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DYNAMICS OF LITTORAL BIOTA OF NIGERIA AFTER THE EXXON MOBIL-IDOHO JANUARY 1998, OFF-SHORE OIL SPILL: LONG-TERM (1998 - 2001) MONITORING

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ABSTRACT

During September 1998 - 2001, the long term impact of Exxon Mobil Idoho offshore oil spill of 12 January 1998 was quantitatively determined for the littoral biota of Nigeria. The mean surface sediment hydrocarbon concentrations were markedly higher (15.5 pl $20g^{-1}$) at middle eulittoral zones than at high tide levels (upper eulittoral) (8.1 pl $20g^{-1}$) at the beginning of the survey. At deeper levels, oil concentrations decreased from 0.8 pl $20g^{-1}$ sediment in the first year of spills to 0.28 pl $20g^{-1}$ sediment at the end of the survey. The upper shore appearance and colonization of epibenthic *Rhizophora* mangle root by algae was markedly evident in 2000 and this signaled the beginning of biological recovery of the Nigerian coastline. Biota abundance and diversity on muddy shores remained below the control shore at all tidal levels which provided the baseline for natural fluctuations in biota on Nigerian coastline and are used here as indicator for early biota recovery. Abundance and diversity exceeded the control shore level by 65 and 80% on the sandy and mangrove shores. Recruitment of marine larval forms enhanced the mangrove shore high mean faunal densities. The ecological implications of these findings are discussed and strategies highlighted for the management and mitigation of future oil spill incidents.

Keywords: Exxon-Mobil Idoho offshore oil spill, biota recovery, Nigerian coastline.

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INTRODUCTION

Following the rupture of a 24-inch oil pipeline at Mobil-Idoho offshore platform, off the Atlantic coast of south eastern Nigeria in January 12-28 1998, over 40,000 bbls (approximately 6000 tonnes) of crude oil was released into the marine environment. More than 900km stretch of the Nigerian coastline including estuaries and lagoons were impacted, as currents and prevailing winds stranded oil ashore along most parts of the coastline.

The magnitude of impact of this spill along the Nigeria coastline has been reported and documented (Antia, 1998, Ewa-Oboho, 1998).
Initial report based on visit to the impacted area shortly after the spill suggested large scale extermination of marine life and gave a pessimistic prognoses as to the future recovery of the environment. The recovery of aquatic biota from habitat anthropogenic perturbation is best recognized by observable increase in the abundance of pollutant sensitive-taxa and decline in abundance of pollutant tolerant ones (Keller *et al*, 1992). If the damage was not too severe, then the chances are high that the nearshore benthic communities would recover after a certain reasonable time frame, depending on the containment treatment applied and the prevailing environmental conditions (Ewa-Oboho 1998). Chemical recovery of water and sediment in the spill area with regards to total hydrocarbon contents could improve markedly (Asuquo, 2000) after an impact. In response, the benthic communities in many localities along the oiled coastline should equally recover from the spill effect.

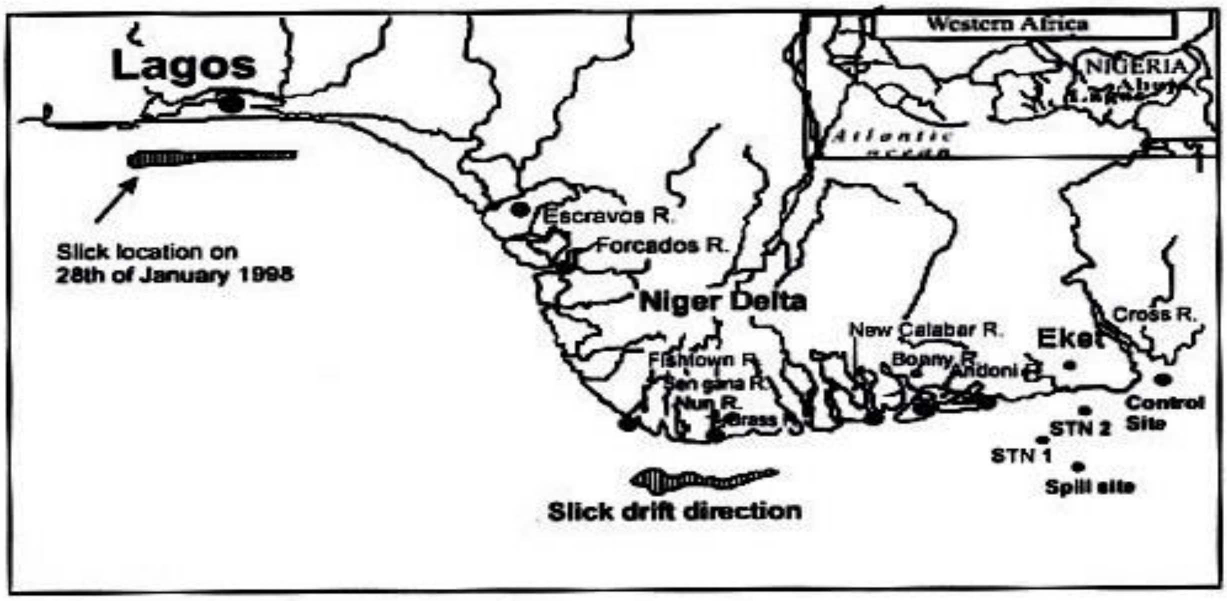

Fig. 1:Map of Nigerian coastline with inset map of West Africa showing the sampling locations during the long-term 1998-2001 survey.

Presently, little is known about the impact of oil and its long term effect and recovery of littoral benthos of West Africa (Sell *et al.* 1996), compared to similar environment else where. This may be due to the complicated nature of the mangrove swamps and the enormous seasonal and spatial variability of resident fauna and its challenging taxonomy. The present study attempts to quantitatively evaluate the rate of recovery of biota along the Nigerian coastline after what appeared to be the largest oil spillage that had ever occurred in the region.

A unique feature of this study is the monitoring of recovery at the level of specific habitats within the ecosystem. The recovery rate is assessed at 3 shore levels viz: lower eulittoral, middle eulittoral and high eulittoral zones. Other similar but less spatially intensive studies had indicated that species richness and densities of individual taxa tend to increase after water quality improvement (Asuquo 2000). However, by studying individual habitats within the impacted area, it was possible to quantify the time lag between chemical (oiling) and biological responses. These types of quantitative data are required for future development of biological response models that link changes in marine coastal biota to improvement in environmental quality.

A reconnaissance study was undertaken during September 2-12, 1998, during which coastal beaches were investigated for the presence and/or absence of typical macrobiota and estimate of overall abundance at each site. Analysis of physical characteristics and associated macrobiota showed that not all areas along the coast was impacted by oil to have inflicted damage as earlier predicted and results provided a basis for selection of long term transects (LLT) on impacted areas and control for regular quantitative monitoring of recovery of macrobiota at 3 habitat types between 1998 - 2001.

MATERIALS AND METHODS

STUDY AREA AND SAMPLING LOCATIONS

The study area extents from a control location, 5km east of the spill point in Cross River estuary (04°32.06'N and 08°04:46'E) to Takwa Bay, Lagos (06°25.47'N and 03°32.51'E) (Fig. 1) approximately 870km east of the pipe break point. The area lies within the equatorial climatic zone greatly influenced by the dominance of North East Trade winds during the dry months (December—February) and the South West monsoon which bring rains during May — September.

METHODS

Ten stations and a control at 5km east of the spill point, were chosen for regular bimonthly monitoring (sampling). The stations were grouped on the basis of their degree of oiling after the spill viz: heavily oiled, highly oiled and no oil (Fig. 1). The heavily oiled areas included the intertidal zones around Bonny, Brass, Forcados, Escravos and Lagos Lagoon, while the lightly oiled sites included shores around Imo river, Cross river, Qua Iboe and Nicholas rivers. At each station samples were collected along long-term transect (LTT) established for regular monitoring, namely, mud (LTTm 3,4 and 5), mangrove (LTTmg 7,8 and 9) and sandy mud (LTTsm 10,6) (Fig.1). In this report, only results for 1 transect from each shore type is included in the analysis.

PHYSICO-CHEMICAL MEASUREMENTS

In-situ salinity and temperature were measured on selected LTT and all control sites and over annual cycle for oil contaminated and non-polluted surfaces. Surface water temperature was measured from scooped bucket using a mercury-in-glass thermometer, while salinity measurements were done with Atago 8257 model refractometer.

INTERTIDAL INVESTIGATIONS

These investigations, which began in September 1998 and terminated in September 2001, made use of a standard key species presence/ absence data sheet specifically designed for the West African coastal region based on the field guide by Powell (1984), and a Standard Site Information Sheet developed by the Marine Biology unit, University of Science and Technology, Port Harcourt (Ekweozor, 1984; Ombu 1987; Ewa-Oboho 1988, 1993, 1994). Assessment of overall abundance of organisms together with anthropogenic and topographic information, and the list and figures of species and taxa collected from the region as obtained in literature, were included in both sheets. All species encountered during the survey, were identified and recorded and when in doubt, samples were preserved for further verification and confirmation in the Natural History Museum. To determine similarities between sites and shore levels based on species lists, records from key species sheets were entered into a computer and subjected to the following methods of analyses. Principal Component Analysis (PCA) based on species presence and absence data, Covariance Matrix (CM) using species presence at more than two stations, Hierarchical Agglomeration (cluster analysis) using Tanimoto and Kulczynski Indexes (Jone & Richard, 1992, Prena, 1996). Both principal component and cluster statistical analyses methods separated sand, mud and mangrove habitats clearly based on biota alone, confirmed partially the physical data collected from each site and provided a habitat classification for establishment of LTT monitoring method. Epibenthos were sampled bimonthly by counting organisms within 5 random 1 cm^2 quadrats or macrobiota recorded as percentage cover. On soft sediment locations, a 0.25m area was initially sifted by hand for macrobiota and then all surface (to 10cm depth) materials scrapped and sieved. Triplicate 0.1m^2 cores to a depth of 15cm, collected infauna samples , which were sieved through a 1mm mesh and fauna preserved in 5% formalin solution to which borax neutral solution was added.

RESULTS AND OBSERVATIONS

Temperature and Salinity

The temperature of the surface water remained fairly constant at 28^{0}C mean value through out the investigation period. However at the mud flats and water pools, temperatures of 35^{0}C to 48^{0}C were recorded. Salinities were generally low at low tides and high at high tides. Annual river mouth salinity ranged from 15 to 28‰. There was no significant difference in the spatial (site to site) changes in salinity values (P = NS, ANOVA) through out the survey.

Mineral hydrocarbons in the sediment

Total hydrocarbon concentrations in the sediments were monitored at two tidal levels namely high tide (upper eulittoral) and midtide (middle eulittoral) zones. Mean concentrations were generally higher (15.5 µl 20g-^{1} sed.) at MTL in 1998 when the spill occurred, than in 2001, 3.8 pl 20g-^{1} sed.) at the end of the survey (2001). Lower concentrations at high tide level (HTL): 6.3 pl.20g-^{1} sediment in 1998 and 0.86 pl. 20g^{-1} in 2001, could be attributed to the sandy substratum occasionally is associated with this zone of the shore, which characteristically retains little oil, between the coarse particles.

Biota recolonization

The appearances of epibenthic algal mat at the upper eulittoral habitats signaled the first stage in the recolonization of the Nigerian shores from the spill effect. The structure, distribution and dynamics of macro algal of this region has been described by Ewa-Oboho, (1993, 1988). Fig. 3 shows the year to year mean densities of four dominant macro epi-algae in the study area. Except for *Rhizoclonium* species that showed no apparent change after oiling mean densities, of spices *Caloglossa*, *Catenella* and *Bostrychia* showed drastic reduction in 1999 and 2000 when means densities were 100% than at the reference (control). By 2001, mean values have returned to >80% that on the control shore for all species.

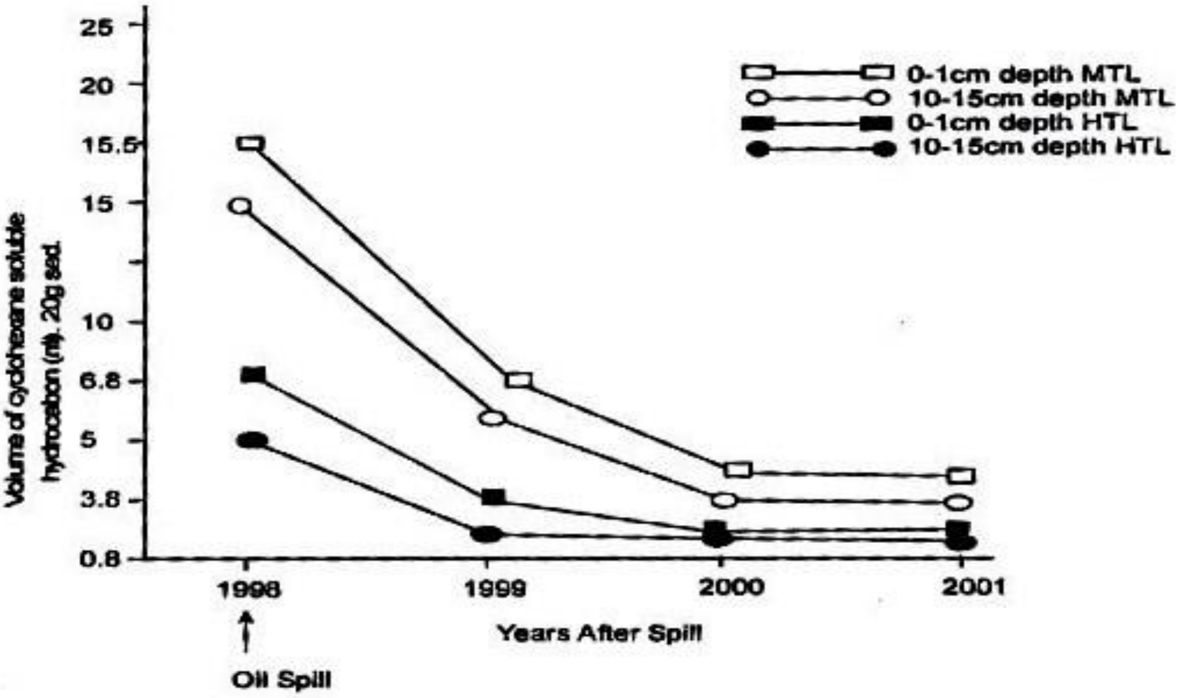

Fig. 2: Volume of cyclohexane soluble hydrocarbons (μ1) present in a 20g sediment sample at middle and upper shore zones.

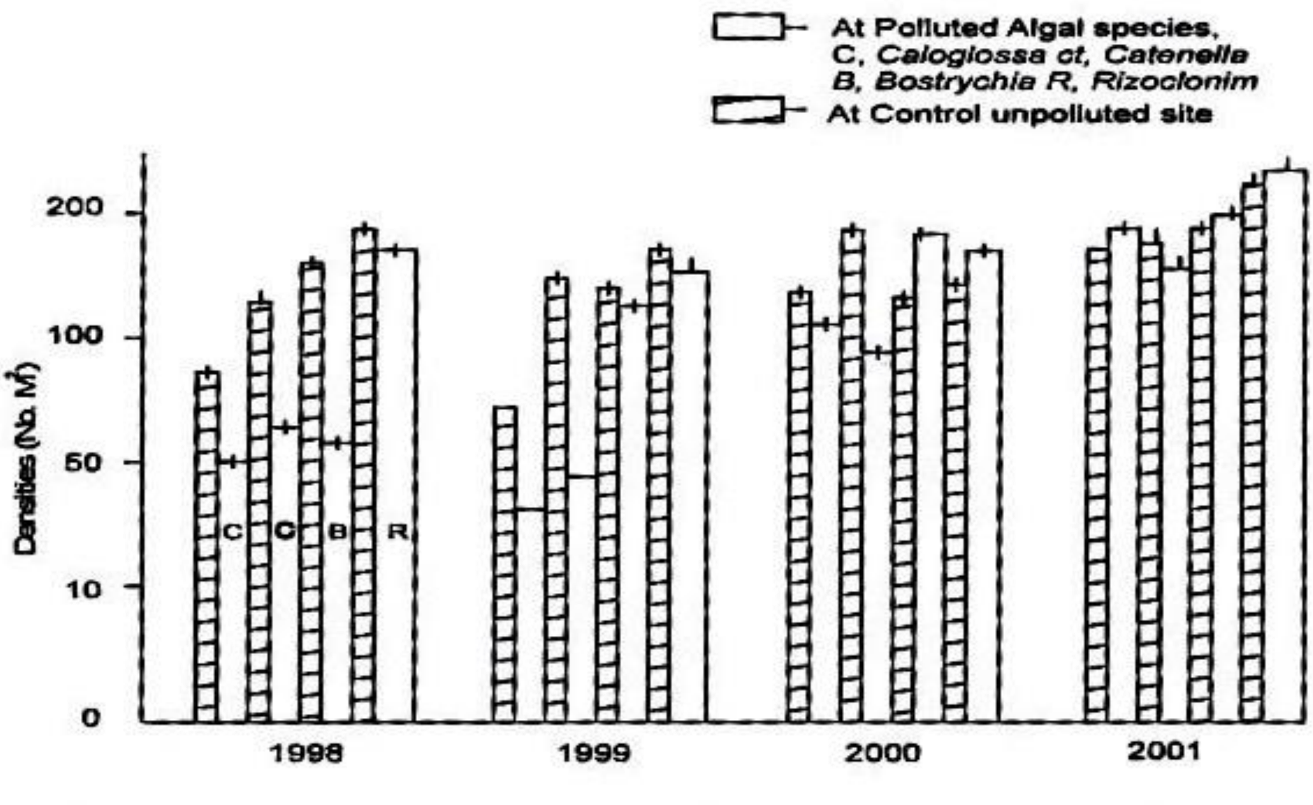

Fig. 3: Year to year spatial changes in macro-algal abundance after Idoho 12th January, 1998 oil spill.

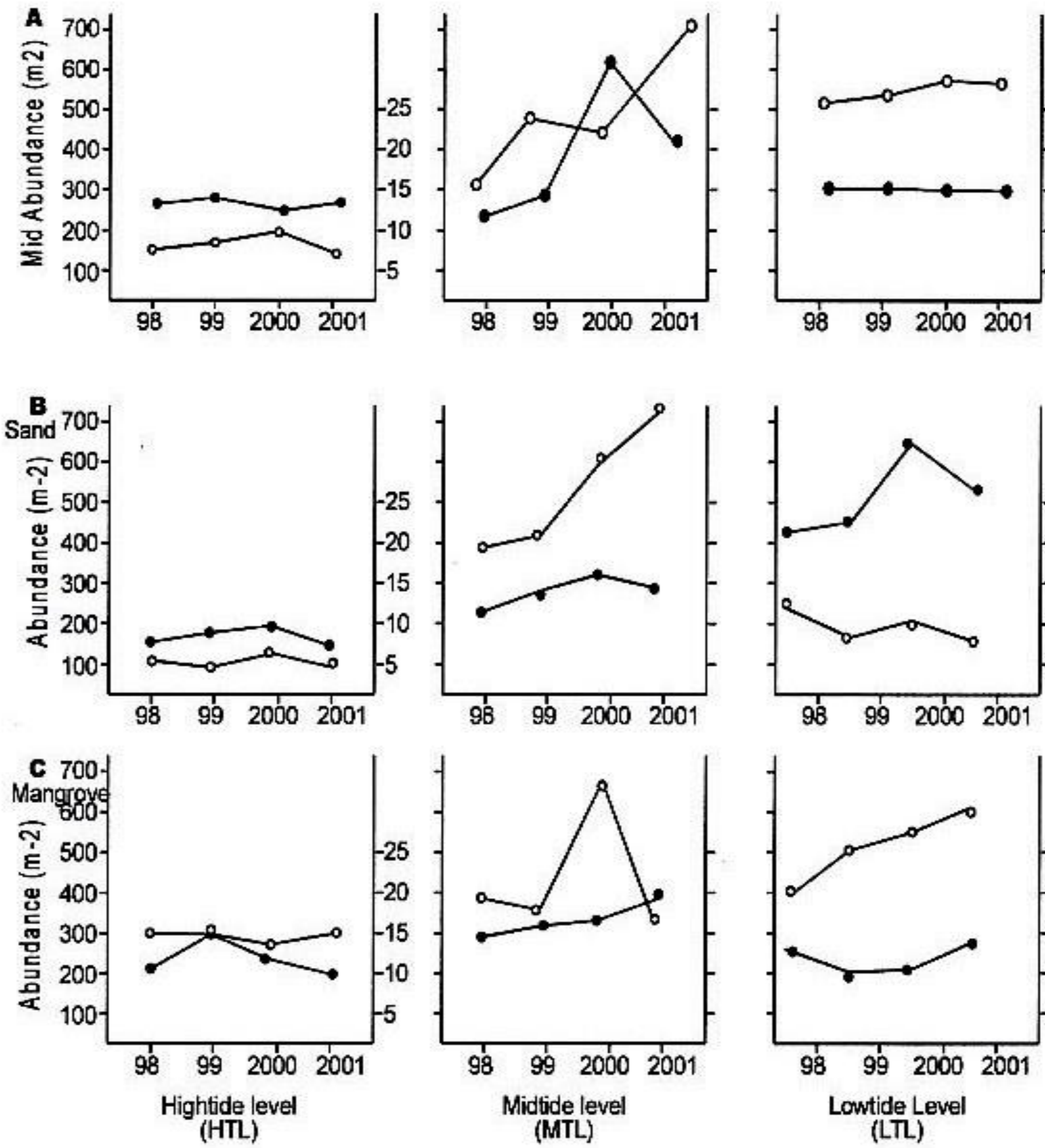

Fig. 4: Mean annual numbers and abundance for 1998-2001 at three shore levels for the control (unoiled sites).

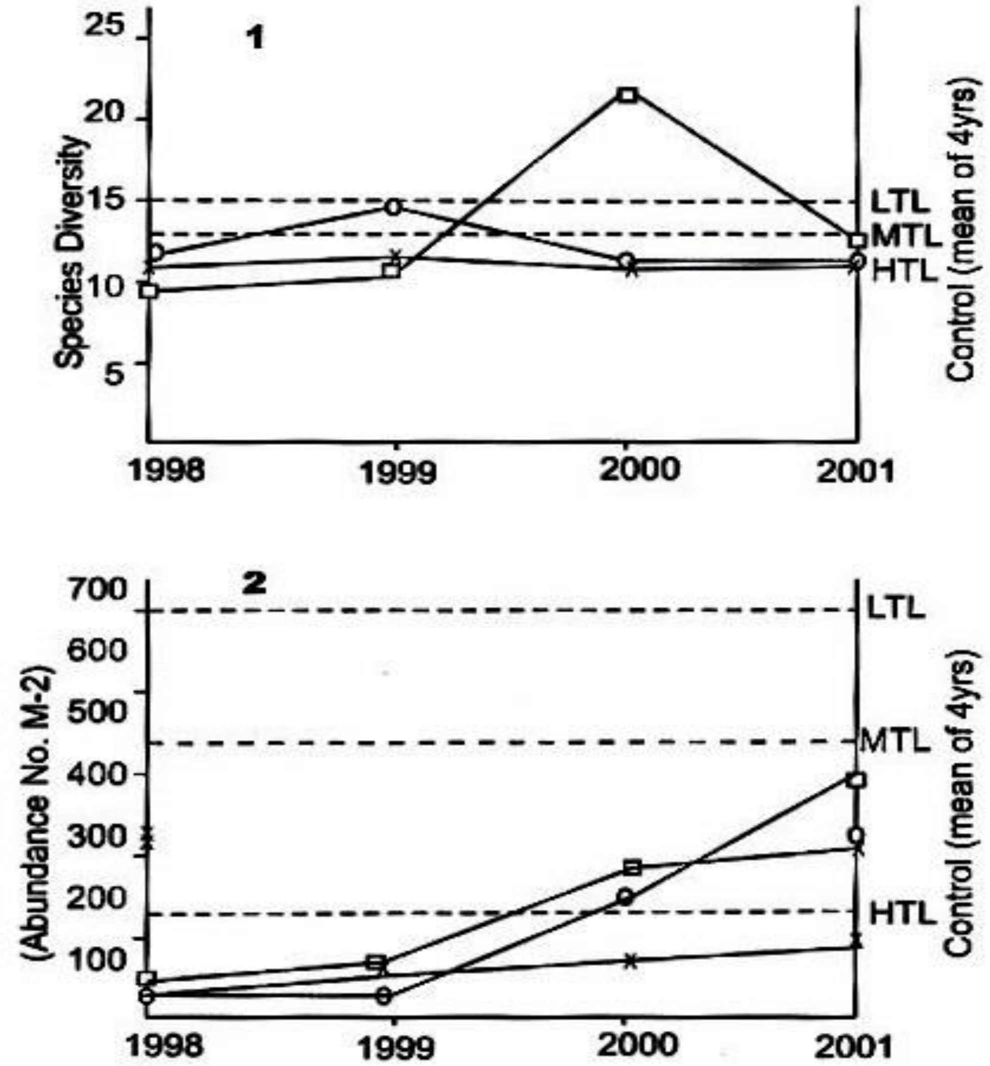

Fig 5: Number of species (1) and their abundances (2) on an oiled □ LTTL, 5(Mud) and control LTTL control. Mud HTL., X, HTL; □Midtide level (MTL): O, Lowtide level (LTL)

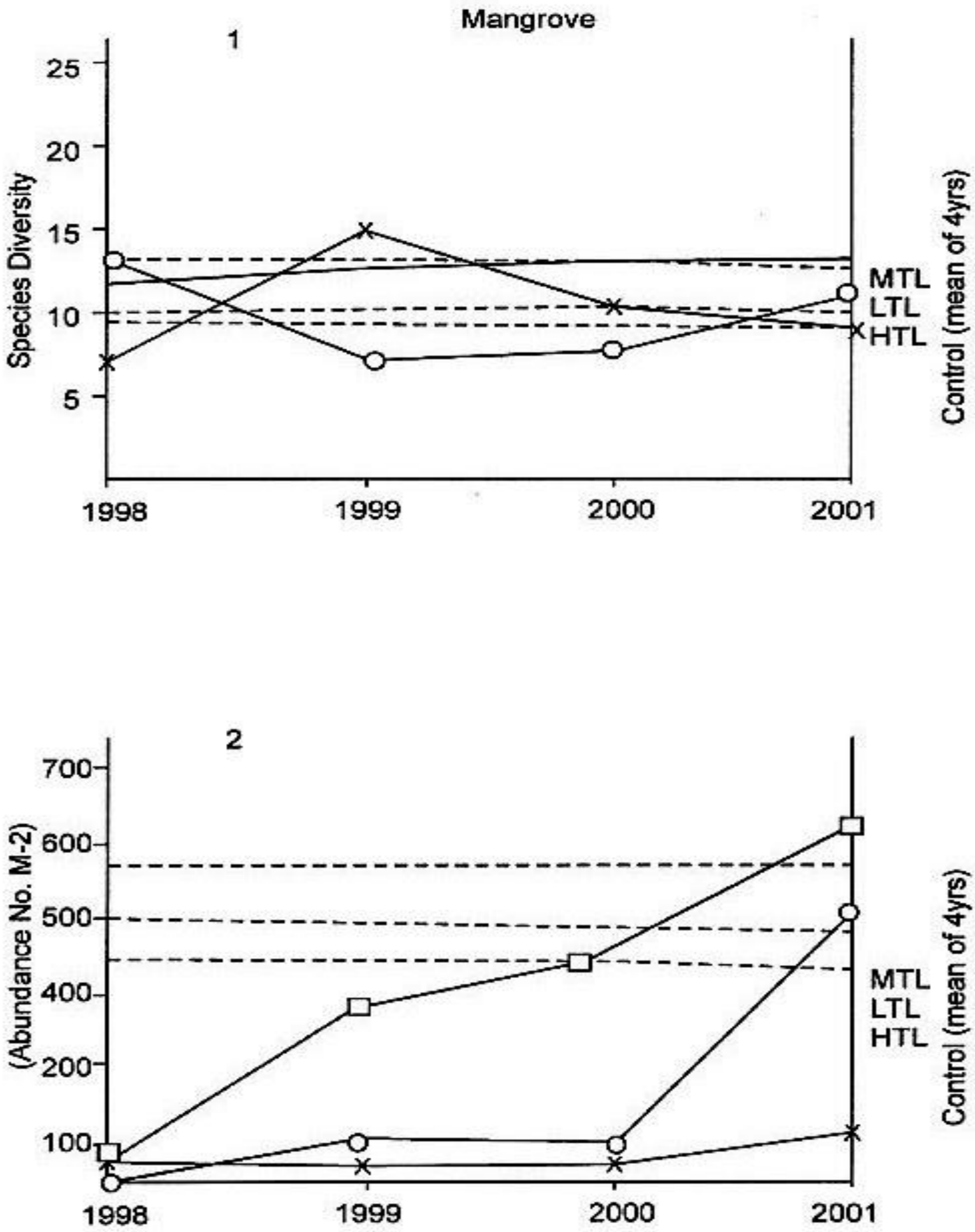

Fig. 5: Numbers of benthic species X, and their abundances Y on impacted LTTL5 and control sandy shore (Cmd).

Comparison of mean densities of these species after each year and also with control sites provided a clue to the algal recovery of the impacted shores.

Control sites survey

Fig.4 summarizes the mean annual abundance and species diversity of macro zoobenthos quantitatively sampled on control sites during the survey. Each data point is a mean of 2 seasonal periods though abundance rises over the period *1999* — 2001 on upper litoral (HTL) and middle eulittoral (LTL) zones due to the large number of juvenile crabs present in these the period, but large fluctuations in abundance of individual species caused by the influx of *Hydrobia* sp, juvenile sesamid crabs and the gastropod *Littorina* sp. While species diversity is relatively constant on sandy shore (Fig.4b), abundance fluctuated from year to year due to the change in population densities of the sandy shore brachyuran *Ocypode cursor* (Ewa-Oboho 1992, 1998) and the influx of the polychaetes *Nereis diversicolor* and *Pectineria*, the amphipod *Haustorious* and the cockle *Cardium edulis*. These data which provide a baseline for natural fluctuations in biota along the Nigerian coastline for the first time, was used as indicator to guage the early stages of recovery of the oiled coastal marine ecosystem.

Impacted areas

Recolonization regime of the annual abundance and species diversity is shown in Figs. 5-7 for macrobenthos sampled quantitatively from long term transects (LTT) 1,2,3 representing the lightly oiled and LTT 4,5,10 representing the heavily oiled areas over the period 1998-2001. On each figure, LTT data are compared with the diversity and abundance of the appropriate control shore averaged over the years 1998-2001.

Muddy shores recolonization

Fig. 5 shows the recolonization in diversity and abundance at the heavily impacted LTT-5 which had a muddy bottom. Recovery on the midtidal zone commenced in 2000, when diversity had increased, reaching approximately 107.1 % of that found on the control muddy shores at Bakassi.

At lowtide, diversity was 100% in 1999 and fell 50% short of the values in the control in 2000 and 2001 (Fig.5). After early recolonization in population densities (Fig.5), abundances are slightly below the control values in all tidal zones but was about 50% that on the reference control.

SANDY SHORES RECOLONIZATION

The temporal variation in species diversity and abundances of biota are shown in Figs. 6a and 6b representing the sandy shores oiled during the spill. There was no significant differences ($P<0.05$, F-test by ANOVA) in species diversity at all shore levels between 1998 and 1999 suggestive of the lingering effect of the oil on biota soon after spill. But by 2001 diversity on the lower and upper shore zones had increased to ca 80 and 66% respectively that on the control shores. Abundance were 65% (260 indiv. m^{-2}) of the control on the middle shore, and over 64% above that on the lower eulittoral zone by 2001. A marked increase in abundance was absent in 2000 and could be ascribed to the "high energy" of the environment at sandy beaches, and the porosity of sand both of which shorten the retention period of oil in sediment, allowing speedy recovery from the out fall. The generally low species diversity and abundance in the sand is associated with the usually low organic matter available to biota in sand.

DISCUSSION

Biota recovery of oiled estuaries in the Nigerian coastal areas was documented to have lagged behind chemical recovery (Ewa-Oboho in press). Based on macrobenthos results from 13 rivers mouth and estuaries along the coast, partial recovery appears to be progressing. Given that benthos have rapid turnover times, dispersion to new habitat is generally not an issue and estuarine sediments are enormous seed bank for species, one would expect these populations to recover rapidly. There are several factors that may impede the rapid recovery of benthic biota.

It has been hypothesized that a geological region that undergoes long-term stress may become species impoverished thus impacting on the ability of the ecosystem to recover their natural diversity (Vinebrooke *et al*, 2002). However, biota species composition in several of the oiled estuaries that had increase total hydrocarbon (THC) due to oil operational activities in the Niger delta region were spill occurred, had similar communities to Cross river estuary/Bakassi that were unaffected by oiling. This would suggest that the macrobenthos species pool for the Nigerian coastal marine ecosystem was not impoverished.

The recovery rates of the Nigerian coastline ecosystem from the Idoho oil spill, seemed to fall within the overall time scale for shores elsewhere (Sell *et al*, *1995)*. Although they appear to be shorter than shores in the subtropical areas where recovery could take 4-6 years, complete recovery seemed to have been hampered by the predominance of silt clay sediment type, which traps oil to prolong its retention time and perhaps the severity of damage. The generally relatively short period of recovery for biota is explained by the effect of prevailing high temperatures, which accelerate weathering of oil and the massive round year planktonic settlement that enhances recolonization. The recovery documented in this study adds to our evidence that recovery can occur to a state typical of non-oiled areas given sufficient habitat quality improvements. Recovery of many groups of aquatic biota continues, but the rates, patterns and extent in specific habitat within the estuarine ecosystem may be complicated by environmental and biological factors, including changing abiotic condition, dispersal barrier and biotic resistance. Future monitoring will track the extent and trajectories of recovery of oiled ecosystem. The degree of recovery document here boders well for the future of other oil-sensitive tropical regions in the world.

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