udvada (South Gujarat)." National Academy Science Letters-India **18**(9-10): 193-198.

An impending threat to our coastline is through the green house effect and the consequent rise in the sea-level. However, long before began the talk of global warming several of our shorelines came under the assault of the advancing sea. One of the glaring examples is of the settlement of Udvada in South Gujarat housing the oldest Fire Temple of the Parsis. The first onslaught occurred nearly five decades ago and gradually the beach has been eroding. Horizontal walls have not proved very effective IVT) doped with chromium oxide have been determined by A two pronged attack envisages protecting the beach by raising plantations of suitable species (*Casuarina*, *Agave* *Ipomoea*) to bind the sand, to serve as shelter belt preventing the salt spray from invading fertile land in the interior, reducing the salinity of well-water and soil (through back-mangrove species of economic importance like *Salvadora*). In a location facing acute fuelwood shortage, alternative energy plantations of fast growing species like *Acacia holosericea* will provide fire-wood for the weaker sections of the society, sparing the trees raised for the protection

of the shorelines. Sloping, permeable walls and sand injection are alternatives on the engineering side. Understanding the problem from geomorphological angle is the first necessity. The experiment of combating sea-erosion launched by the Bombay based SAVE UDVADA Committee with support of the Central and State (Gujarat) Governments will lay a foundation for restoration work elsewhere in the country.

Hoorn, C. (1993). "Marine Incursions and the Influence of Andean Tectonics On the Miocene Depositional History of Northwestern Amazonia - Results of a Palynostratigraphic Study." Palaeogeography Palaeoclimatology Palaeoecology **105**(3-4): 267-309.

New palynological and sedimentological data permit the age of Neogene sediments in northwestern Amazonia to be established more precisely, and indicate that major environmental changes occurred in the area during this time. Based on a study of borehole samples the age of the Solimoes Formation (Solimoes Basin, northwestern Brazil) is determined as Miocene and five pollen zones are distinguished which are correlated with existing zonations for northern South America. In addition, 30 new sporomorphs are described which belong to the following 12 genera: Psilamonocolpites, Retimonocolpites, Retitricolpites, Retibrevitricolpites, Psilatroporites (nov. gen.), Bombacacidites, Psilatroporites, Retitricolporites, Rugutricolporites, Psilastephanoporites (nov. gen.), Psilastephanocolporites and Heterocolpites. A correlation is made between; the Brazilian wells and some of the studied outcrops in Colombian and Peruvian Amazonia based on palynological marker species. The presence of coastal elements such as mangroves (Zonocostites), indicates that during the Miocene this area was influenced by marginal marine conditions caused by several marine incursions. These incursions may be related to global sea level fluctuations. Miocene marine phases also are known from sites elsewhere in northern South America which at present, like northwestern Amazonia, are entirely ruled by continental conditions. Sediment composition shows that during the Early Miocene the Guyana Shield was the major source area of sediment input in the basins of northwestern Amazonia. In the interval from Early to Middle Miocene the Andes became the major sediment source area. The change in provenance is related to the uplift of the Eastern Cordillera. This event caused a major change in palaeoenvironment and palaeogeography in northwestern Amazonia which was characterized by the reverse of a northwestward directed fluvial system into an eastward directed fluvial-lacustrine system with an estuarine character.

Hoorn, C. (1994). "An Environmental Reconstruction of the Palaeo-Amazon River System (Middle-Late Miocene, Nw Amazonia)." Palaeogeography Palaeoclimatology Palaeoecology **112**(3-4): 187-238.

New sedimentological and palynological data from the Tertiary sediments in the Upper Amazon River area suggest that these sediments are fluvio-lacustrine deposits of Middle to Late Miocene age. They were generated as a result of the uplift of the Eastern Cordillera (Andes) and constitute possibly the oldest relics of the Amazon River system. The palaeoenvironment in which these sediments were deposited is characterized by extensive wetlands environments formed by swamps, shallow lakes, crevasse splay channels and crevasse-delta lakes where the channel environment is poorly represented. The palaeovegetation was dominated by palms (e.g. *Mauritia* and *Grimsdalea*), riverine taxa (e.g. *Bombacaceae*, *Amanoa* and *Alchornea*), ferns and fern allies (e.g. *Polypodiaceae* and *Selaginellaceae*), floating meadows (*Gramineae*) and aquatic taxa (*Ceraropteris*, *Botryococcus* and *Azolla*). The relative abundance of *Gramineae* and the occurrence of Andean-type pollen taxa is related to the Andean origin of the fluvial system. The varzeas of the present Upper Amazon River flood-basin are probably the best analogue for the Middle to Late Miocene environment. Intervals rich in marine palynomorphs, mangrove pollen, brackish tolerant molluscs and ostracods, and ichnofossils of the *Thalassinoides*-*Teichichnus* association suggest that the palaeoenvironment was characterized by brackish conditions and marine influence. These marine incursions are possibly related to the Langhian and the Serravallian global sea-level rise. Although in the Middle Miocene a global cooling is known to have occurred, no indicators of a cooler climate have been observed in the Miocene palynoflora of the Upper Amazon River area. Finally, four new sporomorph species are described belonging to the form-genera *Psilatrilletes*, *Clavainaperturites* and *Psilaperiporites*.

Ishshalomgordon, N., G. H. Lin, et al. (1992). "Isotopic Fractionation During Cellulose Synthesis in 2 Mangrove Species - Salinity Effects." Phytochemistry **31**(8): 2623-2626.

Carbon, non-exchangeable hydrogen, and oxygen isotope ratios of cellulose of *Avicennia germinans* and *Rhizophora* mangle plants hydroponically grown under different salinities (0, 18, 45‰ sea water, but with irrigation waters having the same isotopic ratios) were measured to determine the possibility of using isotopic ratios of plant tissues as biological recorders of sea level rise. There was a large variability in the δ -D values of leaf nitrated cellulose between different treatments and even within a single

treatment for both *A. germinans* and *R. mangle*. Thus, delta-D values of non-exchangeable hydrogens of cellulose cannot be used as a historical tracer for utilization of ocean water or freshwater by mangroves. In contrast, delta-O-18 values of cellulose were not significantly different between different salinity treatments for both mangroves, indicating that delta-O-18 of cellulose can be used as a sea water tracer. Delta-C-13 values of cellulose did not vary directly with salinity as has been observed with other plants. Delta-C-13 values of cellulose from *A. germinans* were the lowest for plants growing at 18% sea water, with cellulose from plants growing in 0 and 45% sea water having significantly higher delta-C-13 values. delta-C-13 values of cellulose from *R. mangle* were the highest for plants grown in 45% sea water, with plants grown in 0 and 18% sea water having equally lower delta-C-13 values.

Jahns, S. (1996). "Vegetation history and climate changes in West Equatorial Africa during the Late Pleistocene and Holocene, based on a marine pollen diagram from the Congo fan." Vegetation History and Archaeobotany 5(3): 207-213.

Palynological investigation of the marine core, GeoB 1008-3, from near the mouth of the Congo river (6 degrees 35.6 ' S/10 degrees 19.1 ' E), provides information about the changes in vegetation and climate in West Equatorial Africa during the last 190 ka. The pollen diagram is divided into zones 1-6 which are considered to correspond in time with the marine isotope stages 1-6. Oscillations in temperature and moisture are indicated during the cold stage 6. During stage 5, two cooler periods (5d and 5b) can be shown with an expansion of Podocarpus forests to lower elevations on the expense of lowland rain forest. Extended mangrove swamps existed along the coast in times of high sea level (stages 5 and 1).

Jallow, B. P., M. K. A. Barrow, et al. (1996). "Vulnerability of the coastal zone of The Gambia to sea level rise and development of response strategies and adaptation options." Climate Research 6(2): 165-177.

The coastal zone of The Gambia consists of 70 km open ocean coast and 200 km sheltered coast. Only about 20 km of the open coastline is significantly developed and this includes Banjul (the capital city), Bakau and Cape St. Mary, Fajara and the Tourism Development Area (TDA). Tourism is the most important economic sector in the coastal zone and contributes about 10% of the government revenue. Fisheries and agriculture are also important coastal industries. In this study the Aerial Videotape-assisted Vulnerability Analysis (AVVA) technique has been used to provide a detailed analysis of vulnerability to sea level rise, and adaptation strategies have been identified. The data used

includes a video recording of the coastline, color infrared and black and white aerial photography, topographic maps, bathymetric maps, a geological map of The Gambia and still photographs. The data have been used to characterize the coastal zone into 9 geomorphological units, wherein the cultural and heritage sites of economic importance have been delineated and characterized according to their biophysical and economic importance. Future erosion rates have been projected by applying the Bruun Rule, and future total land loss due to inundation in response to global warming and accelerated sea level rise has been determined. The sea level rise scenarios considered are 0.2 m, 0.5 m, and 1.0 m per century. Inundation is estimated to be about $92.32 \times 10^6 \text{ m}^2$ for a 1.0 m sea level rise, $45.89 \times 10^6 \text{ m}^2$ for a 0.5 m sea level rise and $4.96 \times 10^6 \text{ m}^2$ for a 0.2 m sea level rise. The greater part of this area lost will be wetlands and mangrove systems important for fish spawning areas and habitats for wildlife. Shoreline retreat is estimated to vary between about 6.8 m in cliffy areas to about 880 m for more flat and sandy areas based on the Bruun Rule. Population and physical structures at risk have been determined. Attempts have been made to report this loss in monetary terms, but firm figures are not yet available. Only one unit of the coastal zone has been evaluated. In this unit, it is expected that the capital city will be completely lost through both erosion and inundation within 50 to 60 yr with a total of 42000 persons displaced. Lands and physical structures to be lost are estimated at US\$ 217 million. Response strategies and adaptation options identified include: innovative sand management, building and rehabilitation of groins, construction of revetments to protect important areas, construction of sea-walls/bulkheads, public outreach and awareness, building regulations and urban growth planning, wetland preservation and mitigation, and development of a coastal zone management plan.

Jelgersma, S., M. Vanderzipp, et al. (1993). "Sealevel Rise and the Coastal Lowlands in the Developing-World." Journal of Coastal Research 9(4): 958-972.

About two hundred low-lying coastal areas in the developing world were characterized in terms of a range of variables influencing the nature of the effects on each area of a gradual eustatic sealevel rise. The areas were clustered with weightings emphasizing the variables considered most important, and a brief description of the probable effects was given for one area from each of the main clusters. This paper summarizes processes affecting low-lying coastal areas, methods of characterization and clustering, and reports descriptions for examples from three clusters. A sea level rise does not only affect the coastline

and the structures along it, but may also change the hydrology, the soils and the natural vegetation of the potential for agriculture over an appreciable distance inland. The nature and extent of these changes depends on, for example, the length of the dry season, the sediment supply from rivers, and the incidence of tropical cyclones. The basic tabular data set and the transformed one used for clustering are available from the third author for reanalysis on the basis of improvements in data, knowledge or insight. The maps are being entered into a geographic information system and should in due course be available in digital form.

JinEong, O., G. W. Khoon, et al. (1995). "Structure and productivity of a 20-year-old stand of *Rhizophora apiculata* BI mangrove forest." Journal of Biogeography **22**(2-3): 417-424.

Mangroves are dominant interface ecosystems between the land and the sea in the tropics, and are of importance in the economy of many of these regions in terms of mangrove-linked fisheries and forestry. Recently, mangroves have been of particular interest in relation to global change both because of the possible high carbon sequestration as well as being in the 'forefront' of any sea-level change, because of their location. To understand the impact of global change on these ecosystems (considered terrestrial and aquatic at the same time) and vice versa, it is necessary to obtain 'a more comprehensive and realistic picture of the terrestrial carbon cycle', which is one of the aims of the GCTE Programme. We therefore present here some of the results of our long-term study (started in the mid-1970s) on the carbon and nutrient budget of a mangrove ecosystem as a basis for further studies, including the proposed large-scale biogeochemical transects and climate models proposed by GCTE. The tree density of the 20 m x 40 m plot in the 20-year-old stand was equivalent to 2425 stems per hectare (1975 live trees per hectare). Size (girth at breast height) of *Rhizophora apiculata* trees ranged from 9 to 75.5 cm with a mean at 39 cm. The smallest live tree weighed 10 kg and the biggest weighed 510 kg with a mean biomass of 122 kg. About 70% of the trees were below 100 kg but the 30% of the bigger trees contributed to slightly more than half of the total biomass of the plot. The canopy had an average height of 21 m. The total standing biomass was 114 t C ha⁽⁻¹⁾; 74% of the biomass was in the trunk, 15% in the roots (10% in stilts and 5% belowground) and 10.6% in the canopy (only 2.6% in leaves). Using allometric regressions, we obtained a net productivity (root turnover and loss through leaching were not measured but only approximated as equal to small litter production) of 17 +/- 5 t C ha⁽⁻¹⁾ yr⁽⁻¹⁾. If greater accuracy (than +/- 30%) is needed, direct measurements of

root turnover and leaching from roots would be needed. Using the gas exchange method and using the mean value for a whole day's net photosynthesis measurements (averaged at $6 \mu \text{mol m}^{-2} \text{s}^{-1}$), $1.5 \mu \text{mol m}^{-2} \text{s}^{-1}$ for leaf respiration, a leaf area index of 4, and assuming respiration of the non-leaf tissues to be the same as for leaves, we estimated net productivity to be $11.35 \text{ t ha}^{-1} \text{ yr}^{-1}$, almost at the lower limit of the allometric estimate. Use of leaf to tree to stand models may improve the accuracy of this method. The main gaps are in fine root turnover and possible loss of carbon through leaching from the roots.

Kamaludin, B. H. (1993). "The Changing Mangrove Shorelines in Kuala Kurau, Peninsular Malaysia." Sedimentary Geology **83**(3-4): 187-197.

A considerable extent of the shoreline along the west coast of Peninsular Malaysia is vegetated by mangrove forests. Typically, one observes frequent change of position of the mangrove outer shore limit. The Kuala Kurau coastline in northwest Perak which provides a good example is selected for this study. The geological evidence indicates that marine sediments prevail throughout the Kuala Kurau coastal plain. Greenish-gray clay predominates with varying amounts of silt and sand, underlying the basically flat topography. The present shoreline has prograded from its initial position within a time span of about 5000 years. Similarly, from 1914 to 1969 a prograding shoreline trend is indicated. However, from 1969 to 1986 there was widespread erosion although both accreting and retreating situations were indicated. Erosion in the mangrove fringes, in the later years is related to sediment budget, freshwater supply, over-exploitation and utilisation of mangrove forest, and the effects (indirect) of the fishing industry.

Kamaludin, B. H. and B. M. Y. Azmi (1997). "Interstadial records of the last glacial period at Pantai Remis, Malaysia." Journal of Quaternary Science **12**(5): 419-434.

Two eustatic high sea stands during the last glacial period are recognised at Pantai Remis. These highstands, lower than present-day sea-level, are tropical manifestations of the ameliorating interstadial climate during the Weichselian/Devensian/Wisconsin glaciation in the Northern Hemisphere. The earlier highstand corresponds to a sea-level of 14.6 m below mean sea-level (MSL). It is interpreted as synchronous with Oxygen Isotope Stage 5a and is correlated with other known sea-level curves in other parts of the world. The younger high sea stand, dated 55810 +/- 1140 to 53870 +/- 1400 yr BP, indicates sea-level of 4.3 m below MSL. It represents an interstadial equivalent that lasted for at least 2000 yr, whereas the earlier interstadial period indicates a minimum duration of twice

this amount or very likely even longer, as reflected from the thickness of the accumulated deposits. The palynological records indicate that during interstadial times, climatic stability in the tropics is attained and was sufficiently long for vegetation to thrive and develop. The palynofloral constituents of the earlier interstadial phase at Pantai Remis showed the establishment of vegetation in a coastal setting, initiated by Pandanus swamp forests. Simultaneously, mangrove swamp flourished in the lower lying parts of the area, hence the presence of direct tidal influence is evident. Both the Pandanus and mangrove swamps were succeeded by mixed freshwater swamp forests of a *Camposperma*-*Calophyllum* assemblage. Subsequently a slightly open and somewhat drier mixed swamp forest prevailed, marked by the increase in fern spore representation. The later interstadial phase showed shorter vegetation successions, which commenced on the landward edge of a mangrove swamp forest. The mangrove was successively replaced by strand forest, as indicated by domination of *Casuarina equisetifolia*. The palynological assemblages in both the interstadial periods indicate similarity to the present-day coastal vegetation. This implies that during the interstadials the climate in the lowlands of Peninsular Malaysia and presumably throughout the equatorial region, was as that prevailing today. (C) 1997 by John Wiley & Sons, Ltd.

Kenig, F., A. Y. Huc, et al. (1990). "Sedimentation, Distribution and Diagenesis of Organic-Matter in a Recent Carbonate Environment, Abu-Dhabi, Uae." Organic Geochemistry **16**(4-6): 735-747.

In the modern hypersaline carbonate lagoon and sabkha sedimentary environments of Abu Dhabi (United Arab Emirates), three types of organic matter originate respectively from microbial mat, *Avicennia* mangrove, and *Halodule* lagoonal seagrass. The study of recent sedimentary processes and cross sections through the sabkha sediments lead to the definition of organo-sedimentary facies based on geochemical and sedimentological criteria. This permits the construction of an organo-sedimentary sequence which expresses the Holocene sedimentary record involving a transgressive and a regressive sequence. The various organic facies occur in both sequences. Heterogeneity within the individual organic facies reflects several factors, including sedimentation dynamics, mineral matrix, oxidation and reduction, and selective organic and mineral diagenesis. These parameters are discussed in terms of depositional environment and location within the organo-sedimentary sequence. Changes in distribution, quantity, and preservation potential of the buried organic matter are discussed in terms of sea level changes and sedimentary

accretion rates.

Larcombe, P., R. M. Carter, et al. (1995). "New Evidence For Episodic Postglacial Sea-Level Rise, Central Great-Barrier-Reef, Australia." Marine Geology **127**(1-4): 1-44.

We present an extensive database of 364 radiocarbon dates from coastal and marine sediments of the central Great Barrier Reef (GBR) shelf, of which 110 are previously unpublished. The elevation data have been reduced to a common datum (Australian Height Datum, AHD) and the various sources of error have been assessed. Using modern lithological and biological relationships with sea level, the elements of the radiocarbon database have been converted into sea-level indicators. The upper bound of the assembled dataset corresponds to a best-estimate sea-level curve, and the full dataset provides a narrow envelope for sea-level rise on the GBR shelf for the last 11-12 kyr (not including hydro-isostatic crustal flexing). The envelope is consistent with episodic rise in post-glacial sea levels. The rising post-glacial sea level probably included stillstands (or minor falls), at ca. -45 m AHD (at ca. 10.5 kyr B.P.), -5 m (7.8 kyr B.P.), -2 m (ca. 6 kyr B.P.) and +1.7 m (5.5 kyr B.P.). There is evidence for a significant fall in sea level between stillstands at -11 m (8.5 kyr B.P.) and -17 m (8.2 kyr B.P.). Stillstand durations apparently ranged between <200 years and ca. 1800 years. Rates of sea-level change varied between a fall of 20 mm/yr (20 m/kyr, pre-8.2 kyr B.P.) and a rise of 30 mm/yr (30 m/kyr, post-8.2 kyr B.P.). The vertical spread in the derived sea-level data is very wide. The use of shell material for dating seems unreliable and prone to large and unpredictable errors. Data from bulk mangrove muds appear reliable for determination of ancient sea level, but may at times result in sea level being placed up to 4 m below the true level. In-situ biogenic carbonates such as preserved oyster beds and coral micro-atolls are the most reliable indicators of sea-level position, while deposits of mangrove mud give a useful first-order approximation of ancient sea levels. Caution should be used in drawing 'sea-level curves' from few data points. We conclude that the post-11-12 kyr B.P. relative rise in sea level was episodic on the central GBR continental margin. More data are required to define clearly sea-level change up to ca. -20 m at 9 kyr B.P.

Larcombe, P. and R. M. Carter (1998). "Sequence architecture during the Holocene transgression: an example from the Great Barrier Reef shelf, Australia." Sedimentary Geology **117**(1-2): 97-121.

The application of sequence stratigraphic analysis to post-glacial sediments requires the correct identification of sequence boundaries, flooding surfaces and systems

tracts. The nature of coastal sediments deposited during sea-level cycles is complex and misinterpretation is easy, particularly in ancient sequences for which eustasy is inferred rather than demonstrated. A large core, seismic and radiocarbon database from Cleveland Bay, in tropical Queensland, allows detailed analysis of the systems tracts and parasequences developed during the late Holocene. Despite the large database, a unique sequence stratigraphic interpretation is not possible, because oscillations in the sea-level curve apparently occurred at a frequency higher than the resolving power of radiocarbon dating. Our best estimate is that the final stages of the Holocene sea-level rise comprise four parasequences, each deposited during episodic slowdowns in sea-level rise and/or a pulse of rapid sediment supply. Sea-level pauses probably occurred at 12-10 m below modern levels at 8.5 ka BP, followed by a fall to ca. -17 m at 8.1 ka BP, a very rapid transgression to ca. -10 m at 7.9 ka BP, a further transgression to ca. -5 m at 6.8 ka BP, and a final rise to the Holocene highstand at 1.65 m at 5.5 ka BP. The stratigraphic record of these sea-level rises is complex, occurs within the 'modern' shore-connected sedimentary wedge, and comprises parasequences associated with shorelines at -11 m (P-11), -17 m (P-17), -10 m (P-10), -5 m (P-5) and +1.65 m (P+1.7). Each parasequence comprises, in ascending order, overlapping estuarine-shoreline sediment (including mangrove mud and beach sand), and progradational shallow-bay muddy sand. Across the bay, units up to and including the lower parts of the shallow-bay mud correspond to the transgressive systems tract (TST) of the last 18 ka glacial/interglacial cycle (the particular parasequence represented being dependent upon location, especially depth). Bay mud above this level corresponds to the post -5.5 ka BP highstand systems tract (HST), which comprises sand cheniers on the coastal plain and bioturbated muddy sand in the shallow bay. The junction between the TST and the HST lies within the bay mud, and corresponds approximately to the local flooding surface for the P+1.7 parasequence deposited at the +1.65 m shoreline. Offshore, terrigenous TST strata do not occur over most of the middle and outer shelf, which instead is veneered with a thin 'mid-cycle shellbed'. The lower part of this shellbed is time-equivalent to the later part of the TST and the upper part is time-equivalent to the HST. Offshore, the maximum flooding horizon (MFH) and peak eustatic sea-level horizon (PESH) of the Late Pleistocene-Holocene sea-level cycle lie at some level within the mid-cycle shellbed. Nearshore, the MFH and PESH lie within the shore-connected sediment wedge at levels near the TST/HST boundary. However, at no locality do either the MFH and PESH necessarily correspond to a physical boundary within the stratigraphy.

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Lezine, A. M. and J. J. Chateaufneuf (1991). "Peat in the Niayes of Senegal - Depositional Environment and Holocene Evolution." Journal of African Earth Sciences **12**(1-2): 171-179.

The "Niayes" peat deposits north of Dakar, in Senegal, provide an unusual opportunity to study the continental and littoral detrital environment of the Holocene in West Africa. These organic deposits, that may attain a thickness of 10 m, accumulated in Late Pleistocene interdune basins whose extent and morphology depend closely upon the palaeohydrologic evolution of and the continental model for this zone during the Holocene. The present sub-Canarian climate of this region allows the preservation of an azonal vegetation of Guinean chorological affinity that is evidence of the wider development of now more southerly vegetation during the older Holocene. The nature of the sedimentary facies of these peatfields is closely related to the altitude of the basins of accumulation and the position of the fresh/salt water interface which conditions the recharge of the shallow aquifer. Thus, fresh-water and mangrove-swamp peats exist more or less closely associated according to the site. C-14 age determinations gives ages for these deposits between 12000 B.P. and the present, and detailed palynological studies have shown that there were two periods of climatic optimum, one between 9000 and 7000 B.P. and one between 4000 and 2000 B.P. The highly variable rates of sedimentation (0.2-12,5 mm/y for the continental zones and 2 mm/y for the mangrove swamps) are related to the paleotopography of the water-table or to very local fluctuations of sea level. The evolution of the vegetal biomass, evaluated both qualitatively (relative representation of the various vegetation levels) and quantitatively (concentration of pollen per gram of dry sediment) during the course of the Holocene enables reconstruction of the complete climatic and hydrologic history of the region up to the dawn of the Present.

Lezine, A. M. (1996). "The West African mangrove: An indicator of sea-level fluctuations and regional climate changes during the last deglaciation." Bulletin De La Societe Geologique De France **167**(6): 743-752.

The review of modern and late Quaternary pollen data recording the mangrove evolution in West Africa shows that littoral and deep-sea sediments have registered different signals. The first one gives evidence for past sea-level variations from ca. 12,000 B.P. to ca 5,000 B.P. The second one records the first widespread response of tropical forest ecosystems to the last deglaciation step and enhanced monsoonal rains at ca. 9,500 B.P.

Lezine, A. M. (1997). "Evolution of the West African mangrove during the Late Quaternary: A review." Geographie Physique Et Quaternaire 51(3): 405-414.

The review of pollen data on mangrove pollen deposition in modern and late Quaternary sediments of West Africa points to two distinct signals linked to the sedimentary environment concerned. Along the littoral and on the slope of the continental shelf, mangrove peat deposits recording more than 40% of *Rhizophora* percentages reflect the postglacial sea-level rise and give evidence for the associated paleogeographical modifications (e.g. during the Nouakchottian transgression). Deep oceanic records show that the mangrove was present along the West African coasts during the Late Glacial Maximum reflecting local conditions of fresh water input and sea surface temperatures not as low as previously suggested. Mangrove developed after 12 500 BP as far north as 21 degrees N; its maximum extension was recorded ca. 9500 BP reflecting the enhanced monsoon circulation over West Africa.

Lin, C. and M. D. Melville (1993). "Control of Soil Acidification By Fluvial Sedimentation in an Estuarine Floodplain, Eastern Australia." Sedimentary Geology 85(1-4): 271-284.

A shallow stratigraphic sequence with associated pyrite-induced soil acidification was investigated along a transect from the levee to the backswamp in an estuarine floodplain of eastern Australia. Three sedimentary layers were identified and interpreted to correspond with three depositional stages. Firstly, a layer of humic, pyrite-rich, silty mud was deposited under a saline, mangrove-inhabited, intertidal environment during the present high sea level episode. This pyritic layer is buried by the second sedimentary layer of grey brown mud with limited pyrite content, that was deposited in a brackish lagoonal environment. This material now represents much of the contemporary backswamp surface. The third sedimentary layer is a sandy mud without pyrite, that has been deposited by freshwater overbank floods. It is concluded that fluvial sedimentation has been increasingly important in the development of the stratigraphic sequence, controlling the pyrite content, thickness and occurrence depth of the pyritic layer. The present drainage conditions have allowed oxidation of pyrite in the soils of the backswamp and the resulting acidification has caused elevated concentrations of toxic aluminium that threaten the local environment. However, in the levee, the pyritic layer is covered by thick non-pyritic freshwater sediments and low-pyritic lagoonal sediments, and the soil profiles are unlikely to contribute to any acidification hazard.

Long, B. G. and T. D. Skewes (1996). "A technique for mapping mangroves with Landsat TM satellite data and Geographic Information System." Estuarine Coastal and Shelf Science **43**(3): 373-381.

The mangroves in a 2845 km² area in the Southern Gulf of Carpentaria, Australia, were mapped from Landsat TM satellite data. The mangroves were mapped by selecting 10 training set areas in dense mangrove (100% cover), and using the maximum and minimum training set values for green, red, near-infrared (NIR) and NIR/red to map the remaining mangroves. The accuracy of the map was improved by using ecological information about mangroves—they are found in tidally inundated areas—to derive simple rules in a Geographic Information System, to subdivide the areas labelled 'mangrove' from image processing of satellite data on the basis of nearness to water (next to water and not adjoining water), ground elevation [higher and lower than 10 m above mean sea level (MSL)] and distance from water (> 2 and < 2 km). Each zone was cross-checked with 1:50 000 panchromatic aerial photographs. Zones that were still mixed vegetation after applying these simple rules were further subdivided by eye. This process resulted in a map with zones identified as either 100% mangrove or 0% mangrove. The areas that were identified as mangrove were also subdivided on the basis of the three main river systems in the study area. The Norman, Bynoe and Flinders Rivers had 40.86, 10.09 and 5.42 km² of mangroves, respectively. These areas combined with the 9.89 km² of coastal mangrove to give a total of 66.25 km² of mangrove in the study area. (C) 1996 Academic Press Limited

Mackey, A. P. and S. Mackay (1996). "Spatial distribution of acid-volatile sulphide concentration and metal bioavailability in mangrove sediments from the Brisbane River, Australia." Environmental Pollution **93**(2): 205-209.

Acid-volatile sulphide (AVS) was measured at regular positions along eight transects through a mangrove forest in the Brisbane River, Queensland, Australia. Concentrations ranged from 0.33 to 22.61 $\mu\text{mol S g}^{-1}$ sediment dry weight. There was no correlation between AVS concentration and the proportion of clay-sand in the sediment, but sediments with high AVS concentrations tended to contain more water ($r(s) = 0.42$; $p = 0.01$). AVS concentrations were used to assess the potential bioavailability of the sediment heavy metal burden. The spatial variability of potential bioavailability was high and depended to a great extent on which metals were considered as part of the AVS complexing system. It is suggested seasonal variations would further increase the observed variability in bioavailability. This variation should be taken into account when monitoring and assessing long-term trends in sediment toxicity. Copyright

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Martinez, J. O., J. L. Gonzalez, et al. (1995). "Tropical Barrier Islands of Colombia Pacific Coast." Journal of Coastal Research **11**(2): 432-453.

Sixty-two barrier islands on the Pacific Coast of Colombia are reported and described. The islands, covered by tropical rainforest and backed by mangrove forests, line the seaward margin of a narrow, extensive, deltaic plain formed from rivers draining the northwestern Andes. The islands are of interest because of a combination of factors including: their position on a leading-edge coast which contributes to relative sea-level rise through long-term subsidence; short-term seismic subsidence and tsunamis; their tropical setting where deltaic sedimentation and heavy vegetative cover influence island dynamics in terms of subsidence, river channel switching and quality and quantity of sand supply, the possible shortterm influence of El Nino events; and the lack of human influence on island dynamics. Five genetic island groups are identified: two groups associated with straight stretches of coastal lowland and three delta lobe groups (Rio San Juan, Rio Patia, and Rio Mira deltas). A few of the islands formed due to spit detachment. initially the islands were probably transgressive, then became regressive for an indeterminate period before recent reinitiation of a transgressive phase, and severe island front erosion. Many of the islands are sand starved due to sediment supply loss when distributary switching occurred, or because they are in areas with little sand in the associated mangrove substrate and no fluvial sand supply. The recognition of the barrier island nature of this coast provides a new management tool to guide coastal hazard mitigation and future development. Future stratigraphic studies may provide a basis to identify the frequency of shortterm events such as El Nino and tsunamis and to establish recent sea level history for specific island groups.

Mascarenhas, A. (1997). "Significance of peat on the western continental shelf of India." Journal of the Geological Society of India **49**(2): 145-152.

Peat layers 2 to 30 cm in thickness, 22 to 46 m below present sea level, are found along the inner shelf of India, up to 27 km from the coast. They are rich in plant debris, organic carbon and sulfur. These organic-rich layers are not sedimentary deposits. Lack of favourable substrates, absence of sheltered habitats, high energy physical environments, and a very rapid sea level rise during early Holocene indicate an unfavourable paleogeography and adverse oceanographic conditions for mangrove development and in situ peat formation. On the contrary, significant siliciclastic minerals, lithogenous elements and type III

kerogen suggest a continental origin of peat. Restricted thickness, limited lateral distribution, absence of matted structures and laminated deposition imply transport of organics. Anomalous ages of wood with respect to present sea level are evidences of sediment reworking. Hence, peats on the continental shelf are not transgressive deposits.

Middelburg, J. J., J. Nieuwenhuize, et al. (1997). "Organic carbon isotope systematics of coastal marshes." Estuarine Coastal and Shelf Science **45**(5): 681-687.

Measurements of nitrogen, organic carbon and $\delta^{13}\text{C}$ are presented for *Spartina*-dominated marsh sediments from a mineral marsh in SW Netherlands and from a peaty marsh in Massachusetts, U.S.A. $\delta^{13}\text{C}$ of organic carbon in the peaty marsh sediments is similar to that of *Spartina* material, whereas that in mineral marshes is depleted by 9-12 parts per thousand. It is argued that this depletion in $\delta^{13}\text{C}$ of organic matter in marsh sediments is due to trapping of allochthonous organic matter which is depleted in C-^{13} . The isotopic composition and concentration of organic carbon are used in a simple mass balance to constrain the amount of plant material accumulating in marsh sediments, i.e. in terms of the so-called net ecosystem production. Net ecosystem production (similar to 2-100 g C m⁻² year⁻¹) is a small fraction (1- 5%) of plant production (similar to 2000 g C m⁻² year⁻¹). This small amount of plant material being preserved is nevertheless sufficient to support marsh-accretion rates similar to the rate of sea-level rise. (C) 1997 Academic Press Limited.

Mildenhall, D. C. (1994). "Early to Mid Holocene Pollen Samples Containing Mangrove Pollen From Sponge Bay, East-Coast, North-Island, New-Zealand." Journal of the Royal Society of New Zealand **24**(2): 219-230.

Mangroves (*Avicennia marina* var. *resinifera* (Forst.f.) Bakh.) lived in the Poverty Bay-East Cape region during the early to mid Holocene for about 4,000 years, from c. 9,800-6,000 years BP. This suggests an essentially frost-free climate at least one degree warmer than the present day, as required to allow germination and growth of *Avicennia* seedlings. Sea levels were then lower which would have provided a suitable substrate for the plants on the continental shelf, the local extinction of *Avicennia* was due to the combination of subsequent sea level rise, increased frostiness, and the disappearance of habitat. Pollen samples from four localities on the east coast of the North Island were examined, and all contain abundant evidence of recycled pollen from Cretaceous and Cenozoic sediments. Several samples from one locality (Sponge Bay, near Gisborne, about 7 km southeast of the only previously known North Island east coast early Holocene record of *Avicennia*) contain

Avicennia pollen. Precise paleoclimatic studies were hampered by a massive influx of modern pollen into many of the samples, possibly caused by unrecognised modern cut and fill, recycling of the sediments, and hydrostatic injection of spore- and pollen-bearing water into the soft Holocene sediments under the pressure of the frequent flood conditions. However, radiocarbon dates are internally consistent, suggesting that the last-named is probably the prime cause.

Mimura, N. and P. D. Nunn (1998). "Trends of beach erosion and shoreline protection in rural Fiji." Journal of Coastal Research **14**(1): 37-46.

A study of beach erosion and sea encroachment in the rural South Pacific was undertaken. Two islands of Fiji were chosen as study areas. On the basis of observation and interviews with elderly inhabitants of long-established coastal settlements, the coastal problems and countermeasures which they applied traditionally and recently were evaluated. Beach erosion in most of Fiji became significant only some 40 years ago. The causes of this change are considered to be a combination of human-induced development and global sea-level rise. Though people tried to respond to it mainly by building seawalls, there are many inappropriate elements in design and materials. Suggestions are made to improve coastal protection and to address the threats of predicted future accelerated sea-level rise and climate change.

Morris, J. T. (1995). "The Mass-Balance of Salt and Water in Intertidal Sediments - Results From North-Inlet, South-Carolina." Estuaries **18**(4): 556-567.

Salinity can be used as a conservative tracer of porewater turnover in circumstances when evapotranspiration is great enough to concentrate porewater salts in intertidal sediments. At two intertidal sites situated at mean high tide at North Inlet, South Carolina, porewater drainage was estimated by this method to be $9.41 \text{ m}^{-2} \text{ d}^{-1}$ and $16.61 \text{ m}^{-2} \text{ d}^{-1}$, depending on physical soil properties and assuming that solute losses occur by simple diffusion across the sediment surface, by uptake and excretion by vegetation, and by drainage. Mass balance simulations indicated that sediment physical properties, evapotranspiration, and elevation are important determinants of seasonal salinity extremes. At sites situated near mean high tide, small differences in elevation significantly affect salinity and drainage rate. As site elevation increases, losses of solutes by drainage and diffusion decrease, and the variability of porewater salinity increases. This is significant because interannual changes in mean sea level, which average ± 2.9 cm on the South Carolina coast, can

have a great impact on the structure and function of estuaries due to changes in the solute balance of intertidal zone sediments. Mass balance simulations that used reduced evapotranspiration rates typical of colder climates significantly reduced the mean and variability of porewater salinity, which suggests that at lower latitudes salinity becomes a more dominant determinant of biological processes. This should influence a number of processes including primary productivity, strategies of water conservation and osmoregulation, and community structure. This conclusion is consistent with published data that show tropical mangroves to have lower photosynthetic rates, and presumably lower gas exchange rates in general, than mid- and high-latitude salt marsh gasses.

Mulrennan, M. E. and C. D. Woodroffe (1998). "Holocene development of the lower Mary River plains, Northern Territory, Australia." Holocene 8(5): 565-579.

Extensive coastal and estuarine plains, associated with several large seasonal rivers, characterize the southern shore of van Diemen Gulf, Northern Territory, Australia. The Mary River is unique among these rivers in that, despite a catchment of 7700 km², it fails to reach the sea as a discrete channel but breaks up into a series of terminating, multiple channels, leaving much of the freshwater discharge to evaporate from the plains. The extent and morphology of these plains have changed markedly during the Holocene. Drilling, radiocarbon dating and pollen analysis indicate a transgressive phase that began about 7000 years ago as the rising seas hooded the prier valley. This was followed by a big swamp phase as sea level stabilized around 6000 years ago, during which widespread mangrove forest development occurred. Rapid progradation of the coast occurred between 6000 and 4000 years BP. The shoreline has prograded little since that time, but has been modified by episodic chenier ridge deposition and palaeochannel abandonment, infill and reoccupation. The lower Mary River differs from adjacent systems in that several former estuarine channels across the plains appear to have become completely blocked with sediment, leaving low-lying billabongs and palaeochannels which have been preferentially reinvaded by later channels. Several alternative explanations are examined, but it remains unclear what has driven major variations in palaeochannel activity and sedimentation during the mid-Holocene, and why these have decreased so markedly in the last 2000 years.

Nittrouer, C. A., S. A. Kuehl, et al. (1996). "The geological record preserved by Amazon shelf sedimentation." Continental Shelf Research 16(5-6): 817-&.

A recent study of the subaqueous delta and coastal

plain near the mouth of the Amazon River provides insight to the geological record created there and elsewhere. A compound clinoform structure is forming across the Amazon shelf. The uppermost portion is the shoreline, whose aggradation brings the modern sedimentary deposit to sea level and produces a deposit 5-10 m thick. It contains sediments accumulating primarily in shallow subtidal areas, intertidal mudflats and mangrove forests, and progradation occurs by overlapping of northward-extending mudcapcs. Through these processes, the coastal plain has been widened by 10-100 km during the Holocene. The shoreline deposits are prograding across topset strata of the modern subaqueous delta, which is the lowermost and dominant portion of the compound clinoform structure. The subaqueous delta extends to a water depth of 70 m, with a depositional break between topset and foreset strata at 30-40 m. Advective sediment input to the foreset region causes high accumulation rates, which control the geometry and progradation of the clinoform structure. On time scales of 10^2 - 10^3 y, physical processes (e.g. waves, currents) have changed and the upper portions of the coastal plain and subaqueous delta have been eroded. One expression of this is a widespread unconformity recorded within late Holocene strata on the inner shelf. Over longer time scales (10^3 - 10^4 y) sea-level changes have led to more extensive erosion and only the lower 20 m of the compound clinoform structure is preserved, overlain by a transgressive sand layer. On other continental margins with different regional characteristics (e.g. more rapid subsidence) larger fractions of the clinoform structures could be preserved.

Ong, J. E. (1995). "The Ecology of Mangrove Conservation and Management." Hydrobiologia 295(1-3): 343-351.

Despite the recent better understanding and awareness of the role of mangroves, these coastal forest communities continue to be destroyed or degraded (or euphemistically reclaimed) at an alarming rate. The figure of 1% per year given by Ong (1982) for Malaysia can be taken as a conservative estimate of destruction of mangroves in the Asia-Pacific region. Whilst the Japanese-based mangrove wood-chips industry continues in its destructive path through the larger mangrove ecosystems of the region, the focus of mangrove destruction has shifted to the conversion of mangrove areas into aquaculture ponds and the consequences of the unprecedented massive addition of carbon dioxide to the atmosphere by post industrial man. Mangroves are non-homogeneous; characterised by distinct vegetative zones that occupy the interface between land and sea and dynamically interacting with the atmosphere above as well as with the influences of the adjacent land and sea. The conservation of mangroves should thus include not only the

various vegetation and tidal inundation zones but also the adjacent marine and terrestrial areas (including the water catchment area). On the current concern with global climate change, it is pointed out that relative sea level change is very much site dependent. For effective planning and management, it is vital to know if a particular site is stable, rising or sinking so efforts should be directed to find suitable methods for determining this. However, should rapid relative sea level rise take place, there is very little likelihood of saving mangroves whose landward margins have been developed by man, a fact to bear in mind when selecting sites for conservation. The Matang mangroves of Malaysia is a rare case of successful sustainable management of a tropical rain forest. Although the tools of management are available they are not widely applied. We particularly urge the Japanese mangrove wood-chips industry to look to long term sustainable use rather than short term gains. A suggestion is made to appeal to the new Government of Japan to take the lead in environmental friendliness especially to the rain forests of the Asia-Pacific region.

Parkinson, R. W., R. D. Delaune, et al. (1994). "Holocene Sea-Level Rise and the Fate of Mangrove Forests Within the Wider Caribbean Region." Journal of Coastal Research 10(4): 1077-1086.

This paper (1) reviews mangrove forest pest accretion data obtained from carbonate settings of the Wider Caribbean Region and (2) evaluates the fate of these forests based upon current global eustatic sea-level rise projections. Historical pest accretion rates calculated using Cs-137 or Pb-219 average 3.7 mm yr⁻¹. Feat accretion rates calculated using C-14 average 1.0 mm yr⁻¹. The discrepancy between historical and geological accretion rates, also recognized in salt marsh settings, is attributed to organic decomposition and sediment compaction. Our conceptual model, which is based upon comparisons between projected rates of global eustatic sealevel rise and pest secretion, predicts stable forest conditions only if historical accretion rates persist during a conservative (low) sea-level rise of similar to 1.3 mm yr⁻¹. Best guess (middle) and high estimates of a sea-level rise of as much as 8 mm yr⁻¹ will likely submerge mangrove forests located within carbonate settings of the Wider Caribbean Region.

Pezeshki, S. R., R. D. Delaune, et al. (1995). "Gas-Exchange and Growth of Bald Cypress Seedlings From Selected Us Gulf-Coast Populations - Responses to Elevated Salinities." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 25(9): 1409-1415.

Bald cypress (*Taxodium distichum* (L.) Rich.) seedlings from two sources in Louisiana were tested for a possible

difference in salt tolerance. The study was conducted in rhizotrons under controlled environmental-conditions. Seedlings were subjected to a control (no flood or salt) and three combinations of flooding salinity: flooding only, flooding plus 68 mol . m(-3) salt (4, ppt), and flooding plus 136 mol . m(-3) salt (8 ppt). Both populations survived the flooding and salinity treatments for the duration of the study. However, gas exchange and net biomass production were reduced in both populations as salinity of floodwater increased from 0 to 136 mol . m(-3). The gas exchange and biomass data indicated that plants from the freshwater source had higher growth rates than the brackish plants. This superiority was also maintained under all the treatments except the highest salinity treatment. Significantly greater net photosynthetic capacity per unit area of leaf was found for the freshwater population than for the brackish population in 68 mol . m(-3) salt. In addition, greater root porosity, height growth, and biomass production (shoot, root) were found for the freshwater population than for the brackish population under different treatments. The data indicate that there is a potential for population differentiation in bald cypress, as shown primarily by differences in growth traits. However, the data do not support the hypothesis that bald cypress plants from the brackish source have a capacity to survive and grow better in saltwater than plants from the freshwater source. In fact, combined flooding and salinity treatments resulted in significant reductions in net photosynthesis as compared with the control in both sources.

Phillips, S. and R. M. Bustin (1996). "Sedimentology of the Changuinola peat deposit: Organic and clastic sedimentary response to punctuated coastal subsidence." Geological Society of America Bulletin **108**(7): 794-814.

An extensive peat deposit on the Caribbean coast near Changuinola, Panama, has developed in an area subject to periodic earthquake-driven coseismic subsidence. Thick, low-ash, low-sulfur peat is accumulating immediately behind an aggrading and prograding barrier system and adjacent to a flood-prone, sediment-laden river. Measurements of changes in local sea level as a result of a recent (April 1991) earthquake reveal 30-50 cm of subsidence, greatest at the southeastern extent of the study area, where the peat surface is submerged to a depth of 3 m beneath the shallow waters of Almirante Bay. Transgression is proceeding from southeast to northwest, parallel to the trend of the coast and the long axes of both the peat deposit and the major sand bodies. In the eastern part of the deposit, the effects of sea-level rise are evident in the degree of humification, mineral matter, and sulfur content of mangrove and back-mangrove peats offshore and immediately adjacent to the

marine margin, and in peats associated with brackish tidal channels that drain the deposit, However, most of the deposit shows no indications of marine influence, even though approximate to 40 % of the peat is below present sea level, The western section of the deposit has evolved from low-lying palm swamps, which originated in swales on the barrier bar, into an oligotrophic bog plain with a water table elevated 6.75 m above sea level, As the mire evolved, transitions in vegetation resulted in transitions in peat types, Highly humified forest-swamp and palm-swamp peats underlie and surround well-preserved, fibric sedge peats, and create a partial hydrological bounding surface that restricts subsurface drainage from the central bog, The high water table and elevated topography of the mire and the low permeability and erosion resistance of the dense, moody peat effectively insulate most of the deposit from both elastic influx and the extensive intrusion of rising marine waters, It is evident that thick peat, and hence coal, deposits can accumulate due to tectonically driven, punctuated subsidence without leaving a record of high elastic input within the peat, even immediately adjacent to environments of active clastic deposition.

Phillips, S. and R. M. Bustin (1996). "Sulfur in the Changuinola peat deposit, Panama, as an indicator of the environments of deposition of peat and coal." Journal of Sedimentary Research **66**(1): 184-196.

The sulfur (S) content of coal is often used to infer aspects of paleoclimate, tSophic state, and proximity to marine influence, of the mire in which it was deposited. In this study, the S content of peat in a large back-barrier mire complex on the Caribbean coast of Panama is related to climatic, biological, and tectonic factors of the depositional environment. Earthquake-generated subsidence is greatest to the southeast, leading to drowning of the deposit beneath Almirante Bay, and 40% of the peat is now below sea level, Coastal mangrove peats with moderately high S content (1-5 wt % S) and high salinity (> 1.0 wt %) dominate the eastern margin and extend beneath the salt water and shallow marine sediments of the adjoining bay. Marine influence extends only a short distance onshore, except in the vicinity of brackish blackwater creeks that drain the swamp. Peats associated with these tidal channels are low in salinity (< 1.0 wt %) and very high in S (5 to similar to 14 wt % S), apparently the result of a biogeochemical chain of S reactions leading to the concentration of C-S sulfides. The western part of the deposit is domed, and the vegetation and the peat are concentrically zoned. Stunted, sawgrass-dominated vegetation that produces fibric, very low S (< 0.25 wt % S) peat occupies the central bog plain. Around the bog plain, mixed-

forest and palm-forest swamps produce dense hemic and fine hemic peat with higher S content (0.25-0.5 wt % S). The S content is in proportion to the degree of humification of the peat, and both are independent of the pH of the groundwater. The distribution of forms of organic and inorganic sulfur in the tropical peats are found to be comparable to published values for temperate and subtropical peats, despite differences in vegetation and climate. The distribution of high-sulfur peats in the eastern part of the deposit and low-sulfur peats in the western part, and the SE-NW transgression parallel to the trend of the coastline, reflects the regional structural trend of coseismic subsidence greatest to the southeast.

Phillips, S., G. E. Rouse, et al. (1997). "Vegetation zones and diagnostic pollen profiles of a coastal peat swamp, Bocas del Toro, Panama." Palaeogeography Palaeoclimatology Palaeoecology **128**(1-4): 301-338.

A survey of the dominant vegetative cover of a large domed coastal swamp near Changuinola in the Province of Bocas del Toro, Panama, has been undertaken as an initial step in reconstructing the Holocene history of peat accumulation on this coast. Seven phasic communities of peat-forming vegetation are defined and mapped: (1) *Rhizophora mangle* mangrove swamp; (2) mixed back-mangrove swamp; (3) *Raphia taedigera* palm swamp; (4) mixed forest swamp; (5) *Camptosperma panamensis* forest swamp; (6) Sawgrass +/- stunted forest swamp; (7) *Myrica*-*Cyrilla* bog-plain. Pollen extracted from surface peat samples and collected from dominant vegetation, at representative sites, is used to prepare a pollen profile of each phasic community. These profiles are then compared to pollen distribution in 2 peat cores, one from the deep central part of the deposit and the second from a site near the marine margin, in order to construct a history, by floral succession, of the 4000 year evolution of the deposit. The Changuinola mire originated as freshwater palm and hardwood forest swamps that developed in close proximity to both the Changuinola River mouth, probably behind a barrier bar and freshwater lagoon system adjacent to a low energy, mangrove-dominated bay. The early swamp was likely drained to the southeast by brackish blackwater creeks much as it is today, and formerly extended considerably farther in the direction of Almirante Bay. The palm swamp was succeeded by hardwood forest swamp dominated by a very limited number of specialized species, only one of which (*Camptosperma panamensis*) is prone to forming monospecific stands. Increasing accumulation of woody peat promoted by the everwet climate impeded drainage of the mire, leading to doming, increased oligotrophy, and establishment of bog-plain conditions in a manner similar to that described by

the Anderson model of succession in the coastal swamps of Malaysia and Indonesia. Development of the *Changuinola mire* did not require the initial mangrove phase which is common to the peat swamps of southeast Asia, as the palm *Raphia taedigera* is able to colonise and institute peat accumulation in a variety of freshwater and brackish environments.

Pickett, J. W., M. K. Macphail, et al. (1997). "Middle Miocene palaeotopography at Little Bay, near Maroubra, New South Wales." *Australian Journal of Earth Sciences* **44**(4): 509-518.

The Little Bay Shale is a poorly consolidated buff to pale grey shale whose estuarine nature is indicated by the presence of marine dinoflagellate cysts, microforaminiferal liners and mangrove pollen in the microflora and the mangrove *Bruguiera* in the macroflora. Palynological evidence places it in the *Triporopollenites bellus* Zone of latest Early to early Late Miocene age, with Middle Miocene being the most probable. Its occurrence is restricted to a narrow valley incised into Triassic Hawkesbury Sandstone, situated in the southeastern Sydney suburb of Little Bay. The age of the deposit corresponds broadly with the maximum Neogene eustatic event. though eustasy was not necessarily the prime or only cause. The reconstructed drainage pattern indicates a possible westerly drainage and therefore a possible pre-Middle Miocene age for the Botany Bay Basin. Palaeobotanical and plate tectonic evidence suggest a climatic shift since the Middle Miocene of the equivalent of at least 11 degrees of latitude. Implied local sea-level in the Middle Miocene was + 30 m. Lateritic weathering of the Hawkesbury Sandstone is older than the deposition of the shale.

Plaziat, J. C., F. Baltzer, et al. (1995). "Quaternary Changes in the Egyptian Shoreline of the Northwestern Red-Sea and Gulf of Suez." *Quaternary International* **30**: 11-22.

On the NW, Egyptian, shoreline of the Red Sea, remarkably preserved Pleistocene-Holocene marine (reefs, beaches, mangrove swamps, gypsum-salinas) and non marine (alluvial fans and wadi terraces) deposits are located within a complex Neogene rift frame. The Early and Middle Pleistocene reefs are uplifted to a maximum of 40 m, subsequent movement being limited to a few metres (except on the S Gulf of Suez shores) which suggests a decreasing tectonic activity of the northern part of the rift. A new series of radiometric dates and precise levelling have demonstrated a short-lived, low stand of relative sea level during the Last Interglacial high stand (5e). At that time, flooding of the Isthmus of Suez has enabled exchanges between Mediterranean and Indian Ocean faunas and the biogeographic limit was temporarily located in the Southern

Gulf of Suez, thus explaining the Late Quaternary introduction of *Potamides conicus* into the Indian Ocean subprovince.

Ramanathan, A. L. (1997). "Sediment characteristics of the Pichavaram mangrove environment, south east coast of India." Indian Journal of Marine Sciences **26**(3): 319-322.

The heavy metal and phosphorous fractionation geochemistry and textural aspects of sediments in a tropical mangrove ecosystem have been studied and discussed. The sediments are characterised by the abundance of sand and silt with small amount of clay. The organic matter concentration ranges from 1.5 to 13.4% and are controlled by the particle size of the sediments. Enhanced concentration of heavy metals in the surficial sediments were due to the abundance of greater surface area fine particles, high organic matter content and flocculation process. This mangrove sediments may act as a sink for the metals derived from marine and fluvial processes. Different forms of available phosphorous in the mangrove sediments shows spatial variation within the mangrove environment.

Ramanathan, A. L., V. Subramanian, et al. (1999). "Environmental geochemistry of the Pichavaram mangrove ecosystem (tropical), southeast coast of India." Environmental Geology **37**(3): 223-233.

Spatial and temporal geochemical variations of various parameters in the water and sediment of a relatively small mangrove situated on the southeast coast of India were examined in detail for the first time. The water quality generally reflects the impact of seawater and the Vellar estuary (mixing effect) aided by evaporation and in situ biological productivity. The depletion and fluctuation of dissolved silica are controlled by biological processes. Nitrate and phosphate are contributed by fertilizer input from adjoining agriculture fields. Total suspended matter (TSM) shows an erratic range and trend due to deforestation and resuspension processes. Sand and silt constitute 70-90% of the sediments. Statistical analysis of the sediments shows the prevalence of a moderately high- energy environment with very effective winnowing activity. Organic matter content is higher in the mangrove sediments in comparison to adjacent estuaries. Water and sediment show fluctuations in their chemical concentration, but no specific trends could be identified. Heavy metals are also enriched in the mangrove sediments, indicating their unique chemical behavior and the existence of trapping mechanisms. Factor analysis and correlation analysis of water and sediments show the complexity of the system and the multitude of contributing sources. The core sediment chemistry suggests the depletion of metal input due to the

damming of the detrital inputs. The Pichavaram mangrove seems to be relatively unpolluted, since the anthropogenic signal observed is small and acts as a sink for heavy metals contributed from a multitude of sources without an adverse effect.

Reid, W. V. and M. C. Trexler (1992). "Responding to Potential Impacts of Climate Change On United- States Coastal Biodiversity." Coastal Management **20**(2): 117-142.

Accelerated rates of sea level rise and other impacts of climate change resulting from global warming are likely to aggravate threats to coastal biodiversity in the United States. Species restricted to or dependent upon a narrow band of habitat close to sea level will be subjected to continuing threats of development from above, and rising sea levels from below. In five states alone, almost 500 rare and imperiled species utilize the coastal fringe below the 10-foot contour. Some 53 species federally listed as threatened or endangered or as candidates for listing are found only within the narrow band below the 10-foot contour. Rising seas will stress coastal habitats including wetlands, barrier islands, coral reefs, and mangroves, in some cases substantially reducing their area. To ensure the conservation of coastal biodiversity global warming must be slowed as much as possible. Steps must also be taken quickly to establish coastal zone policies that allow adaptive response to rising seas by making way for the shoreward movement of coastal ecosystems as sea level changes.

Riaza, A., M. L. Martinez-Torres, et al. (1998). "Evolution of equatorial vegetation communities mapped using Thematic Mapper images through a geographical information system (Guinea, Equatorial Africa)." International Journal of Remote Sensing **19**(1): 43-54.

The diverse spectral behaviour of vegetation permits the use of satellite imagery to map the extent and variety of different vegetation communities. The comparison with historical maps through a geographical information system facilitates the mapping of the temporal evolution of the coverage of different vegetation communities. Maps summarising the evolution of vegetation cover over forty years are produced, orientating future land use and planning. Progress or recession of estuarine vegetation communities such as mangroves growing on river banks under the influence of tides may be used as indicator of sea level changes.

Ross, M. S., J. J. Obrien, et al. (1994). "Sea-Level Rise and the Reduction in Pine Forests in the Florida Keys." Ecological Applications **4**(1): 144-156.

Forests dominated by *Pinus elliottii* var *densa* have

undergone a reduction in area in the Florida Keys (USA). A previous investigation interpreted the presence of halophytic species in a former pine forest in Key Large as evidence of sea-level rise. We therefore examined aerial photos and field evidence to learn how the 15-cm rise in local sea level over the last 70 yr had affected the distribution of pines on a second island, where intact pine forests still remained in 1991. The distribution of in situ dead pine stems showed that the area occupied by pines on Sugarloaf Key was 88 ha at some time prior to the earliest available aerial photographs, in 1935. The area of pine forest was reduced to 46 ha by 1935, and continued to decrease through 1991, when it covered 30 ha. The pattern of pine mortality was related to topographic position, with the areas where pines died earliest occupying the lowest elevations. Our analysis of current vegetation patterns showed that the areas of earliest pine mortality are now populated by a higher proportion of halophytic plant assemblages than areas of more recent pine mortality. We also compared the physiological responses of pines in two portions of the island: one where pine forest reduction had been most pronounced, and a second where the extent of the forest had changed little over the past 50 yr. Both groundwater and soil water salinity were higher in the area of rapid pine forest reduction, and the pines sampled there exhibited higher physiological stress, as indicated by pre-dawn water potential and stemwood carbon isotope ratios. These results suggest that the salinization of ground- and soil water that occurs as sea level rises is a major factor in the reduction of pine forests of Sugarloaf Key. If sea level continues to increase, the Florida Keys will experience a decline in both landscape and species diversity, as species-rich upland communities are replaced by simpler mangrove communities. This pattern may also occur in other low-lying island ecosystems with limited freshwater resources.

Rull, V. (1998). "Middle Eocene mangroves and vegetation changes in the Maracaibo Basin, Venezuela." Palaios **13**(3): 287-296.

As a part of a general project that aims to reconstruct the paleosuccession of Paleogene mangroves of the Maracaibo Basin, this paper deals with the quantitative reconstruction of Middle Eocene mangrove communities, and their relation to potential forcing factors. Four palynological assemblages were found. These represent, respectively inland forests (A1) back-mangrove herbaceous swamps (BI), mangroves (B2) and an unknown plant community dominated by the extinct *Echitriporites trianguliformis*. Mangroves were dominated by *Pelliciera* and *Nypa*; *Brevitricolpites variabilis*, which has been considered the dominant taxon of the early and middle

Eocene mangroves in nearby areas, has not been found in this study. The succession of coastal vegetation, linked to sea-level changes, could be reconstructed from these assemblages. The trends constitute a palynocycle which began and ended with a low sea-level plant community dominated by unknown stands represented by *E. trianguliformis* and interpreted low paleosalinities; intermediate high sea-level vegetation is represented by mangroves and interpreted high paleosalinities. This cycle is correlated chronologically with the global eustatic cycle TEJAS A 3.4, extending from 44 to 42.5 Ma (Lutetian). The floristic composition of middle Eocene mangroves was very different from those of the Oligocene to Recent. An important, probably worldwide, evolutionary change occurred during the late middle Eocene and the late Eocene in these communities. Pollen taxa botanically related to known and extant mangrove elements seem scarce for this time span.

Scott, L., B. Cooremans, et al. (1992). "Preliminary Palynological Evaluation of the Port Durnford Formation At Port-Durnford, Natal, South-Africa." South African Journal of Science **88**(9-10): 470-474.

Fossil pollen analysis of some organic layers in the Pleistocene Port Durnford Formation in Zululand, along the South African east coast, sheds new light on environmental conditions during the accumulation of the formation. Pollen in the formation differs from modern pollen spectra along the present coast. Fossil spectra in the lower part of the sequence were probably deposited under lagoonal conditions and consist of a combination of marshland, grassland and Podocarpus forest elements. Pollen in an overlying relatively younger peat layer indicates a succession of swampy marshland to terrestrial Podocarpus forest. The presence of freshwater elements, Podocarpus trees, some fynbos elements, and the absence of mangroves suggest that the environment may have had more inland than coastal characteristics during deposition of the peat layer and sands immediately overlying it. The succession in the peat from open marshland to terrestrial conditions is not in keeping with previous proposals that the sea level was rising up to a point when it flooded the swamp. This evidence and the stratigraphical position of marine fossils suggest that the peaty deposits post-date a marine transgression of the coastline which possibly occurred during Eemian times.

Semeniuk, V. (1994). "Predicting the Effect of Sea-Level Rise On Mangroves in Northwestern Australia." Journal of Coastal Research **10**(4): 1050-1076.

The patterns of mangrove distribution in tropical northwestern Australia are related to coastal dynamics,

habitats and salinity. They also respond to the sedimentology of the tidal flats that back them, to coastal (sheet) erosion, and to the effects of some industrial impacts. These patterns provide information useful in predicting the variable effects of sea-level rise on mangroves. For instance, fundamental changes to soil regimes and salinity can be expected as tidal flat surfaces and groundwaters sedimentologically and hydrologically adjust to new levels of wave base and frequency of inundation as sea-level rises. Since mangrove assemblages and their zones are closely related to shore profile, soils, habitat stratigraphy and salinity fields, any change in these can lead to alteration of the structure and composition of mangrove systems. The mangrove response to a rising sea level will depend on the environmental setting of the mangrove system. This includes the relative geomorphic and sedimentologic homogeneity of the coast, its tidal range, its stability, and the history of Holocene sea levels in regard to development of coastal gradients and the climatic setting which determines the variety of species that will respond to this Holocene sea level rise and the type of reproduction the mangroves will utilise to keep pace with encroaching seas. A dichotomous key is presented which suggests that the response of mangrove coasts to a rising sea level will be quite varied from coastal sector to sector and even from site to site within a single coastal sector and climate setting. Some case studies illustrate the probable effect of rising sea level on mangrove systems in Western Australia. The macrotidal shores of King Sound, a relatively simple coast in terms of habitat and stratigraphy, is eroding naturally by creek and cliff erosion and by sheet erosion progressing at 1-3 cm/yr. This erosion specifically simulates the effects of a rising sea. With coastal retreat, the mangroves are migrating landwards, generally keeping pace with the retreat. Mangroves colonise by seedling recruitment on the new substrates that become available through the processes at erosion, inundation, and dilution of hypersaline groundwater of the salt flats. As erosion and progressive dilution of hypersalinity proceeds, each zone within the mangrove belt displaces the adjoining one. Thus, sea level rise in a system like King Sound would most likely result in the migration of mangroves, with similar composition and structure, into habitats made available by increased inundation. In arid zones, however, where mangrove population is maintained by vegetative reproduction, sheet erosion of tidal flats also causes landward migration of zones, but the individual zones keep pace with a relative rising sea level by vegetative processes. Elsewhere in NW Australia, various mangrove assemblages with different composition, structure and population maintenance have developed along highly indented (ria) shores, in a

heterogeneous suite of habitats that have evolved over the late Holocene. These habitats are defined by their geomorphic setting, sedimentologic processes, stratigraphic evolution, and ground water dynamics, and each is related to a specific height in relationship to sea level. A sea-level rise would inundate the various geomorphic/habitat systems, dislocating their suite in relation to the formative sea level. It is likely that these mangroves would not adjust as rapidly as the more homogeneous systems, and hence be disrupted.

Silva, C. A. R., L. D. Lacerda, et al. (1990). "Metals Reservoir in a Red Mangrove Forest." Biotropica **22**(4): 339-345.

This study presents heavy metal concentrations and distributions in a mangrove forest in Sepetiba Bay, Rio de Janeiro. Sediments are the main reservoir of the total metal contained in mangrove studied: 99 percent for Mn; 100 percent for Fe; 100 percent for Zn; 99 percent for Cu; 100 percent for Cr and 100 percent for Pb and Cd. Rhizophora mangle biomass contained less than 1 percent of reservoir. Within the biotic compartment, perennial tissues accounted for almost all of the metals present in biomass. The results indicate that mangrove may act as an efficient metal trap in tropical coastal environments.

Snedaker, S. C., J. F. Meeder, et al. (1994). "Mangrove Ecosystem Collapse During Predicted Sea-Level Rise - Holocene Analogs and Implications - Discussion." Journal of Coastal Research **10**(2): 497-498.

Snedaker, S. C. (1995). "Mangroves and Climate-Change in the Florida and Caribbean Region - Scenarios and Hypotheses." Hydrobiologia **295**(1-3): 43-49.

The principal scenario concerning the potential effects of climate change on mangrove forest communities revolves around sealevel rise with emphases on coastal abandonment and inland retreat attributable to flooding and saline intrusion. However, at the decade to century scale, changes in precipitation and catchment runoff may be a more significant factor at the regional level. Specifically, for any given sealevel elevation it is hypothesized that reduced rainfall and runoff would necessarily result in higher salinity and greater seawater- sulfate exposure. This would likely be associated with decreased production and increased sediment organic matter decomposition leading to subsidence. In contrast, higher rainfall and runoff would result in reduced salinity and exposure to sulfate, and also increase the delivery of terrigenous nutrients. Consequently, mangrove production would increase and sediment elevations would be maintained. Support for this scenario derives from

studies of the high production in saline mangrove impoundments which are depleted in seawater sulfate. This paper also examines other components of climate change, such as UVb, temperature, and storm frequency, and presents a suite of hypotheses and analytical protocols to encourage scientific discussion and testing.

Stirling, C. H., T. M. Esat, et al. (1998). "Timing and duration of the Last Interglacial: evidence for a restricted interval of widespread coral reef growth." Earth and Planetary Science Letters **160**(3-4): 745-762.

We report new mass spectrometric U-series ages for eight Last Interglacial fossil reefs along the continental margin of Western Australia. Corals were selected in growth position from localities that are characterized by apparently low levels of diagenesis and relative tectonic stability so that the fossil reefs provide critical information on Last Interglacial sea-levels without requiring corrections for tectonic movements. In addition, we have improved the constraint on the timing of onset of reef growth by recovering drill core coral from the base of the reefs. Uranium and thorium isotopes were measured with high levels of precision, leading to improvements in age resolution and allowing samples which have undergone diagenetic exchange of uranium and thorium to be more easily identified and discarded. These data supplement our previous results for Rottneest Island and Leander Point, leading to more than seventy mass spectrometric U-series ages from which constraints can be placed on the timing, duration and character of the Last Interglacial sea-level highstand. Reliable ages show that reef growth started contemporaneously at 128 ± 1 ka along the entire Western Australian coastline, while relative sea-levels were at least 3 m above the present level. Because Western Australia is located far from the former Penultimate Glacial Maximum ice sheets and are not significantly effected by glacial unloading, these data constrain the timing of onset of the Last Interglacial period to 128 ± 1 ka, assuming reef growth started soon after sea-level approached interglacial levels. A unique regressive reef sequence at Mangrove Bay constrains the timing of termination of the Last Interglacial period to 116 ± 1 ka, The major episode of reef building, however, both globally and locally along the Western Australian coast, is restricted to a very narrow interval occurring from similar to 128 ka and similar to 121 ka, suggesting that global ocean surface temperatures were warm and/or sea-levels were stable enough to allow prolific reef growth only during the earlier part of the Last Interglacial. (C) 1998 Elsevier Science B.V. All rights reserved.

Szefer, P., J. Geldon, et al. (1998). "Distribution and association of trace metals in soft tissue and byssus of *Mytella strigata* and other benthic organisms from Mazatlan harbour, Mangrove lagoon of the northwest coast of Mexico." Environment International **24**(3): 359-374.

Concentrations of Cd, Pb, Zn, Cu, Ag, Cr, Co, Ni, Mn, and Fe in soft tissues and byssal threads of *Mytella strigata* (Mytilidae) and other benthic organisms (clam *Chione subrugosa* and algae *Enteromorpha intestinalis*, *Ulva lactuca*) from four sampling sites in a tropical mangrove lagoon, on the northwest coast of Mexico, were determined by atomic absorption spectrophotometry (AAS). Some inter-regional differences in metal concentrations, especially concerning Ni, Cu, and Mn in both soft tissue and byssus, were identified. The concentrations of the majority of the metals analyzed were significantly greater in byssus than in soft tissue, even as great as an order of magnitude for Pb, Co, Cr, Ni, Mn, and two orders of magnitude for Fe. Significant correlations ($p < 0.01$; $p < 0.05$) were observed between tissue concentrations of Ni-Mn, Cu-Ni (positive), Pb-Ni, Pb-Mn, Mn-Fe (negative) as well as byssal concentrations of Pb-Cr-Fe, Cu-Zn-Mn (positive), Pb-Ni, Ni-Fe, Cd-Zn (negative). Inter-comparison of the present data with those published previously (for Mytilidae from Japanese and Yemeni coastal waters) indicates that the soft tissue (mainly for Cd) and byssus (especially for Co, Ni) are useful in detecting areas of selected metallic contaminants. Molluscs such as *M. strigata* and *C. subrugosa* appear to be convenient biomonitors for identification of coastal waters exposed to Cd, Pb, Cu, Zn, Cr, Co, Ni, Mn, and Fe in the tropical American region. (C)1998 Elsevier Science Ltd.

Tam, N. F. Y. and Y. S. Wong (1994). "Nutrient and Heavy-Metal Retention in Mangrove Sediment Receiving Wastewater." Water Science and Technology **29**(4): 193-200.

Soil column studies were carried out to examine the capacity of mangrove sediments in retaining wastewater nutrients and heavy metals. Synthetic wastewater of three different concentrations, namely diluted sewage (DW), medium sewage (MW) and concentrated sewage (CW), were applied to the columns daily over a period of 54 days. Leachate from each column was collected and analyzed. The study revealed that the concentrations of ammonium in the leachates from all sewage treatments decreased dramatically in the first week with a pattern similar to the control. After this initial decrease, ammonium contents increased rapidly especially in the column treated with CW, then remained at a steady level. At the end of the experimental period, the concentrations of ammonium found in the leachate were in the declining order of CW > MW > DW > control. Organic nitrogen, nitrites and nitrates were not detected in the leachates

from all sewage treatments. This suggested that denitrification might have occurred and some of the nitrogen from sewage might have been retained in the mangrove sediment. The changes in leachate K concentration were similar to that of $\text{NH}_4^+\text{-N}$ content. On the other hand, the soluble phosphorus and heavy metal contents of leachates from sewage treated columns were similar to those of the control. Most of the heavy metals, including Cu, Zn and Cd, were not detected in the leachate. The sediment data showed that $\text{NH}_4^+\text{-N}$, ortho-P, and heavy metals were accumulated on the top layer of the soil column and their contents decreased with the depth of the soil column. The highest metal content was found in the column treated with concentrated sewage. It is clear that mangrove sediments acted as a good filter/trap for phosphorus and metals, but were less efficient for ammonium nitrogen.

Tam, N. F. Y. and Y. S. Wong (1995). "Spatial and temporal variations of heavy metal contamination in sediments of a mangrove swamp in Hong Kong." Marine Pollution Bulletin **31**(4-12): 254-261.

Spatial and temporal variations of heavy metal contamination in sediments of a small mangrove stand in Hong Kong were examined by laying two transects perpendicular across the shore, Surface sediment samples were taken along the two transects running landward to seaward at intervals of 5 or 10 m during December 1989, and March, July and September 1990, Total concentrations of Cu, Zn, Mn and Pb did not show any specific trend along each transect, although the maximum concentration of heavy metals tended to occur at the landward edge, There was a high level of variability among locations within each transect; for instance, the Cu concentrations fluctuated from 1 to 42 $\mu\text{g g}^{-1}$, Certain sites contained exceptionally high levels of total metals, Total concentrations of Cu, Zn, Mn and Pb, as high as 42, 150, 640 and 650 $\mu\text{g g}^{-1}$, respectively, were recorded, implying contaminated sediment. A comparison of the two transects indicated that the sediments of Transect B seemed to contain higher total Zn but lower Cu and Mn concentrations than those of Transect A, Most of the heavy metals accumulated in the sediments were not extractable with ammonium acetate and no Cu or Pb was detected in these extracts, The concentrations of extractable Zn and Mn were low, less than 10% of the total metal concentration in the sediment, and appeared to decrease from the landward to seaward samples, For both total and extractable metals, there were significant seasonal fluctuations for both transects, but no specific trends could be identified, These spatial and temporal variations suggest that the scale and representativeness of sampling require careful planning, and a single sample might not give a satisfactory evaluation of

the levels of heavy metal contamination in mangrove ecosystems.

Tam, N. F. Y., S. H. Li, et al. (1995). "Nutrients and Heavy-Metal Contamination of Plants and Sediments in Futian Mangrove Forest." *Hydrobiologia* **295**(1-3): 149-158.

An ecological survey was carried out to determine the levels of nutrients and heavy metals in the sediments and leaf tissues of two dominant mangrove plant species, *Kandelia candel* and *Aegiceras corniculatum*, in Futian mangrove forest, Shenzhen, the People's Republic of China. The spatial and seasonal variations of these elements were also investigated. The results show that there was no major difference between two sampling sites 150 m apart. In both sites, the sediment concentrations of total and $\text{NH}_4^+\text{-N}$, total and extractable P, total and extractable K, total organic carbon were consistently higher in the landward locations and decreased gradually towards the sea. The sediment samples collected at the seaward edge of the mangrove plant community had the lowest levels of nutrient and organic matter. The vertical variations (from the land to the sea) of sediment heavy metals were less obvious and no particular trend could be identified. Extremely high contents of Cu, Cd, Pb, Cr and Zn were found at certain locations, suggesting the occurrence of some local contamination. The mean total metal concentrations in sediments decreased in the order $\text{Mn} > \text{Zn} > \text{Cu} > \text{Cr} = \text{Pb} > \text{Cd}$ for the sample locations. Most of the heavy metals were not in a bioavailable form as the concentrations of extractable metals were relatively low (< 1% of total metals). Pb, Cr and Cd were not detected in leaf samples. Leaf C, N, P and K contents were similar between the two species and no significant difference was found among locations, although *A. corniculatum* seemed to have lower Mn concentrations than *K. candel*. With reference to temporal variations, no significant difference in sediment concentrations of some nutrients and metals was found between the spring and autumn seasons.

Tam, N. F. Y. and Y. S. Wong (1995). "Mangrove Soils As Sinks For Waste-Water-Borne Pollutants." *Hydrobiologia* **295**(1-3): 231-241.

Soil column leaching experiments were conducted to assess the retention of nutrients and heavy metals in two types of mangrove soils receiving strong wastewater throughout a period of 5 months. $\text{NH}_4^+\text{-N}$ was the dominant form of nitrogen, nitrite and nitrate were in relatively low concentrations in all leachate collected. The concentrations of $\text{NH}_4^+\text{-N}$ in leachate collected from columns packed with Sai Keng of Hong Kong mangrove soil were higher than those packed with soils collected from Shenzhen of China. The

leachate $\text{NH}_4^+\text{-N}$ contents of Shenzhen columns were significantly lower than that of the synthetic wastewater even at the end of the experimental period, indicating Shenzhen soils had very high capacity to bind nitrogen, and the amount of ammonium added from wastewater did not exceed the binding capacity of mangrove soil. The data also suggest that soils collected from Shenzhen mangrove swamp had higher capacity in retaining wastewater nitrogen than the Sai Keng soils. In contrast, leachate from Sai Keng columns had significantly lower ortho-P contents than those from Shenzhen columns. Actually, the leachate P concentrations of the Sai Keng columns treated with wastewater were similar to those receiving seawater ($< 0.1 \text{ mg l}^{-1}$). This finding implies Sai Keng soils were very effective in retaining wastewater P. Throughout the experiment, most heavy metals, including Cu, Zn, Cd, Ni and Cr were not detected in all leachate samples by flame atomic absorption spectrophotometry, indicating that both types of mangrove soils were capable of trapping wastewater-borne heavy metals. The study demonstrates that mangrove soils were good traps to immobilize wastewater-borne phosphorus and heavy metals but they were less efficient in retaining nitrogen from wastewater.

Tam, N. F. Y. and Y. S. Wong (1996). "Retention and distribution of heavy metals in mangrove soils receiving wastewater." Environmental Pollution **94**(3): 283-291.

The distribution and chemical fractionation of heavy metals retained in mangrove soils receiving wastewater were examined by soil column leaching experiments. The columns, filled with mangrove soils collected from two swamps in Hong Kong and the People's Republic of China, were irrigated three times a week for 150 days with synthetic wastewater containing 4 mg l^{-1} Cu, 20 mg l^{-1} Zn, 20 mg l^{-1} Mn and 0.4 mg l^{-1} Cd. Soil columns leached with artificial seawater (without any heavy metals) were used as the control. At the end of the leaching experiments, soil samples from each column were divided into five layers according to its depth viz. 0-1, 1-3, 3-5, 5-10 and > 10 cm, and analyzed for total and extractable heavy metal content. The fractionation of heavy metals in the surface soil samples (0-1 cm) was investigated by the sequential extraction technique. In both types of mangrove soils, the surface layer (0-1 cm) of the columns receiving wastewater had significantly higher concentrations of total Cu, Cd, Mn and Zn than the control. Concentrations declined significantly with soil depth. The proportion of exchangeable heavy metals in soils receiving wastewater was significantly higher than that found in the control, about 30% of the total heavy metals accumulated in the soil masses of the treated columns were extracted by ammonium acetate at

pH 4. The sequential extraction results show that in native mangrove soils (the soils without any treatment), the major portion of Cu, Zn, Mn and Cd was associated with the residual and precipitated fractions with very low concentrations in more labile phases. However, in mangrove soils receiving wastewater, a significantly higher percentage of Mn, Zn and Cd was found in the water-soluble and exchangeable fractions. Copper appeared to be more strongly adsorbed in mangrove soils than the other heavy metals. In general, heavy metal accumulation in the surface mangrove soils collected in Hong Kong was higher than those in the PRC, although the metals in the latter soil type were more strongly bound. These findings suggest that whether the heavy metal retained in mangrove soils becomes a secondary source or a permanent sink would depend on the kinds of heavy metals and also the types of mangrove soils. (C) 1997 Elsevier Science Ltd.

Tam, N. F. Y. and Y. S. Wong (1997). "Accumulation and distribution of heavy metals in a simulated mangrove system treated with sewage." *Hydrobiologia* **352**: 67-75.

Constructed tide tanks were used to examine the accumulation and distribution of heavy metals in various components of a simulated mangrove ecosystem. Young *Kandelia candel* plants grown in mangrove soils were irrigated with wastewater of various strengths twice a week for a period of one year. The amounts of heavy metals released via tidal water and leaf litter were monitored at regular time intervals. The quantities of heavy metals retained in mangrove soil and various plant parts were also determined. Results show that most heavy metals from wastewater were retained in soils with little being uptake by plants or released into tidal seawater. However, the amounts of metals retained in plants on a per unit dry weight base were higher than those in soils as the biomass production from the young mangrove plants was much smaller when compared to the vast quantity of soils used in this study. A significantly higher heavy metal content was found in roots than in the aerial parts of the mangrove plant, indicating that the roots act as a barrier for metal translocation and protect the sensitive parts of the plant from metal contamination. In both soil and plant, concentrations of Zn, Cd, Pb and Ni increased with the strengths of wastewater, although the bioaccumulation factors for these metals decreased when wastewater strengths increased. These results suggest that the mangrove soil component has a large capacity to retain heavy metals, and the role of mangrove plants in retaining metals will depend on plant age and their biomass production.

Tam, N. F. Y. and M. W. Y. Yao (1998). "Normalisation and

heavy metal contamination in mangrove sediments." Science of the Total Environment **216**(1-2): 33-39.

The concentrations of Zn, Ni, Cr, Cu, Mn, Fe and Al in surface sediments collected from three mangrove sites in Hong Kong were determined following aqua regia digestion. The heavy metal concentrations were normalised to reference elements to facilitate comparison between mangrove sites. Iron was found to be a good normaliser for Mn ($r = 0.892$), Zn ($r = 0.443$) and Ni ($r = 0.318$) in 35 sediment samples from three mangrove sites. However, the correlation coefficients between Fe and Cu, and Fe and Cr were low. Total organic carbon and aluminum could be alternate normalisers for certain heavy metals such as Cu and Cr in mangrove sediments. Among three mangrove sites in Hong Kong, Sha Tau Kok was contaminated with Zn and Cu, elevated levels of Mn and Ni were recorded in Chek Keng and Sai Keng was enriched with Cr based on the ratios between metal and normaliser concentrations. (C) 1998 Elsevier Science B.V.

Tam, N. F. Y. and Y. S. Wong (1999). "Mangrove soils in removing pollutants from municipal wastewater of different salinities." Journal of Environmental Quality **28**(2): 556-564.

Soil leaching experiments were conducted to assess the capacity of mangrove soils in purifying synthetic wastewater containing pollutant concentrations four times of that found in local municipal sewage and of two salinities (fresh vs, saline water). Results on leachate nutrient and heavy metal concentrations reveal that the mangrove soils were capable of removing certain amount of pollutants from wastewater, and the removal efficiency varied between pollutants. The soils were most effective in retaining heavy metals such as Cu but were less effective for Mn and Zn. Similarly, the wastewater-borne NH_4^+ was more easily leached than P. The soil data show that most pollutants were accumulated in the top layer (0-1.5 cm) of the soil tray, with little downward migration. Differences between treated and control soil nutrient and heavy metal concentrations were not found in the soil masses below the surface 1.5 cm. In the surface layer, the mangrove soils treated with wastewater had significantly higher concentrations of $\text{NH}_4^+\text{-N}$, total and extractable P, total and extractable Cu, Cd, Zn and Mn. On the other hand, there was no significant elevation in total nitrogen content in mangrove soils treated with wastewater when compared with the control. Soils receiving wastewater prepared in deionized water (fresh) had slightly higher pollutant concentrations, and larger enrichment factors than that treated with saline wastewater (containing 1.5% salinity). These results suggest that mangrove soils could retain pollutants from wastewater but its efficiency would slightly be affected by salinity.

Tan, K. S. (1997). "A new species of *Thais* (Mollusca: Neogastropoda: Muricidae) with direct development from northwestern Australia." Journal of Natural History **31**(11): 1723-1742.

Thais wutingi, a new species of Muricidae, is described from rocky and mangrove shores in the vicinity of Darwin, northern Australia. It is relatively common where it occurs but the species may have previously been mistaken for *T. gradata* (Jonas) or *T. javanica* (Philippi). The new species differs from the latter two species in having a penis with a narrow groove along the greater curvature of the penial base. The larvae of *T. wutingi* undergo direct development, hatching from egg capsules as crawling juveniles, in contrast to the majority of *Thais* (s.l.) species found in the tropics which have planktotrophic development. Its mode of development may explain the relatively restricted geographical distribution of this species, which is confined to the north and northwestern coasts of Australia.

Vance, D. J., M. D. E. Haywood, et al. (1996). "Seasonal and annual variation in abundance of postlarval and juvenile grooved tiger prawns *Penaeus semisulcatus* and environmental variation in the Embley River, Australia: A six year study." Marine Ecology-Progress Series **135**(1-3): 43-55.

We studied the 2-weekly, seasonal and annual variation in abundance of postlarval and juvenile *Penaeus semisulcatus* on a seagrass and an algal bed in the Embley River, Australia, from September 1986 to May 1992. The climate in this region is dominated by the wet and dry seasons, which lead to clear seasonal patterns of salinity, temperature and mean sea level in the estuaries. Similarly, catches of postlarvae entering the estuary and of postlarvae and juveniles in the estuary showed strong seasonal variation; they were highest just before and during the wet season, from September to April each year. Catch rates often had a bimodal distribution each year, but the relative size of each recruitment peak varied considerably between years. Long-term sampling over several years is clearly necessary to identify seasonal patterns in abundance and the range of variation in these patterns for juvenile penaeids. Total catches also varied substantially between years. The bimodal juvenile catch distribution suggests that recruitment to the offshore adult fishery should occur over 2 periods during the year. This is in contrast to previous work on adult *P. semisulcatus* in the Gulf of Carpentaria, which found only 1 period of recruitment and has important implications for the management of the fishery. Using multiple regression analysis, the most significant factor in determining the abundance of juvenile *P. semisulcatus* in the estuary was the number of benthic postlarvae that settled on the seagrass

and algal beds. Rainfall was the most important environmental variable in the postlarval catch models. Increased rainfall was associated with a lower catch of postlarvae at the seagrass and algal sites but its major influence was through reducing the amount of algal habitat during the wet season. The mean sea level, or the amount of time that the seagrass bed was exposed, was also significant in the regression models for benthic postlarval and juvenile catches; increased exposure of the seagrass bed was associated with decreased catches of *P. semisulcatus*. However, because the proportion of juvenile catch variation explained by environmental variables was low, it is unlikely that predictive models of adult catches can be developed based on environmental factors acting on the estuarine stages of the life cycle of this species.

Vanderkaars, W. A. (1991). "Palynology of Eastern Indonesian Marine Piston-Cores - a Late Quaternary Vegetational and Climatic Record For Australasia." Palaeogeography Palaeoclimatology Palaeoecology **85** (3-4) : 239-&.

Pollen analyses on Late Quaternary sediments from nine marine piston-cores reveal a continuous vegetation and environmental record for eastern Indonesia and northern Australia. On the island of Halmahera a montane oak forest largely replaced the tropical lowland vegetation during the last glacial period, while fern cover was strongly reduced during its maximum (18,000 yr B.P.). Climate was cooler and slightly drier than today. Around 10,000 yr B.P. mangrove vegetation expanded following the rising sea-level. In our western New Guinea record, at 14,000 yr B.P. climate grew warmer and slightly wetter, until it stabilised around 10,000 yr B.P. At that time the mid- to upper montane forests expanded to their full altitudinal range and fern cover increased, while montane oak forest, grassland and woodland areas had contracted. In our marine pollen records, during the last glacial the climate of northern Australia was distinctly drier than today. Grassland vegetation with sedges increased considerably at 38,000 and 24,000 yr B.P. replacing eucalypt forest and culminating in a maximum grassland cover at the height of the last glaciation (18,000 yr B.P.). The rapid sea-level rise allowed the expansion of mangrove forests and salt-bush marshes which had become established on the large tidal flats of the drowning Sahul Shelf, around 12,000 yr B.P. One piston-core (G6-4) extends to 300,000 yr B.P. and shows that glacial periods are characterised by high pollen concentrations in marine sediments, recording expanding grassland vegetation. During interglacial woodland and fern cover increased, while pollen concentrations in the sediments were low. After 190,000 yr B.P. a more open vegetation suggests that conditions were in

general much more arid than before. Repeated mangrove vegetation expansions suggest major rises in sea-level at around 244,000, 220,000 and 130,000 yr B.P.

Ward, I. A. K., P. Larcombe, et al. (1995). "Stratigraphic control of the geochemistry of Holocene inner-shelf facies, Great Barrier Reef." Marine Geology **129**(1-2): 47-62.

Cleveland Bay and Halifax Bay are adjacent embayments, situated on the inner-shelf region (0-20 m) of the central Great Barrier Reef shelf off Townsville, northeast Australia. These bays contain Holocene sediments up to 5 m in thickness, deposited during the last stages of the post-glacial sea-level rise. X-ray diffraction and X-ray fluorescence techniques were used to examine the mineralogy and geochemistry of the main Holocene facies, sampled in 40 vibrocores. The sediments of southern Halifax Bay and Cleveland Bay consist mainly of quartz (ca. 50%), alkali feldspars (ca. 20%), clay minerals (ca. 20%) consisting of mixed-layer clays, smectite, kaolinite and illite, and carbonate (ca. 10%) including aragonite and calcite. The Holocene facies sequence comprises, in order of increasing age, modern bay, shoreline and mangrove sediments. The oxides of the major components (SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, K₂O, Na₂O, P₂O₅) in Halifax Bay show the predicted linear correlations with geochemically related minor elements (Pb, Rb, Sr, Y, Zr, Ga, Zn, Ni, Co, Mn, Cr, Ti, Sc, V, Ba), and can be used to discriminate Holocene facies. However, in Cleveland Bay these elements are poorly correlated within each facies and provide very poor facies discrimination. These findings probably result from the presence of sandy shoreline sediments up to 2 m in thickness in the Holocene sequence of Cleveland Bay, with the consequent development of a weak oxic zone and migration of elements between adjacent facies. A similar oxic zone is poorly developed in Halifax Bay because the shoreline facies there is either thin or absent. That the chemical signatures of Holocene inner-shelf facies are spatially-variable, and are strongly influenced by the stratigraphy, has wide implications for geochemical studies of marine sediments.

Wolanski, E. and J. Chappell (1996). "The response of tropical Australian estuaries to a sea level rise." Journal of Marine Systems **7**(2-4): 267-279.

Estuaries in tropical Australia have a low sediment yield (about 5-20 tonnes km⁻² yr⁻¹). The estuaries formed when rising post-glacial sea level invaded coastal valleys 7 to 9000 years ago. Geomorphological and stratigraphic data show that mangrove swamps developed on the flooded plains and in some cases their substrate kept pace with the rising sea level. The bulk of the sediment originated from the sea. When sea level stabilised, 6000

years ago, the flood plains prograded seaward. The channels now are generally stable and in some cases are inherited from the progradation phase. The response of these estuaries to a sea level rise may be inferred both from their evolution during post glacial sea level rise and from hydrodynamics-sedimentological models calibrated against measurements of tidal processes. This was undertaken for Coral Creek, the South Alligator River and the Norman River in north Australia. Modelling indicates that a future sea level rise will generate changes in the dynamics and channel dimensions which mimic post glacial changes. In the macrotidal South Alligator the floodplain will revert to mangrove, the mouth region will widen and sediment will move upstream and onto the floodplain. In the mesotidal, diurnal Norman the channel will widen throughout and sediment will be transported seawards. In Coral Creek the mangrove will retreat landwards.

Wong, Y. S., N. F. Y. Tam, et al. (1997). "Response of *Aegiceras corniculatum* to synthetic sewage under simulated tidal conditions." *Hydrobiologia* **352**: 89-96.

Young plants of *Aegiceras corniculatum*, a dominant mangrove species, were collected from Futian Mangrove Swamp in Shenzhen, The People's Republic of China, and grown in simulated tide tanks containing mangrove sediments. After acclimatisation in the greenhouse for 6 months, the plants were irrigated with either synthetic sewage of various strengths (NW, FW and TW) or artificial seawater (as control). NW had the characteristics and strength equivalent to municipal wastewater, while FW and TW contained 5 and 10 times the nutrient and heavy metal concentrations of the NW, respectively. Results showed that the young plants of *A. corniculatum* were able to tolerate the wastewater (TW) with highest concentration of nutrients and heavy metals after one year treatment. The growth of TW treated plants, measured in terms of stem height, basal diameter and biomass, was comparable to that found in the control. The plants treated with NW and FW had significantly greater growth than the control, indicating that the nutrients contained in sewage are beneficial to mangrove plants. Physiological parameters such as chlorophyll content, the ratio of chlorophyll a and b, proline concentration and root activity did not show any significant changes among plants treated with wastewater of various strengths and the control, suggesting that sewage addition did not cause any apparent physiological impact on growth of *A. corniculatum*. Nevertheless, the plants which received sewage with highest levels of heavy metals (TW treatment) appeared to have lower content of free water but higher amount of bound water than FW, NW and the control. Higher electric conductance was also found in plants treated with TW.

Woodroffe, C. D. (1990). "The Impact of Sea-Level Rise On Mangrove Shorelines." Progress in Physical Geography **14**(4): 483-520.

Woodroffe, C. D. and J. Grindrod (1991). "Mangrove Biogeography - the Role of Quaternary Environmental and Sea-Level Change." Journal of Biogeography **18**(5): 479-492.

Mangroves and corals have broadly similar patterns of global distribution with a major disjunction between New World and Old World populations. However, while palaeogeographic interpretations of present coral distributions have emphasized the role of environmental and sea-level fluctuations during the Quaternary, the traditional explanation of mangrove distributions has invoked gradual dispersal over the Tertiary and Quaternary from a Southeast Asian centre of origin. The distribution of mangroves at their latitudinal limits and on oceanic islands is examined. These observations together with palynological evidence for substantial changes in mangrove extent in the Holocene are used to suggest that sea-level fluctuations in particular have caused major disruptions to mangrove distributions during the Quaternary. Many species of mangroves have recolonized oceanic islands during the Holocene and their present distribution is, at least in part, a function of their successful transoceanic dispersal to these islands. Although little evidence of Pleistocene distributions of mangroves is preserved, environmental and especially sea-level fluctuations are likely to have played a similar role in the biogeography of mangroves as they have in influencing the biogeography of corals.

Woodroffe, C. D. and J. Chappell (1993). "Holocene Emergence and Evolution of the McArthur River Delta, Southwestern Gulf of Carpentaria, Australia." Sedimentary Geology **83**(3-4): 303-317.

The McArthur River drains from a semiarid, sandstone catchment into a shallow embayment behind the Sir Edward Pellew Group of islands in the southwestern Gulf of Carpentaria. It has built a broad Holocene delta, present with two active distributaries and several abandoned, mangrove-lined, former distributaries. Augering indicates that much of the delta is underlain by shelly sands which contain distinct shell beds in their position of growth. These are interpreted as delta front deposits, and the elevation of the landwardmost beds above high tide level implies emergence of 1-2 m over the last 4000 years. This relative sea-level fall appears to have been a major cause of rapid mid-Holocene delta progradation. The eastern margin of the delta has undergone little net progradation over the last 2000 years, though there has been accretion of small

mangrove- covered islands to the northwest of the delta. Distributaries have migrated across the upper deltaic plain by lateral migration, leaving nested sequences of fluvial ridges. In the lower deltaic plain, channel migration appears to have occurred mainly by avulsion; former distributaries have been infilled with fluvial sands and are now tidally dominated.

Woodroffe, C. D. (1995). "Response of Tide-Dominated Mangrove Shorelines in Northern Australia to Anticipated Sea-Level Rise." Earth Surface Processes and Landforms **20**(1): 65-85.

The exact response of mangrove shorelines to anticipated sea- level rise will depend upon the balance between sedimentation and sea-level change. Within the Top End of the Northern Territory of Australia there are extensive, relatively unmodified, tide-dominated mangrove forests, where tidal processes redistribute sediment. Harbours, such as Darwin Harbour, and tidal rivers, such as the South Alligator River with its associated coastal and estuarine plains, represent opposite extremes in terms of Holocene sedimentary infill, and will respond differently to sea-level rise. In Darwin Harbour, mangrove assemblages can be recognized in geomorphologically defined habitats. Similar topography within and between creeks implies morphodynamic equilibrium with tidal processes. Tidal reworking of sediment may maintain an equilibrium profile under gradually rising sea level, with resuspension of lower intertidal and subtidal muds and their redeposition within upper intertidal mangrove habitats. In contrast, the plains along the coast and tidal rivers draining into van Diemen Gulf developed during the post-glacial marine transgression, and since sea level stabilized, around 6000 years ago, coastal plains have prograded. These broad plains are presently not extensively influenced by salt water, but are often at elevations close to, or even below, modern high-tide levels. They may, therefore, revert to saline conditions particularly rapidly if the sea rises. The pattern of change may not be directly analogous to marine incursion experienced in the early Holocene, because broad plains have been able to prograde during the last 6000 years of relatively stable sea level.

Yakzan, A. M. and K. Hassan (1997). "Palynology of late Quaternary coastal sediments, Perak, Malaysia." Catena **30**(4): 391-+.

Twenty eight samples of peat, clay and silty clay from a tin mine exposure near Pantai Remis, Perak, Malaysia, were palynologically analyzed. Six pollen zones and eight subzones were delineated based on the dominant floral components. Accelerator mass spectrometry (AMS) radiocarbon

and thermoluminescence datings on selected samples indicate late Pleistocene and older age. The occurrence of *Podocarpus imbricatus* pollen suggests that the deposit is no older than late Pliocene. The fluctuation of sea level during the late Pleistocene is believed to be the main factor that influenced the development of vegetation at the Pantai Remis area. The presence of mangrove peat at depths between 13.0 m and 14.0 m, which overlies a freshwater *Pandanus* peat, indicates the position of a former shoreline at Pantai Remis when the area was inundated sometime during the last interglacial marine incursion. During this period of high sea level, the *Pandanus* swamp was probably being gradually replaced by mangrove vegetation. The mangrove sequence is regarded as equivalent to the Kempadang formation. A slight drop in sea level sometime during the last glacial interstadial stage probably caused a small, open alluvial swamp to be developed over the mangrove forest. This freshwater deposit may be the equivalent of the Simpang formation. (C) 1997 Elsevier Science B.V.

Zann, L. P. (1996). "The State of the Marine Environment Report for Australia (SOMER): Process, findings and perspectives." Ocean & Coastal Management **33**(1-3): 63-86.

SOMER, the first comprehensive description of Australia's marine environment, human uses and impacts, and management, was produced for Australia's government to provide information for a national marine conservation plan. SOMER was based on 90 commissioned reports by 140 scientists. It consists of three Technical Annexes (31 papers); a Technical Summary intended for environmental managers, an overview of the major findings, and an executive summary. SOMER found that Australia's marine environment was of great national and global value. While its condition was rated as 'generally good' (largely because of the large areas of sparsely inhabited coastlines and seas), major problems included declining inshore water quality because of elevated nutrients and sediments, associated declines in estuarine communities and die-back of temperate seagrass, particularly in the south-east and south-west; widespread beach and ocean litter and localised 'hotspots' of heavy metal, hydrocarbon and organochlorine pollution in some metropolitan and industrialised areas, threats to inshore corals; loss of saltmarsh and mangroves on developed coastlines, declines in some fish stocks; effects of trawling on the introductions of exotic species (particularly toxic dinoflagellates); outbreaks of native species such as crown-of-thorns starfish and *Drupella* snails, and declining marine environments around urban areas. The paper concludes with an evaluation of the achievements and deficiencies of SOMER. (C) 1997 Elsevier Science Ltd.

Zheng, W. J., X. Y. Chen, et al. (1997). "Accumulation and biological cycling of heavy metal elements in *Rhizophora stylosa* mangroves in Yingluo Bay, China." Marine Ecology-Progress Series **159**: 293-301.

Absorption, accumulation and dynamics of 7 heavy metal elements were studied in mature *Rhizophora stylosa* mangroves in Yingluo Bay, China. The concentrations of Cu, Pb, Zn, Cd, Cr, Ni and Mn in the sediments of the mangrove forest were determined to be 18.9, 10.0, 46.6, 0.077, 9.27, 14.6 and 89.5 $\mu\text{g g}^{-1}$ dry wt, respectively. Evident differences of heavy metal concentrations have been observed in different parts of the plant, and the weighted means were 0.98, 0.86, 4.91, 0.11, 0.50, 1.06 and 14.60 $\mu\text{g g}^{-1}$ dry wt for Cu, Pb, Zn, Cd, Cr, Ni and Mn respectively. In natural habitat conditions, the ability of *R. stylosa* to absorb each heavy metal except Cd was very low, and the weighted average accumulation indices of Cu, Pb, Zn, Cd, Cr, Ni and Mn in the plant to those in soil were only 0.05, 0.09, 0.11, 1.40, 0.05, 0.07 and 0.16, respectively. The heavy metal concentrations in residues on the floor were much higher than those in the plant and in litter falls. The total amounts of Cu, Pb, Zn, Cd, Cr, Ni and Mn in the standing crop of the forest were 28.73, 25.25, 143.68, 3.14, 14.61, 30.87 and 430.39 mg m^{-2} , among which about 90 to 96% of the total amounts was stored in the parts difficult to consume by the animals. The storages in residues on the floor were 271.7, 323.5, 1983.8, 8.2, 34.4, 63.0 and 1776.9 $\mu\text{g m}^{-2}$, respectively. With the development of leaves from young to old, Cu, Zn and Ni can be translocated and reused before defoliation, while amounts of other heavy metal elements increased in older leaves. In the biological cycle of 7 heavy metals in the forest the following was observed: (1) the annual uptakes of Cu, Pb, Zn, Cd, Cr, Ni and Mn by the forest were 1351.7, 1613.11, 8808.4, 240.7, 759.5, 1627.7 and 53692.0 $\mu\text{g m}^{-2}$; (2) annual retentions were 842.5, 806.9, 4694.2, 95.0, 464.9, 1054.0 and 14038.9 $\mu\text{g m}^{-2}$, respectively; (3) annual returns were 509.2, 806.2, 4114.3, 146.0, 294.6, 573.7 and 3965.3 $\mu\text{g m}^{-2}$, respectively. The estimated turnover periods were 56, 31, 35, 22, 50, 54 and 11 yr for Cu, Pb, Zn, Cd, Cr, Ni and Mn, respectively.