REGIONAL COORDINATING UNIT
EAST ASIAN SEAS ACTION PLAN

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

PROCEEDINGS OF THE SECOND ASEAMS SCIENTIFIC SYMPOSIUM

Edited by
B.P.L. Goh and L.M. Chou

RCU/EAS TECHNICAL REPORTS SERIES NO. 10

Prepared in cooperation with :

ASEAMS Association of Southeast Asian Marine Scientists

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PREFACE

The Regional Seas Programme was initiated by UNEP in 1974. The Regional Seas Programme at present includes 13 regions and has about 140 States participating in it. It is conceived as an action-oriented programme concerned not only for the consequences but also for the causes of environmental problems and addresses them through action plans established according to the needs of the region as perceived by the Governments concerned.

Within the East Asian Seas Region Action Plan, the Governments have approved a number of projects and assigned priority to some of them. UNEP has provided technical backstopping and support for the implementation of these projects, in co-operation with a number of national institutions and specialized agencies. In this context, UNEP Water Branch's Regional Coordinating Unit for the East Asian Seas Action Plan closely co-operated with the Association of Southeast Asian Marine Scientists (ASEAMS) in planning and convening the second Scientific Symposium of the Association (Bangkok, Thailand, 30 August 1995).

The Symposium brought together a number of marine scientists and other professionals from Southeast Asia and other regions, and provided an excellent opportunity for the exchange of information and experiences between experts working in fields related to marine science and management of marine and coastal areas and related ecosystems.

EDITORS' PREFACE

The Association of Southeast Asian Marine Scientists (ASEAMS) held its Third General Assembly and Second Scientific Symposium on 30 August 1995, in Bangkok, Thailand. The events, sponsored by UNEP Water Branch, were jointly organized by the Marine Science Department of Chulalongkorn University, and the UNEP Water Branch's Regional Coordinating Unit for the East Asian Seas (RCU/EAS).

The papers presented by ASEAMS members at the Second Scientific Symposium cover a wide range of topics pertinent to the field of marine science, namely, mapping, remote sensing technology, biology, ecology, pollution, legislation, and management, and only reflect a little of the vigorous research activity currently undertaken by marine scientists in the region. This volume is a compilation of the 10 papers presented.

These Proceedings were prepared by B.P.L. Goh, and L.M. Chou of the Department of Zoology, National University of Singapore, with the invaluable assistance of K.P.P. Tun.

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EVALUATION OF SELECTED FILTERS APPLIED ON SYNTHETIC APERTURE RADAR (SAR) DATA FOR GENERAL COASTAL LAND COVER MAPPING

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ABSTRACT

Speckle are the characteristic light and dark features on a radar image which obscure the immediate interpretation of the image. In this study, a number of available spatial filtering algorithms and the LEE adaptive filter were applied on a SAR image subset of a coastal area to remove the speckle. The enhancement level and statistical parameters of selected filtered images as well as windows of known coastal land cover features were described and evaluated. The statistical evaluation of the raw and filtered images showed a high variability based on their standard deviation values. Specifically, overlaps in the intensity values of the mangroves, coconuts and even the open areas were noted on both the raw and filtered images. Among those used, the LEE filter provided the best averaging of the heterogenous areas and maintained the curvilinear features. Overlaps in the intensity values of the filtered images however, still point to a possible difficulty in separating above coastal features automatically.

INTRODUCTION

Since the 1970s, Landsat MSS, Landsat TM and SPOT remote sensing satellites have been providing data for a wide range of applications particularly for monitoring and mapping purposes. In particular, mapping and monitoring of the coastal areas using remotely sensed data have gained grounds in recent years due to the heightened awareness in the importance of coastal resources and the need to conserve them or maintain their sustained development. In tropical coastal areas though, the optimal use of optical data can be hampered by persistent cloud cover (Lillesand & Kiefer, 1979; Curran, 1985). The advent of radar sensors on both airborne and satellite platforms, particularly the synthethic aperture radar (SAR) in early 1980s, however, provided an alternative source of remote sensing data that is all-weather and time-independent (Avery & Berlin, 1992).

To date, the greater availability of SAR data has heightened interest in using them for a number of applications. The time and weather independence of SAR data acquisition as well as the potential use of its geometric and textural characteristics in combination with the reflective properties of optical sensor data makes SAR data a very promising synoptic information tool.

Utilising SAR data for cartographic and mapping purposes, however, has been made difficult due to the presence of multiplicative noise like speckle and the inherent pixel by pixel tonal variation as a function of surface and system parameters which are very different from the factors affecting the reflectance signatures in optical data (NASA, 1992). These factors render the immediate interpretation of the image quite difficult. The initial process of handling SAR data thus, usually entails some filtering procedures to smooth out the image and improve its interpretability (Lee, 1987).

While filtering can smooth the SAR image, image classification can still remain a problem since the usual spectral pixel by pixel classification method used for optical data cannot be simply applied due to the inherent variability of pixel values in a SAR data. The usual convolution processes designed for optical sensors are not robust enough to account for the intrinsic properties of a SAR image. Filters to be applied on a SAR image have to take into consideration the presence of homogenous areas, heterogenous areas and points that correspond to hard target responses as well as the retainment of edges or feature boundaries (Azimi-Sadjadi, 1987; Desnos & Matteini, 1993; Durand *et al.*, 1987; Frost *et al.*,1982; Li, 1988; Lopez & Touzi, 1988; Nathan & Curlander, 1987). Further, delineation of areas cannot simply be done spectrally without considering the corresponding textural characteristics of the target surface feature. The selection of filters for any application thus, remains as a major challenge due to the speckle that delimit the immediate interpretability of SAR data.

MATERIALS AND METHODS

Acquisition and Description of STAR-1 SAR Data

After the devastating earthquake occurred in July 1990, Intera Canada was commissioned by the NAMRIA to take radar images (STAR-1) of Luzon, the country's largest island and main area affected by the catastrophe. The project was undertaken to get a synoptic post-earthquake view of the country and to facilitate the assessment of the extent of the damage and the identification of hazardous geologic changes.

The SAR data was taken on board a STAR-1 aircraft at a flight altitude of 10,000 meters. The SAR sensor operates in X-band (3cm wavelength), at HH polarization, has a high range and azimuth resolution of 6.0m and can detect distributed targets with a backscattering coefficient of 30 decibels. The SAR data are converted from slant range to ground range in flight. The swath width of the aircraft is 23km flown in stereo with a flight line overlap of 60%. The SAR image strips were taken in a north-south line orientation at a 90° east look direction. The SAR data is available in CCT and exabyte format; photographic strip prints of scale 1:250,000 - 1:25,000; and digital mosaics of similar scale. Adjacent scan lines are averaged or duplicated to replace any dropped lines during the digital mosaicing of the SAR images. Radiometric corrections are done on each scan line by initially selecting a control strip in the area being mosaiced and generating terrain statistics for a sample portion in the strip. All strips in the mosaiced image are then radiometrically corrected sequentially based on the new mean and standard deviation statistics of the portion of the control strip.

Description of the Study Area

Pagbilao, Quezon is located east of Manila at 119° 53' central longitude and 16 23' central latitude. The area, characterised by secondary mangrove growth composed mainly of *Avicennia* spp., *Soneratia* spp., and *Rhizophora* spp. lying on a delta formed essentially by a river and its tributaries, is one of the few areas in the country where sizeable stands of mangroves can still be found. The 1978 mangrove inventory using Landsat MSS data placed the pure mangrove area and the low - density/logged- over area in Quezon at 5,948.1 ha and 2,824.3 ha, respectively (Bina *et al.*, 1978; MSI, 1987). The mangrove forest in Pagbilao has been subjected to land use conversion particularly to fishpond and utilization of mangrove trees for charcoal-making, firewood, housing materials, fishpond dike foundation and even paper manufacturing. These activities have greatly contributed to the rapid depletion of the mangrove forest stand (MSI, 1987). Major mangrove communities used to be found along the river mouths of Pagbilao river to Kanlurang Mulawi in Pagbilao Bay and extends to Silangang Mulawi in Padre Burgos. To date however, the only remaining mangrove stand along these areas is in the Department of Environment and Natural Resources (DENR) mangrove reserve which is bordered by two namely: the Palsabangon river and the Pinagbayanan river along the Pagbilao Bay area. The rest of the stands are thin and serve only as buffer zone between the numerous fishponds and the coastline to inhibit erosion. Numerous fish corrals are also installed along the river mouths (FSP, 1993). The other near- coastal land cover features in the study area are large tracts of fishponds, coconut plantation and open bare/grassland areas.

Filtering of the SAR Image

The main objective of the project was to attempt to delineate the general coastal features using the X-band SAR image. As the SAR image is degraded by speckle, filtering has to be done to remove such noise. For SAR images though, the filter to be used should be able to bring out the inherent tone and texture of the image while at the same time, maintain the curvilinear features. There are numerous filters in the DCONV algorithm of the ERDAS software used in the project. DCONV is the major convolution process in ERDAS and includes filters like low pass, high pass, gradient filters and the like. The low pass and median filters in ERDAS were used on the SAR image using different kernel sizes from 3 X 3 , 5 X 5, 7 X 7 ,etc. In addition to the standard filters found in ERDAS, a new adaptive filter known as the LEE filter was used on the SAR image. The LEE filter, available in the EARTHVIEW software package uses the local statistics (mean and standard deviation) to remove the speckle. This filter, based on the multiplicative noise model, smooths the speckled distributed targets and at the same time preserves the sharpness of point targets (Lee, 1987). Different kernel sizes were used in running the LEE-filter algorithm on the SAR subset image.

Statistical Analysis

After filtering the SAR subset image, the output filtered images were visually examined and those that showed the most information were selected for subsequent evaluation. Coastal cover features were identified through the use of available land cover map and oblique aerial photographs of the subset area. The general features identified were mangroves, fishpond/water areas, open/grassland and coconuts. The statistics of the selected filtered images as well as those of the windows of known cover features for each of the images were generated using the GETINFO command in the EARTHVIEW package. The statistical information included the maximum data value, the minimum data value, the mean value and the standard deviation. To visually show the raw image and the raw feature window intensities, the PLOT3D command was used. The PLOT3D reads the image or window data, then scales and shifts it to be displayed as a three dimensional plot with the image or window intensity values taking up the vertical axis.

RESULTS AND DISCUSSION

The low-pass, median and the LEE adaptive filters were applied on the SAR image subset. The filtered images were then visually examined and those that were noted to have retained substantial information were selected for statistical analysis. The filtered images that were selected visually included the following: the low-pass filtered images (3 X 3, 5 X 5, 7 X 7); the median filtered images (3 X 3, 5 X 5, 7 X 7) and the LEE-filtered images (3 X 3, 5 X 5, 7 X 7). The image statistics of the selected filtered images are summarized in Table 1. The maximum and minimum values in the raw and filtered SAR images notably remained the same. In general, the mean and standard deviation of the filtered images increased as the filter window size was increased. Higher image mean values compared to the mean value of the raw image resulted from the filtering. The standard deviation of all the filtered images using the smallest window size were lower than that of the raw SAR image. Increasing the window size of the filter however, resulted to a corresponding increase in the standard deviation of the filtered images. The increase in the image mean and standard deviation relative to the increase in filter window size denoted a retained variability of pixel values beneath the kernel in all filtered images. Visually, the variability cannot be further attributed to speckle particularly for the SAR images filtered by large kernels since such noise has been noticeably reduced by the filtering algorithm. The variability could therefore, be attributed to the inherent textural characteristic of the scene on the image retained after the speckle was suppressed. Based on the image statistics, the median- filtered images showed the least image variablity while the LEE-filtered images exhibited the highest variability. Specifically, the 7 X 7 LEE-filter was observed to have successfully removed the speckle visually but it retained the general scene texture which was denoted by a high standard deviation compared to the raw SAR image and the rest of the filtered images.

The succeeding sections describe in more detail the raw SAR image and the filtered images that were statistically analysed.

The Raw SAR Image

The rawSAR image (Plate 1) was analysed visually and statistically to form the basis for comparing the effects of the various filters used in the study. As expected, the raw SAR image was characterized by speckle. General coastal land cover features including mangrove areas, coconut, open/grassland areas and water or fishpond sites however, could still be delineated visually using the usual photointerpretation parameters (i.e., tone, texture, association, etc). Three dimensional plots of the intensities of the backscatter of both the raw image (Plate 2) and windows of known cover features showed high variability of the intensities for the image in general and similarity of intensity plots for the mangrove (Plate 3) and coconut (Plate 4) could be observed denoting overlaps in the backscatter intensity ranges for these two features. The intensity plots of these two features also showed high variability shown as sharp changes in contiguous intensity values. Water (Plate 5) showed a flat intensity plot denoting zero variability. The 3D plot of the open areas (Plate 6) showed changes in intensities of contiguous pixels. To quantify the intensity ranges, statistics of sample windows covering each known feature were extracted (Table 2). The minimum and maximum values of mangrove, coconut and open areas indicated extreme overlaps in their intensity values. The high pixel value variability was also manifested by their high standard deviation.

Table 1. Summary of Image Statistics

Image Description	Statistical Parameter			
	Max value	Min value	Mean value	Std deviation
Raw Image	79	16	35.44	14.06
Low 3X3 filtered-image	79	16	36.66	12.84
Low 5X5 filtered-image	79	16	40.51	14.08
Low 7X7 filtered-image	79	16	43.12	14.83
Median 3X3 filtd-image	79	16	34.95	12.33
Median 5X5 filtd-image	79	16	37.31	13.14
Median 7X7 filtd-image	79	16	40.34	14.44
Lee 3X3 filtered-image	79	16	36.24	12.78
Lee 5X5 filtered-image	79	16	40.32	14.29
Lee 7X7 filtered-image	79	16	42.52	15.02

Table 2. Feature statistics for the raw STAR-1 SAR image

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	75	26	48.07	8.02
Coconut	63	22	41.74	6.45
Open/Grassland	51	20	33.77	5.67

The Low-pass Filtered Images

The low-pass filtered images generated from the 3 X 3, 5 X 5 and 7 X 7 searching windows were all selected for further processing. In general, the low-pass filtered images showed the characteristic blurring due to the averaging effect of the low pass filter. The loss of the general image texture as well as edges compared to the raw SAR image, noticeably increased as the filter window size used was enlarged. The statistics extracted from windows of known cover features from each of the low-pass filtered images are shown in Tables 3, 4 and 5. The maximum pixel values for mangrove, coconut and open areas in all kernel sizes were lower than the maximum values for the raw SAR image. The maximum values however, increased as the kernel window size used was increased. The minimum values in contrast were more than that of the raw SAR image and were further increased as the kernel size used were enlarged. The overlap of values between mangrove, coconut and open areas decreased as the window size of the kernel increased. Among the three filtered images, the low-pass 7 X 7 filtered image (Plate 7) showed the variability indicated by the low standard deviation and exhibited the least pixel value overlap between mangrove, coconut and open areas.

Plate 1. Raw SAR Image

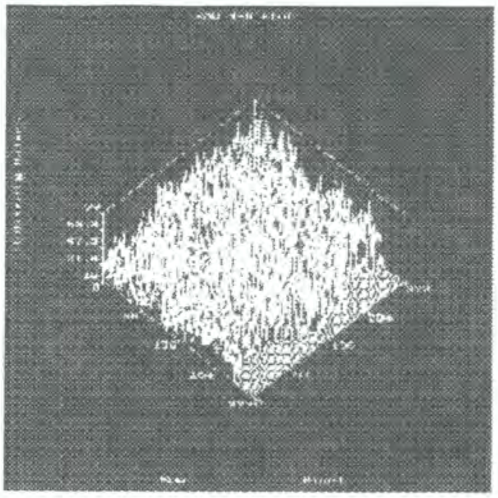

Plate 2. 3D Plot of Raw SAR Image

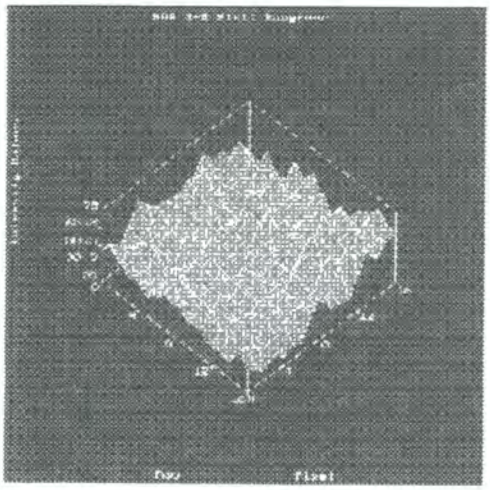

Plate 3. 3D Plot of Mangroves

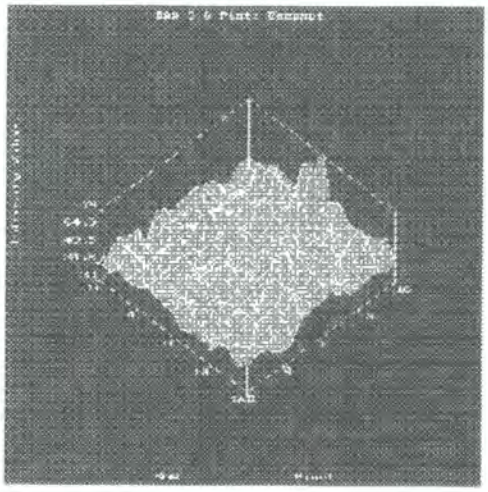

Plate 4. 3D Plot of Coconuts

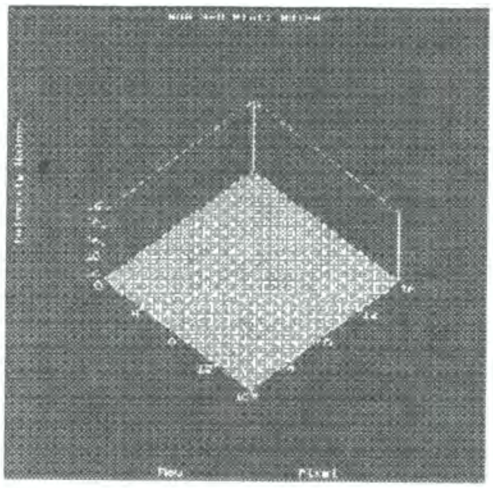

Plate 5. 3D Plot of Water

Table 3. **Feature satistics for the 3 x 3 Low-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	62	39	50.05	5.13
Coconut	55	35	43.41	3.31
Open/Grassland	45	27	34.91	3.79

Table 4. **Feature statistics for the 5 x 5 Low-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	68	46	56.43	4.65
Coconut	56	43	48.54	2.71
Open/Grassland	47	32	37.83	2.99

Table 5. **Feature statistics for the 7 x 7 Low-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	70	52	60.63	4.15
Coconut	58	47	51.89	2.39
Open/Grassland	46	34	39.89	2.61

The Median-Filtered Images/The LANSCAN Filtered Images

The median-filtered images using the 3 X 3, 5 X 5 and 7 X 7 searching windows were all selected for further processing. The resolution of the median-filtered images was degraded as the kernel size used were increased but edges were better preserved compared to the low-pass filtered SAR images. The statistics extracted from windows of known cover features from each of the median-filtered images are tabulated in Tables 6, 7 and 8. The maximum pixel values for mangrove, coconut and open areas in all kernel sizes were lower than the maximum values for the raw SAR image but were higher than those of the low-pass filtered images. The maximum values and minimum values also increased as the kernel window size used was enlarged. The overlap of values between mangrove, coconut and open areas decreased as the window size of the kernel increased but were lower than the decrease in overlapping values noted in the low-pass filtered images. Among the three filtered images , the median 7 X 7 filtered image (Plate 8) showed the least variability indicated by the low standard deviation and exhibited the least pixel value overlap between mangrove, coconut and open areas.

Table 6. **Feature statistics for the 3 x 3 Media-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	61	38	47.89	5.01
Coconut	52	33	42.39	3.54
Open/Grassland	43	28	33.89	3.42

Table 7. **Feature statistics for the 5 x 5 Median-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	63	46	52.31	4.65
Coconut	53	39	45.77	2.93
Open/Grassland	43	29	35.96	2.75

Table 8. **Feature statistics for the 7 x 7 Median-Filtered image**

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	67	49	57.57	4.15
Coconut	57	42	50.19	2.41
Open/Grassland	42	34	38.83	2.31

The LEE- Filtered Images

The LEE- filtered images using the 3 X 3, 5 X 5 and 7 X 7 searching windows were all selected for further processing. The LEE- filtered images removed well the speckle as the kernel size used was increased. However, edges were better preserved in the LEE filtered images compared to the low-pass and median-filtered SAR images. Tables 9, 10 and 11 list the statistics extracted from windows of known cover features from each of the LEE-filtered images.The maximum pixel values for mangrove, coconut and open areas in all kernel sizes were lower than the maximum values for the raw SAR image but higher than those of the low-pass and median-filtered images. The maximum values as well as the minimum values also increased as the kernel window size used was enlarged. The overlap of values between mangrove, coconut and open areas decreased as the window size of the kernel increased but were lower than the decrease in overlapping values of the low-pass and median-filtered images. Among the three filtered images, both the LEE 5 X 5 and 7 X 7 filtered images (Plates 9 and 10) showed the least variability indicated by the low standard deviation and showed the least pixel value overlap between mangrove, coconut and open areas.

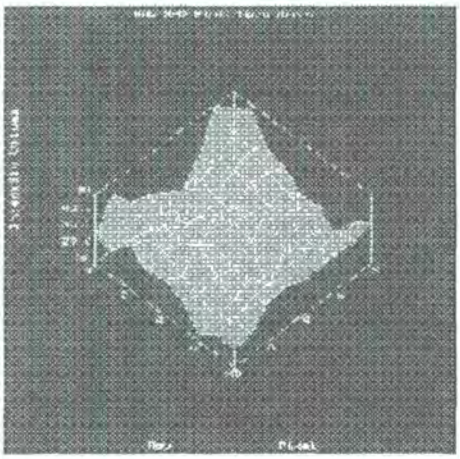

Plate 6. 3D Plot of Open Areas

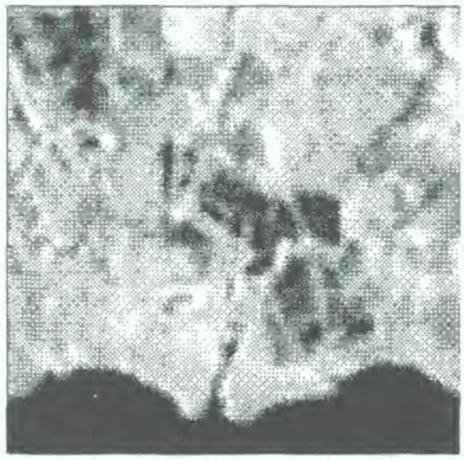

Plate 7. 7 X 7 Low Filtered Image

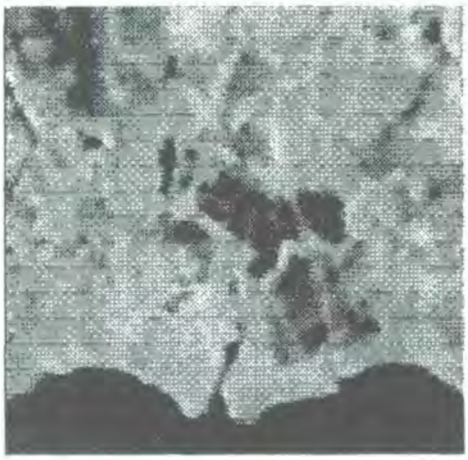

Plate 8. 7 X 7 Median Filtered Image

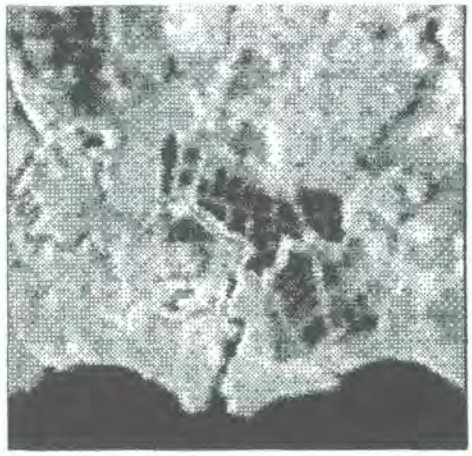

Plate 9. 5 X 5 Lee Filtered Image

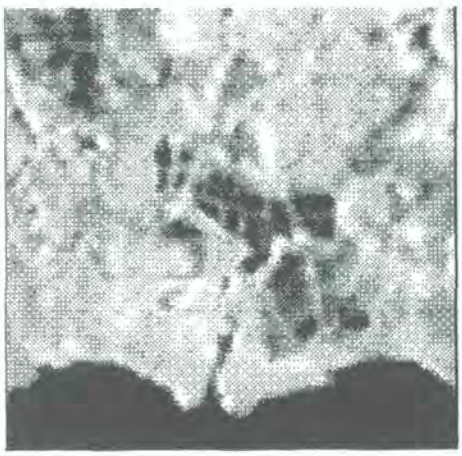

Plate 10. 7 X 7 Lee Filtered Image

Table 9. Feature statistics for the 3 x 3 LEE-Filtered image

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	61	38	49.61	5.12
Coconut	54	35	42.94	3.21
Open/Grassland	45	27	34.41	3.75

Table 10. Feature statistics for the 5 x 5 LEE-Filtered image

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	68	46	56.41	4.81
Coconut	55	42	48.35	2.71
Open/Grassland	46	32	37.46	3.02

Table 11. Feature statistics for the 7 x 7 LEE-Filtered image

Cover Type	Statistical Parameter			
	Maximum Value	Minimum Value	Mean Value	Std. Deviation
Water	16	16	16	0
Mangrove	70	52	60.45	4.51
Coconut	57	46	51.55	2.35
Open/Grassland	46	33	39.35	2.72

CONCLUSION

The need to use an adaptive filter on a SAR image is a necessary step to remove the speckle to facilitate image interpretation and/or automatic classification. However, an understanding of the effects of any filter applied on a SAR image as well as the overall scene characteristics has to be developed to account for the difficulty in further delineating features visually and/or automatically.

Visually, the results of this study show that adaptive filters like the LEE filter could remove speckle but retains edge and curvilinear features better than the usual convolution algorithm. However, statistical evaluation of the filtered images points to the retainment of inherent scene variability in the selected coastal zone area even in the application of both regular convolution algorithms or adaptive filtering. One reason that could account for the retainment of scene variability is the limited penetration capability of the SAR data used. Previous studies have shown that coastal cover like mangroves could be delineated from other near coastal cover by the presence of water beneath the canopy. The bright response observed in flooded forest like mangroves on longer-wavelength L-band SAR images has been explained by the double bounce reflections between the water surface, tree trunks and understoreys like prop roots and pneumatophores (Ford & Casey, 1988; Hess & Simonnett, 1990; Imhoff, 1986, 1990; Richards *et al.*, 1987). It should be noted that at X-band, the response from the radar pulse would be mainly due to surface scattering and at 67° look angle, the canopy surfaces of both mangroves and coconuts could appear as similar rough surfaces. Thus, even in the application of both regular filters and the LEE adaptive filter, the output filtered images exhibited overlapping intensity values as shown by their minimum and maximum values as well as standard deviations. Thus, while the two coastal cover features are different geometrically, their backscatter values even after filtering point to the difficulty in separating them and delineating their distribution automatically.

REFERENCES

Avery, T.E. & G.L. Berlin, 1992. Fundamentals of Remote Sensing and Airphoto Interpretation. Macmillan Pub. Co. U.S.A.

Azimi-Sadjadi, M.R.A., 1987. Speckled image restoration by adaptive block Kalman filtering. IGARSS '87. pp.1449-1455.

Bina, R.T., R.S. Jara, E.N. Lorenzo & B.R. de Jesus, 1978. Mangrove inventory of the Philippines using LANDSAT Multispectral data and the Image 100 System. NRMC Res. Monogr. 2:1-8.

Curran, P.J., 1985. Introduction to Remote Sensing. Longman Group Ltd. England.

Desnos, Y.L. & V. Matteini, 1993. Review on structure detection and speckle filtering on ERS-1. EARSel Adv. in Remote Sensing. 2(2):52-65.

Durand, J.M., B.J. Gimonett & J.R. Pubos, 1987. SAR data filtering for classification. IEEE Trans. Geosci. & Remote Sensing. Vol. GE-24. No.5. pp.629-637.

Fisheries Sector Program (FSP). 1993. Coastal environmental profile of Tayabas Bay. Technical Report. Manila, Philippines.

Foody, G.M., 1987. A method for thematic classification with Synthetic Aperture Radar data. Geocarto International. pp.31-36.

Ford, J.P. & D.J. Casey, 1988. Shuttle radar mapping with diverse incidence angles in the rainforest of Borneo. Int. J. Remote Sensing. 9(5):927-943.

Frost, V.S., J.A. Stiles, K.S. Shanmugan & J.C. Holtzman, 1982. A model for radar images and its application to adaptive digital filtering of multiplicative noise. IEEE Trans. Gesc. & Remote Sensing. PAMI-4(2):157-165.

Hess, L.L., J.M. Melack & D.S. Simonett, 1990. Radar detection of flooding beneath the forest canopy : a review. Int. J. Remote Sensing. 11(7):1313-1325.

Imhoff, M.L., M. Story, C. Vermillion, F. Khan & F. Polcyn, 1986. Forest canopy characterization and vegetation penetration assessment with space-borne radar. IEEE Trans. Geosci. & Remote Sensing. GE-24(4):535-542.

Imhoff, M.L., 1990. The derivation of a sub-canopy digital terrain model of a flooded forest using Synthetic Aperture Radar. Photog. Eng. & Remote Sensing. 56(8):1155-1162.

Lillesand, T.M. & R.W. Kiefer, 1987. Remote Sensing and Image Interpretation. John Wiley and Sons. New York, U.S.A.

Lee, J.S., 1987. Statistical modelling and supression of speckle in SAR images. IGARSS '87. pp. 1331-1339.

Li, C.,1988. Two adaptive filters for speckle reduction in SAR images using the variance ratio. Int. J. Remote Sensing. 9(4):641-653.

Lopez, A. & R. Touzi, 1988. Adaptive speckle filtering for SAR images. IGARSS' 88.

Marine Science Institute (MSI). 1987. Mangroves and seagrasses : Pagbilao Bay Technical site survey. Manila, Philippines.

Nathan, K.S. & J.C. Curlander, 1987. Speckle noise reduction of 1-look SAR imagery. IGARSS '87. pp. 1457-1461.

NASA, 1992. Synthetic Aperture Radar (SAR) : Instrument Panel Report. NASA. U.S.A.

Richards, J.A., P.W. Woodgate & A.K. Skidmore, 1987. An explanation of enhanced radar backscattering from flooded forests. Int. J. Remote Sensing. 8(7):1093-1100.

COASTAL ENVIRONMENTAL SENSITIVITY MAPPING OF BRUNEI DARUSSALAM

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INTRODUCTION

Oil and gas exploration and exploitation are major industrial activities in the coastal zone of Brunei Darussalam. In spite of the stringent safety and other precautionary measures taken during exploration, exploitation, storage, refinement, piping and transport of petroleum hydrocarbons and their products, the possibility of accidents and the potential of oil spills cannot be ruled out. This threat of oil pollution amplifies the need for a description of the distribution of resources in the coastal zone vulnerable to oil, their prioritization for protection, as well as recommendations for defence strategies in case of accidental oil spills.

In response to this need, an analysis of environments and resources along the coastline of Brunei Darussalam was conducted. The coastal areas and resources vulnerable to oil spills have been indicated on a Coastal Environmental Sensitivity Map (Fig. 1) which also highlights the priority areas for protection in the event of an oil spill.

The effects of an oil spill on the environment or a particular ecosystem will depend largely on a number of factors which include the following (De Silva & Ridzwan, 1981):

a) The type of oil and whether it is crude or refined;

b) The quantity of oil;

c) The length of time the oil has been in the water;

d) Exposure time to oil;

e) The sensitivity of the organisms in the ecosystem to the type of oil;

f) The sensitivity of the organisms in the ecosystem to chemical dispersants or other techniques used in oil spill clean up.

Environmental Sensitivity (ES) Maps were first tested during a major oil spill following the IXTOC I blow out in the Gulf of Mexico. These maps became an integral part of the overall federal response plan to protect the Texas coast in U.S.A. providing a scientific basis for setting protection priorities, and clean-up strategies (Getter *et al.*, 1981). Since then, ES mapping has been carried out for 95% of the United States coastline and in several other oil producing countries including Malaysia. The very first Environmental Sensitivity Mapping in the ASEAN region was carried out along the Chukai-Dungun Coastline in Peninsular Malaysia (Ridzwan & De Silva, 1983).

Several coastal environments/living resources of Brunei Darussalam were deemed to be sensitive to dispersants or to a combination of dispersants and dispersed oil. Areas where oil dispersants should not be used or areas where dispersants are not recommended are also indicated in the map (Fig. 1).

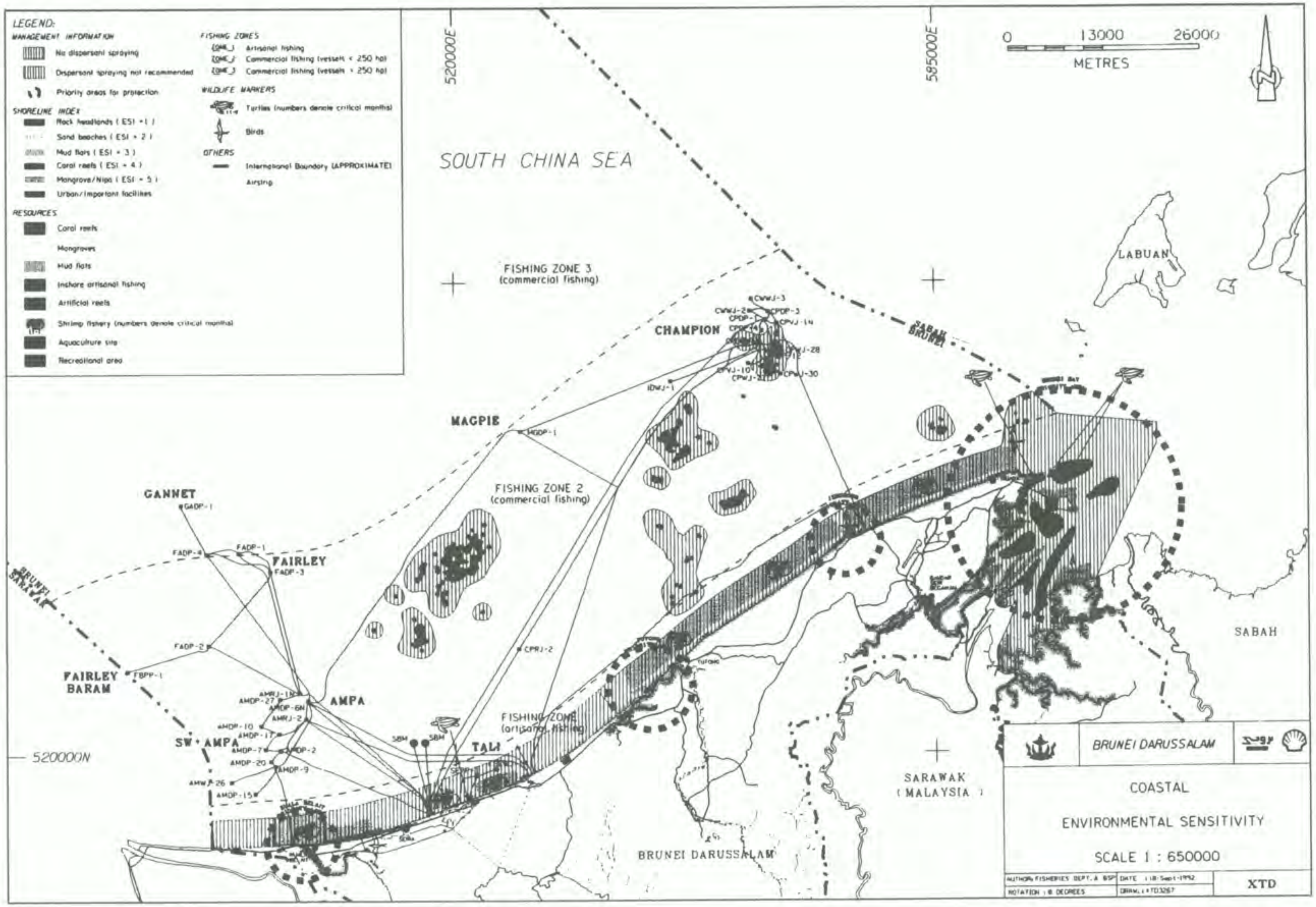

Figure 1. Coastal Environmental Sensitivity Map.

This paper summarizes a report entitled "Coastal Environmental Sensitivity Mapping of Brunei Darussalam" by the authors to Shell Petroleum Co. Sdn. Bhd. Seria, Brunei Darussalam in 1991 with an update on the section on Fisheries.

Purpose of the Coastal Environmental Sensitivity Map and Report

The primary purpose of the Environmental Sensitivity Map is to provide oil spill response teams with information on shoreline sensitivity and resources at risk during a spill. They can also be used to plan the development of appropriate shoreline protection and clean-up strategies even before an oil spill occurs.

Although desirable, it might not be practical to protect all coastal areas in the event of an oil spill. This would be particularly so if the time lag between the occurrence of the spill and it reaching the shore is short and/or equipment and manpower is in short supply. In such cases the priority and sensitivity ranking of the shoreline and resources will be invaluable in making a decision where protection efforts need to be concentrated on a pre-planned basis.

The Study Area

The entire shoreline of Brunei Darussalam, the major river estuarine systems (Sg. Temburong, Sg. Brunei, Sg. Tutong and Sg. Belait), and all major coastal coral areas down to a depth of 10 metres were taken into consideration during the present investigation.

METHODS OF STUDY

The considerable amount of information that had been gathered during the ASEAN-US Coastal Resources Management Project on the coastal resources of Brunei Darussalam (Chua *et al.*, 1987; Silvestre *et al.*, 1992) formed a strong database for the present investigation. Existing information was strengthened through field surveys to bridge essential information gaps. As very little information was available on the coral reefs of Brunei Darussalam, an intensive two and a half month survey was undertaken on this important marine ecosystem (Rajasuriya *et al.*, 1992). A survey of the coastline features of the major river systems, the coast and the Inner Brunei Bay that would be vulnerable to oil was also carried out paying special attention to:

a) Areas representing dominant shoreline types and habitats of critical concern to allow geomorphic and biological characterization of all shoreline types;

b) Ecologically sensitive areas which were projected as likely to be impacted by oil in case of a spill;

c) Socially, culturally and politically sensitive areas;

Analysis of Data

The field data when added to the existing database, allowed examination of parameters which ranked the relative sensitivity of each habitat type. Parameters included the density and diversity of dominant organisms, behaviour and/or persistence of oil in the habitat, potential biological damage, habitat recovery after oil impact and the ease of oil recovery or clean-up in such habitats. The social, cultural and political significance of the shoreline was also considered in determining its overall sensitivity.

Vulnerability of Coastal Environment / Resources

The system of classifying coastal environments in terms of oil sensitivity was developed by Gundlach and Hayes (1978). Their ranking of the shoreline types was based on geomorphic, biological and socio-economic criteria. Although this basic philosophy of classification of shorelines was generally accepted, the special features of the shorelines of Brunei Darussalam as well as the social and cultural values required modification of the classification of Gundlach & Hayes (1978) to suit local conditions. Five shoreline types with Environmental Sensitivity Indices ranging from 1 to 5 of increasing sensitivity have been recognized for Brunei Darussalam. The shoreline types and their Sensitivity Indices are as follows:

a) Rocky Headlands and Seawalls (ESI = 1)

b) Sand Beaches and Sandy Shoals (ESI = 2)

c) Tidal Mud Flats (ESI = 3)

d) Coral Reefs (ESI = 4)

e) Mangrove Swamps (ESI = 5)

In addition to the shoreline types the following were also given due consideration because of possible disruption/impacts of oil spills:

a) Recreational Beaches

b) Aquaculture Sites

c) Fishing Grounds

d) Urban Facilities

e) Wildlife

Geomorphic criteria pertain to the observed interaction and persistence of oil on specific shoreline types. Biological criteria encompass potential long term effects to organisms. Areas of socio-economic and cultural importance include major fishing areas, boat anchorages, recreational beaches, etc..

OIL SPILL SENSITIVE AREAS AND ACTIVITIES

The oil spill sensitive areas and activities considered to be vulnerable to oil spills and included in the Coastal Environmental Sensitivity Map of Brunei Darussalam are :

Rocky Headlands and Seawalls (ESI = 1)

There are a few coastal areas of Brunei that would fall under this category. The rocky headland of the Muara Bluff in Muara and Brunei Cliff near Jerudong in the Brunei Muara District, and the rocky coastlines of the two offshore islands, Pulau Punyit and Pelong Rocks are the only areas in Brunei Darussalam exhibiting such shorelines. The shoreline consists primarily of boulders and platforms of sedimentary rock. These areas are exposed to heavy wave action and harbour organisms adapted to a highly specialized habitat. Man-made sea walls occur along the coast of Seria (to prevent sea intrusion and erosion), Jerudong (to prevent erosion), Pelompong Spit (to prevent erosion) and in the Port areas of Muara and Kuala Beliat.

Plant life found in these habitats are primarily of attached algae. Dominant macro-algal that may be found species along the rocky shores are species of *Sargassum*, *Gracilaria*, *Padina*, *Laurencia* and *Acanthophora*. Common animal species that have been observed are metagrapsid crabs, barnacles, littorinid and neritid snails, and rock oysters. Seawalls, particularly those in the Belait River and in the Muara Port area, were poor in fauna and flora.

As the rocky headlands and seawalls are subjected to strong waves and currents, the persistence of oil on these shorelines are expected to be very low. Although these shorelines are of interest from a biodiversity point of view, the low persistence of oil rank them the least vulnerable to oil spills. As such, rocky headlands and seawalls are rated lowest on the oil vulnerability scale and given the lowest Environmental Sensitivity Index ranking of one (ESI = 1).

Sand Beaches and Sandy Shoals (ESI = 2)

Sand Beaches in Brunei Darussalam are concentrated on the northwestern part of the State which faces the South China Sea. They are spread over the entire length of the open sea coast from the tip of Pelompong Spit near Muara in the Brunei-Muara District, to Sungai Tujoh near Kuala Belait in the Belait District. The continuity of the Sandy Beaches throughout this stretch of coast is disturbed only by the major rivers and the rocky shore headlands of the Brunei Bluff in Muara and the Brunei Cliff near Jerudong. The major Sandy Shoals are found mainly near the river mouths of the Tutong and Belait Rivers, and smaller areas which occur intermittently along the coastline from Muara Bluff to the Belait river mouth. Sand Beaches and Sandy Shoals have been formed from sand movement along the coast, aided by longshore drifts or littoral drifts of the South China Sea.

The productivity of the beaches is not very high. The main organisms isolated from the sand by 2 mm mesh-sized sieves in the midshore region were crabs, isopods, polychaetes and some shells (*Donax* sp. and *Umbonium* sp.).

The beaches are commonly used for recreational activities, such as picnics, fishing, walking, bathing, and as access points for boats. They are natural buffers against land erosion caused by wave action. Some turtles are known to visit the beaches of Pulau Pelompong, Muara, Tutong, Lumut and Anduki, particularly from December to June, for nesting purposes.

The Sand Beaches and Sandy Shoals are composed of fine grained sand particles that would resist deep penetration of impacted oil. Further, waves and currents would also make the persistence of oil on these shorelines relatively low. As such, sand beaches and sandy shoals are rated fairly low on the oil vulnerability scale, and given an Environmental Sensitivity Index ranking of two (ESI = 2).

Mudflats (ESI = 3)

In Brunei Darussalam, the major areas of coastal mudflats are found in the Brunei Bay area. They are mainly located adjacent to mangroves. Most mudflats are expected to be eventually invaded by mangroves as part of the process of land accretion. Large extents of mudflats are exposed during low tides in the Inner Brunei Bay and the estuarine systems of major rivers. Mudflats serve as habitats for many invertebrates: molluscs, crustaceans and a variety of worms. The highly visible transient inhabitants of mudflats are the birds that feed on this biotic community during the low tide. Several mudflats, particularly in the Brunei Bay and in Seria in the Belait District, are known to be important wintering habitats for migrating birds, especially during the period of September to February (Mann, 1987; Mohd. Jaya *et al.*, 1986). During high tide periods, fishes, shrimps, crabs and molluscs forage for food on the mudflats.

Although Brunei Darussalam does not possess extensive sea grass beds, several species of seagrasses of small quantities are found on the shallow mudflats, particularly at the Brunei Bay. These are often exposed during low tides and could be vulnerable to oil spills.

Most animals associated with mudflats tend to be infaunal in nature. The infaunal species diversity in the mudflats of the Inner Brunei Bay has been found to be higher than that of the Tutong or Kuala Beliat Districts (Lai *et al.*, 1992). The dominant fauna are the polychaete worms. Several commercial species of bivalves and snails also occur in these mudflats. A small-scale collection of molluscs carried out on the mudflats. However, no records are available on the economic value of mudflats in terms of harvested food organisms (molluscs and crustaceans).

Because of the biodiversity, the importance to migratory bird populations as feeding grounds, the presence of small, but productive seagrass areas, and the likely persistence of any impacted oil, the mudflats are given an intermediate Environmental Sensitivity Index ranking of three (ESI = 3).

Coral Reefs (ESI = 4)

Brunei Darussalam is not well endowed with large extents of coral reefs or coral formations. Coral reefs and coralline areas in Brunei Darussalam cover an approximate area of 4,500 ha or 45 km^2. As in the case of mangroves, coral reefs are also high productive ecosystems which contribute substantially to the coastal fishery. They are the breeding grounds of multitudes of marine organisms and are increasingly becoming important as storehouses of compounds important to medicine and industry.

A recent coral reef survey of coral reef areas undertaken as part of the present joint Department of Fisheries and BSP investigation indicated relatively undamaged coral reefs of high diversity in Brunei Darussalam. This survey confirmed 97 species and 19 genera of stony corals (Rajasuriya *et al.*, 1992), in addition to the previously recorded 88 species and 52 genera. Recently one more genus, *Flabellum*, has been added to the records (De Silva, pers. comm.), bringing the total number of recorded stony corals for Brunei Darussalam to 186 species distributed within 72 genera, making Brunei Darussalam one of the high diversity coral reef areas of the world.

Rajasuriya *et al.* (1992) have also listed 195 reef associated fish species. Groupers (Serranidae), Snappers (Lutjanidae), Rabbit-fish (Siganidae), Fusiliers (Caesionidae), Surgeon-fish (Acanthuridae) and Parrot fish (Scaridae) were some of the commonly encountered commercially important food fish from the reefs.

The coral reef resources of Brunei Darussalam have hardly been exploited for commercial purposes such as fisheries, coral extraction, tourism and aquarium fish collection. As such many of the coral reefs have remained in a near pristine state.

The present investigation has identified that the fringing reefs of Pulau Punyit and Pelong Rocks are most vulnerable to oil spills. The other coral reef areas are permanently submerged patch reefs and are unlikely to be directly impacted by oil spills. However, these rich and highly diverse reefs could be sensitive to dispersed oil and oil dispersants, and the use of dispersants within a buffer zone of 500 m is not recommended. Taking account of the possible threat to the Inner Brunei Bay by spills originating from the Champion Field, an exception has been made to allow the use of dispersants over the reef area there, in case more sensitive areas or priority protection areas are threatened.

Because of the importance of coral reefs, their high biodiversity and vulnerability to oil, dispersed oil and oil dispersants, they are given the second highest Environmental Sensitivity Index ranking of four (ESI = 4).

Mangrove Swamps (ESI = 5)

Mangroves are among the most productive natural ecosystems in the world and are considered nursery and breeding grounds of fish, shrimp and other marine organisms. In addition to enhancing the nutrient level of coastal waters, and acting as filter buffers between land and water, they act as buffers against storm surges and protect shorelines from erosion.

The mangrove swamps of Brunei Darussalam occur in saline soils subjected to tidal inundation in Temburong, along the upper Belait River, Tutong River, Brunei River and around Muara, and are credited with sustaining at least the coastal fishery, particularly the productive shrimp fishery. The total mangrove forest area has been estimated to be 18,418ha , representing 3.2% of the national land area. Four major subtypes of mangroves have been recognized in Brunei Darussalam: (1) undifferentiated, (2) *Rhizophora* 3) *Xylocarpus* and (4) *Bruguiera*. Other minor subtypes recognized are *Sonneratia* and *Oncosperma* formations.

Forty-nine species of flowering plants have been recorded in the mangrove swamps. Of these, 24 fall into the category of species that are exclusively restricted to the mangrove habitat (Chua *et al.*, 1987). The most prominent species along the river banks is *Rhizophora*. Further up river where the salinity is lower, the salt tolerant mangrove palm *Nipa fruticans* (Nipah) occupies the water's edge. In Brunei Darussalam all major rivers are tidal for very long distances up-river.

Interesting wildlife in mangroves include mammals such as the Proboscis Monkey (*Nasalis larvatus*), Long- tailed Macaque (*Macaca fascicularis*), Silver Leaf Monkey (*Presbytis cristata*), Flying Lemur (*Cynocephalus varigatus*) and Flying Foxes. Birds such as the White bellied Sea Eagle and the Brahminy Kite are often encountered. Banded Kraits and Pythons are snakes that are also found in mangrove areas (NBDMP No. 5, 1986).

In the past, the mangrove resources of Brunei Darussalam have been a major source of:

a) Bark for the manufacture of cutch, a dye extract used in the tanning industry which thrived from 1901 to 1952;

b) Wood for the charcoal industry and firewood, for local use. Between 1942-1960, mangrove wood was exported, mostly to Hong Kong.

At present the mangrove resources continue to be exploited on a limited scale, as poles for piling in construction work, as well as charcoal, and to a much lesser extent, for firewood. These uses are well within sustainable levels. As such, the mangroves of Brunei Darussalam are considered to be well preserved in a region noted for intense and often non- sustainable development pressures on this productive ecosystem.

Fish, crabs, molluscs, shrimps and prawns are economically important organisms of the mangrove ecosystem.

Brunei Darussalam has just started to exploit the potential of the mangroves for ecotourism, with the building of a 2 km long mangrove viewing walkway in the Selirong Mangrove Forest Reserve.

The nature of the mangrove root system causes it to trap any impacted oil, and makes the mangroves and the associated organisms highly vulnerable to oil spills. Because of the contribution of the mangroves to the coastal productivity and the coastal fishery, as well as the possible persistence of impacted oil, mangroves are given the highest Environmental Sensitivity Index ranking of five (ESI = 5).

Artificial Reefs

Two major types of artificial reefs enhance the natural productivity of coral reefs, and are hence important to coastal productivity. One is the unintentional artificial reefs made up of offshore oil and gas structures, such as platforms, rigs, pipelines, buoys etc. The other is purpose-built artificial reefs of the Department of Fisheries, made up of discarded tyres and redundant oil jackets.

Both types of artificial reefs are located at Two Fathom Rocks (05°05.8'N, 114°57.8'E). The Tyre Reef is made up of some 20,000 discarded tyres while the Rig Reefs are made up of redundant oil jackets provided and placed in a horizontal position by Brunei Shell Petroleum Co. Sdn. Bhd. The success of the first Rig Reef of 2 jackets built in 1988 led to the building of a second Rig Reef of 5 jackets in 1994. Plans are underway to put down more redundant oil well jackets as artificial reefs.

Studies carried out by Chou *et al.*, (1992) have shown that compared to natural coral reefs, fish populations in artificial reefs have:

a) a greater diversity and abundance of high market value food fishes; and

b) a larger size distribution.

These studies substantiate the importance of artificial reefs in contributing to the fish production, especially of high market value food fishes in the coastal waters of Brunei Darussalam.

As the purpose built artificial reefs (tyre and rig reefs) are located at Two Fathom Rocks and closely associated with the coral reefs, they are placed in the same category with a similar Environmental Sensitivity Index as coral reefs (ESI = 4).

Islands

Brunei Darussalam has only two small offshore rocky islands. They are the Pelong Rocks and Pulau Punyit. These islands are surrounded by the only fringing coral reefs found in the country. The islands also serve as habitats for resident seabirds, particularly terns and seagulls. The rest of the islands in Brunei Darussalam occur in estuaries or in the major river systems.

The inshore islands are primarily located in the Inner Brunei Bay, Tutong Estuary and associated river estuarine systems. The approximate total area of these islands is 7,929 hectares or 79.29 km^2. The largest of these islands is Pulau Selirong having a land area of 2,566 hectares, and the second largest, Pulau Berambang, with a total land area of 1,939 hectares. Both are located in the Inner Brunei Bay.

There are about 31 inshore islands of varying sizes, all possessing varying extents of mangroves, with some of the smaller islands almost entirely covered by them. Islands in Sg. Brunei, Sg. Temburong and the Tutong estuary, and the associated river systems are edged by mangrove and *Nipa* communities.

Of all the islands in Brunei Darussalam, only Pulau Baru Baru, Pulau Berbunut and Pulau Berambang are inhabited. At present, many of the islands remain undisturbed and in a near pristine state. However, their proximity to population centres (Bandar Seri Begawan and Tutong) could make them vulnerable to development.

The islands provide protection to coastlines by shielding the mainland from strong winds and wave action. The associated mangroves of the islands help to enhance the biological productivity and diversity of the surrounding coastal waters. Several islands are habitats of the endangered Proboscis Monkey and other wildlife.

Part of Pulau Berambang has been designated for conservation by the Museum Department. Other islands that have been proposed for conservation are the two offshore islands, Pelong Rocks and Pulau Punyit, Pulau Chermin and Pulau Siarau.

Because the shorelines of most of the inshore islands are fringed by mangroves or *Nipa*, their vulnerability to oil spills will be similar to the mangrove swamps. Hence they are classified under the same category as mangrove swamps and given the highest Environmental Sensitivity Index ranking of five (ESI = 5).

Similarly, the two offshore islands, Pulau Punyit and Pelong Rocks have fringing reefs and are given an Environmental Sensitivity Index of four (ESI = 4), similar to coral reefs.

Recreational Beaches

Several beaches in Brunei Darussalam are used for recreational purposes. The more popular beaches are:

a) Serasa Beach - a man made sand spit serving recreational needs such as swimming, fishing, windsurfing, boating and picnicking;

b) Pelompong Spit - Although no recreational facilities are available, this beach is popular with people who have access to boats. Popular as a picnic area;

c) Muara Beach - a very popular beach area frequented by large numbers of people during weekends and holidays, with shade and other facilities available. Food and drinks are sold, particularly during weekends;

d) Meragang (Crocodile Beach) - a fine sand beach popular for recreational use. Although no facilities are available as yet, picnicking, bathing, swimming and fishing with rod and line are popular activities;

e) Tunku Beach - has some picnic facilities and areas providing shade. Very popular for swimming and bathing. Some food and drinks are sold particularly during weekends and holidays;

f) Jerudong Beach - a Royal Palace and recreational area are located on the south-western part of the Jerudong Beach. The other beach areas are popular for launching fishing boats, walking, bathing and rod and line fishing. A new luxury hotel complex is being built in the area;

g) Tutong Beach - two areas of Tutong are popular for recreational use, viz. Penanjong Beach and Seri Kenangan Beach. Both beaches are popular for picnics, bathing and fishing, and the former has some recreational facilities;

h) Lumut Beach - has facilities for picnics and is a very popular beach in the Beliat District;

i) Anduki - an area from which sand has been extracted, is a small lagoon-like area which is popular for fishing and picnicking. This area has been developed for recreational use;

j) Seria-Belait Beach - Several areas along this stretch are used for recreation.

Impact of oil on recreational beaches would have wide ranging effects from curbing recreational activities to problems of launching fishing boats. Vendors selling food and drinks would be among those whose livelihoods will be affected.

Aquaculture Sites

Although aquaculture is still in its infancy in Brunei Darussalam this is a rapidly expanding area of the fisheries industry.

Brackishwater Pond Culture

The Fisheries Department has identified potential sites for brackishwater pond culture targeted for commercial shrimp farming. In the Tutong District, there are about 80 hectares in Kg. Keramut and another 200 hectares in Telisai, while in the Brunei-Muara District, 50 hectares in Pangkalan Sibabau and another 200 hectares in Pulau Muara Besar have been identified. In the Temburong District, more than 1,000 hectares of mangrove forest have been identified for future development, but for the time being, these plans are held in abeyance. Most of the areas to be initially developed are sparsely vegetated with some fringes of mangroves, with the exception of Pangkalan Sibabau, which is entirely covered by mangrove forest. The Fisheries Department will strictly implement a mandatory 50 meter mangrove to serve as a buffer belt in mangrove areas.

At present, there are eight (8) operators of brackishwater ponds., with more operators expected to start. The main cultured species is the Tiger Shrimp (*Penaeus monodon*).

Open Water Culture

Aquaculture in open waters (estuary and sea) using pens and cages has been found to be feasible in Brunei Darussalam and attempts to develop net cage culture by the Department of Fisheries (DOF) in

Serasa Bay has been promising. The culture of *P. monodon* has been successfully piloted with the shrimp growing from postlarvae to the marketable size of 30-35gm in about four months, using artificial feed. The culture of Seabass (*Lates calcarifer*), Grouper (*Epinephelus* sp.) and Red Tilapia (Golden Hybrid Tilapia) has also been piloted successfully at the Serasa Bay cage culture facility of the DOF. A new Fish Hatchery at Meragang, southwest of Muara, produce fry and fingerlings to support the pen and cage culture projects.

At present there are 3 commercial, 10 medium/small scale privately owned farms and one joint venture facility for cage culture of finfish. More of such facilities are expected to be established soon.

Fishing Grounds

Brunei Darussalam has an ancient tradition of fishing, and its inshore fisheries resources, particularly those of Brunei Bay, have provided a substantial part of the protein requirements of its people for centuries. The per capita fish consumption of over 40 kg/year is indicative of its importance.

The fisheries in Brunei Darussalam can be broadly categorized into artisanal (small scale) and commercial fisheries. The major fishing grounds of the country are located in estuaries, the Brunei Bay, and the South China Sea.

In a zoning scheme adopted by the Department of Fisheries, the near-shore area of the South China Sea within a 3 mile radius of the coast has been reserved for the artisanal fishery and has been designated Zone 1. Artisanal fishing is primarily confined to this zone, the Inner Brunei Bay and the estuarine systems of the major rivers. Commercial fishing is carried out in Zones 2 and 3. Zone 2 extends from the seaward boundary of Zone 1 and up to a distance of 20 miles from the coast. Fishing vessels of less than 350 hp are licensed to operate in this zone. Beyond 20 miles from the coastline is Zone 3, where fishing vessels of over 350hp are licensed to operate.

Artisanal Fisheries

In 1995, there were 550 full-time and 795 part-time fishermen involved in the artisanal fishery. The majority of part time artisanal fishermen are employed and fish during weekends, non-working hours and holidays. Apart from the fish they use for home consumption, the marketed catch is substantial.

The common fishing gear used in the artisanal fishery are hook and line, gill nets, beach seine, cast nets, ring nets, traps and others. Specific trammel nets (andang karan) and conical tidal traps (tugu) are used for catching shrimp. A special trap (bintur) is used for crabs. Most of the fishing boats used by the artisanal fishermen are equipped with powerful gasoline outboard motors which provide them with great mobility. The fast boats have reduced travel time and enabled the fishermen to complete a day's fishing and get back to the fish landing points by mid-afternoon. At present, the artisanal fisheries contribute a major share to the country's total fish production.

The main shrimp fishery in Brunei Darussalam is concentrated in the Inner Brunei Bay and adjacent areas as far as Berakas and Jerudong. The dominant species caught are the yellow shrimp (*Metapenaeus brevicornis*) and the white shrimp (*Penaeus merguiensis*). Shrimps breed throughout the year with two spawning peaks around February to March and August to September. The spawning peaks occur just prior to the peak rainfall months from April to May and November to December. Shrimp catches peak from February to April in the Inner Brunei Bay. Peak catches occur near Berakas and Jerudong from November to January.

Commercial Fisheries

Beyond Zone I and up to the 200nm seaward boundary of the Brunei Fishery Limits are the Commercial Fishing Zones 2 and 3. These fishing Zones have been allocated primarily for bottom trawling and purse seining. The total area available for offshore demersal trawling is 4,600 km^2.

The Maximum Economic Yield (MEY) potential of demersal fish from accessible fishing grounds in Brunei Darussalam has been estimated at 8,600 mt/yr. Demersal trawlers operate outside Zone 1, but within the 20 fathom isobath. In 1990, there were nine (9), in 1991, eleven (11) and up to June 1995, seventeen (17) licensed demersal trawlers in the country. They berth and operate from the pier of the Fish Landing Complex (FLC) at Muara, a facility of the Department of Fisheries.

Demersal fish caught by bottom trawlers include Slipmouths (family: Leiognathidae), Goatfish (family: Mullidae), Threadfin Breams (family: Nemipteridae), Carangids (family: Carangidae), Croakers (family: Sciaenidae), Lizard Fish (family: Synodontidae), Lactarids (family: Lactariidae), Herrings (family: Clupeidae), Sea Catfishes (family: Ariidae), and Rays (family: Rajidae). Groupers (family: Serranidae), *Stolephorus* sp. (family: Engarulidae), and the family: Pomadasyidae are also represented in the catch. The pelagic fish resources of Brunei Darussalam has been estimated to have a MEY potential of 7,600 mt/yr. These resources are particularly plentiful in shallow waters of less than 100 metres where the mean density of total biomass has been estimated to be 2 tons/km^2.

An area of 4,800,000 ha or 48,000 km^2 is available for the offshore pelagic fishery. At present, pelagic fishing is carried out within the shallower areas of the continental shelf. 4 purse seiners were licensed in 1994.

Most of the pelagic fish caught are Anchovies (Engraulidae), Sardines and Herrings (Clupeidae), Jacks and Trevallies (Carangidae), and small mackerels and tunas (Scombridae).

Urban Facilities

Anchorages, marinas, ports, ferry points are urban facilities that can be disrupted by impacts of oil spills. The lower reaches of the Belait River has several such facilities. The water-based facilities such as the water taxis in the Tutong, Brunei and Temburong rivers as well as the anchorages of fishing boats are liable to be affected if impacted by oil spills.

The Muara Port, the Flotilla and the Fish Landing Complex at Muara are among the major water-front facilities that could be adversely affected by oil spills. If an oil spill moves into Sg. Brunei, Kg. Ayer and the water-front activities in Bandar Seri Begawan are liable to be affected.

Wildlife

Turtles, birds and marine mammals are types of wildlife most likely to be affected by offshore oil spills. Small numbers of turtles are known to visit the beaches of the Pelompong Spit, Muara, Tutong, Lumut and Anduki, to nest during the months of November to June. Elkins (1991) has reported that a large group of turtles numbering a "few hundreds" was reported by a helicopter pilot in August 1990 moving in a north-westerly direction near BSP's Magpie oil platform. It is possible that some turtles pass through the coastal waters of Brunei Darussalam during migration periods. Mud flats and the beaches in Seria and in several other areas including the Inner Brunei Bay are used by several bird species for feeding during low tides. Several migratory bird species are also known to use these areas for wintering. The two off shore islands Pulau Punyit and Pelong Rocks have nesting populations of Terns and gulls which add to the importance of protecting these islands from the impact of oil spills.

Elkins (1991) has reported that a few whales, dugongs, several species of dolphins and estuarine crocodiles (*Crocodilus porosus*) have also been observed in the coastal waters of Brunei Darussalam. Wildlife in inshore mangrove areas and mud flats include the endangered Proboscis Monkey (*Nasalis larvatus*), Long-tailed Macaque (*Macaca fascicularis*), Silver Leaf Monkey (*Presbytis cristata*), Flying Lemur (*Cynocephalus varigatus*) and the Smooth Otter. Common birds include the White bellied Sea Eagle, Brahminy Kite, different species of Waders (seen on mud flats during low tide, Terns, Lesser Adjutant Storks and the Stork Billed Kingfisher. Several migratory birds also use the mud flats during the wintering season. Crocodiles, thoughpresent are rarely seen, and while the Monitor Lizards are more common, Banded Kraits and Pythons are snakes also found in mangrove areas.

PRIORITY AREAS FOR PROTECTION

Four major areas along the shoreline of Brunei Darussalam have been prioritized for protection in the event of acute oil spills. The following criteria were taken into consideration in prioritizing an area for protection:

a) concentration of ecosystems, biological resources and organisms vulnerable to impact of oil;

b) concentration of economic, social and cultural activities liable to disruption by the impact of oil;

c) possible adverse political implications; and

d) persistence of impacted oil.

Priority Areas

The areas that have been identified for prioritization for protection are:

a) Brunei Bay Priority Area

b) Jerudong Priority Area

c) Tutong Priority Area

d) Kuala Belait Priority Area

Brunei Bay Priority Area

The Brunei Bay Priority Area encompasses the off-shore coral areas of Pelong Rocks and Abana Rock; the mangroves of the Temburong District, Muara and lower reaches of the Brunei River; the major productive inshore artisanal fishing grounds of the Inner Brunei Bay; the Muara Port; marine facilities of the Flotilla, Marine Police and Department of Fisheries; aquaculture sites and several recreational areas. The protection of this area will also ensure the protection of the "Water Village", Kampong Ayer, the mangroves and other urban facilities along the Brunei River, and its tributaries.

Because of the shallow, highly productive fishing grounds, large extents of mudflats, mangroves and the high biodiversity, the Brunei Bay Priority Area has been designated as an area where dispersant spraying should not be carried out.

Jerudong Priority Area

The Jerudong Priority Area encompasses the vulnerable fringing coral reefs of Pulau Punyit; recreational beaches associated with the Royal Palaces; the beach accesses to fishing boats and the important Tunku Recreational Beach. This is an area of high biodiversity rocky shores and beaches, where dispersant spraying should not be carried out.

Tutong Priority Area

The Tutong Priority Area encompasses the productive estuary of the Tutong River; Mangroves; tidal flats of the Tutong River; aquaculture areas; river based facilities of Tutong town; water villages along the river; and anchorages of fishing boats. This is a high biodiversity area where no dispersant spraying should be carried out.

Kuala Belait Priority Area

The Kuala Belait Priority Area encompasses the mangroves of the Belait River and several urban water front facilities. The area of the river mouth is an important fishing and shrimp ground and hence no spraying of dispersants should be carried out.

Dispersant Sensitive Areas

The shallow but productive Inner Brunei Bay; the shallow near-shore areas within a 2.5 kilometre distance from the shore, from Muara to Tutong, which include the offshore island of Pulau Punyit and its fringing coral reefs, the two rocky shore areas of Brunei Bluff and Brunei Cliffs, and the important temporal shrimp grounds from Muara to Tutong; all coral reef areas with a buffer zone of 500 m; the productive estuaries and the river mouths of the Tutong and Belait rivers are considered to be sensitive to oil dispersants and have been designated as areas where dispersants should not be used. The near shore areas within a 2.5km radius from Tutong to Sungai Tujoh near Kuala Belait, with the exception of the priority protection areas of Tutong and Kuala Belait (no dispersant spray areas), are designated areas where use of dispersants are not recommended. The coral reef areas of the Champion Field are an exception, and are included in the latter category to allow for dispersant spraying, in case an oil spill originating from this area heads towards the extremely sensitive Brunei Bay Priority Area.

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We wish to thank the Department of Fisheries, Ministry of Industry and Primary Resources and Brunei Shell Petroleum (BSP) Co. Sdn. Bhd. for co-sponsoring the Environmental Sensitivity Mapping Project under which the present investigation was carried out; Mr. Ed Padero and Hj. Mohd. Jaafar Hj. Bakar of BSP for all their assistance; Awang Abdul Hamid Hj. Zainin, Awang Aji Hj. Sapar, Awang Ramli Hj. Hassan, Awang Harun Hj. Puteh, Awang Aji Sapar, Awang Bidin Suru and Awang Ahmad Puteh and the Marine Fisheries, as well as the Transport and Maintenance Sections, Department of Fisheries for their assistance and support; Ms. Jennifer Elkins, Panaga Natural History Society for information on wildlife. Last but not least we wish to thank Mr. Jack Verouden and the staff of the Topography Department of BSP for doing an excellent job of digitizing and printing the Coastal Environmental Sensitivity Map.

REFERENCES

Chua, T.E., L.M. Chou & M.S.M. Sadorra (eds.), 1987. The Coastal Environmental Profile of Brunei Darussalam: resource assessment and management issues. ICLARM Technical Reports 18, Fisheries Department, Ministry of Development, Brunei Darussalam and International Center for living Aquatic Resources Management, Manila, Philippines, 193 pp.

Chou, L.M., G.S.Y. Lim & C.B. Leng, 1992. Fish communities in natural reef and artificial habitats in the coastal waters of Brunei Darussalam. In: G. Silvestre, H.J.H. Matdanan, P.H.Y. Sharifuddin, M.W.R.N. De Silva & T.E. Chua (eds.), The Coastal Resources of Brunei Darussalam: status, utilization and management., ICLARM Conference Proceedings 34, Department of Fisheries, Ministry of Industry and Primary Resources, Brunei Darussalam and International Center for living Aquatic Resources Management, Manila, Philippines, pp. 75-90

De Silva, M.W.R.N. & A.R. Ridzwan, 1981. Coastal resources of Peninsular Malaysia vulnerable to oil spills. Paper presented at Oil Spill Control Workshop, August/September 1981, Port Dickson. Esso Production Malaysia Incorporated, Kuala Lumpur.

Elkins, J., 1991. Seawatch Report. Penaga Natural History Society, Seria, Brunei Darussalam.

Getter, C. D., J. Michel, G.I. Scott & J.L. Sadd, 1981. The sensitivity of coastal environments and wildlife to spilled oil in South Florida. A report to the South Florida Regional Planning Council, RPI/R/81/ 9-1, 126 pp.

Gundlach, E.R. & M.O. Hayes, 1978. Vulnerability of coastal environments to oil spill impacts. J. Marine Tech. Soc. 12(4): 18-27.

Lai, H.C., B. Ong & A.O. Kessler, 1992. Benthos composition and diversity in the coastal waters of Brunei Darussalam. In: G. Silvestre, H.J.H. Matdanan, P.H.Y. Sharifuddin, M.W.R.N. De Silva & T.E. Chua (eds.), The Coastal Resources of Brunei Darussalam: status, utilization and management. ICLARM Conference Proceedings 34, Department of Fisheries, Ministry of Industry and Primary Resources, Brunei Darussalam and International Center for living Aquatic Resources Management, Manila, Philippines, pp. 109-126.

Mann, C.F., 1987. A checklist of the birds of Brunei Darussalam. J. Brunei Mus. 6(3): 170-210.

Mohd. Jaya, S., S. Nyawa, J.R. Howes, D. Parish, A.H. Samat & J. Jumat, 1986. A study of the littoral ecosystem in Brunei Estuary, Brunei Darussalam. Draft Report of Brunei Museum - Interwader, Kuala Lumpur, Malaysia. (Unpublished).

NBDMP No. 5, 1986. Negara Brunei Darussalam Special report on wildlife conservation and management. Vol 1-4, Department of Town and Country Planning, Ministry of Development, Brunei Darussalam.

Rajasuriya, A., M.W.R.N. De Silva & H.Z. Abdul Hamid, 1992. Survey of coral reefs of Brunei Darussalam in relation to their vulnerability to oil spills. Report of a survey on coral reefs carried out under the Department of Fisheries and Brunei Shell Petroleum Co. Sdn. Bhd. Environmental Sensitivity Mapping Project, Department of Fisheries, Ministry of Industry and Primary Resources, Bandar Seri Begawan, Brunei Darussalam.

Ridzwan, A.R. & M.W.R.N. De Silva, 1983. Coastal Resources of the Chukai-Dungun Coastline sensitive to impacts of oil spills - Report accompanying the Environmental Sensitivity Index (ESI) Maps of the Chukai- Dungun Coastline. Universiti Pertanian Malaysia, Selangor, Malaysia.

Silvestre, G., H.J.H. Matdanan, P.H.Y. Sharifuddin, M.W.R.N. De Silva & T.E. Chua (eds.), 1992. The Coastal Resources of Brunei Darussalam: status, utilization and management. ICLARM Conference Proceedings 34, Department of Fisheries, Ministry of Industry and Primary Resources, Brunei Darussalam and International Center for living Aquatic Resources Management, Manila, Philippines, 214 pp.

IMPACT STUDY OF SHRIMP FARMS ON MANGROVE AREA AND SOME AQUATIC ANIMAL PRODUCTION

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ABSTRACT

The satellite images of Welu estuary at Khlung district, Chantaburi province during 1982 - 1992 were classified using Nearest Neighbour Algorithm. The results were delineated into 7 categories, namely (1) Mangrove (2) Standing tree (3) Paddy field (4) Shrimp farm (5) Grassland (6) Mangrove cleared (7) Swamp and/or Mangrove cleared. Analysis of these data sets indicates that shrimp farm area had increased from 29.98 km^2 in 1982 to 105.48 km^2 in 1992 (251.83 % increase). About 82.62 km^2 of shrimp farm (78.33 % of total shrimp farm area) operated in the mangrove area. During the same period, mangrove area had decreased from 190.34 km^2 to 63.23 km^2 (66.78 % decrease). This multi-temporal study also showed a 65 % decrease in mangrove resulting from shrimp farm expansion. The result of relationship analysis between mangrove area and the production of the nearshore mangrove-dependent fisheries revealed that obvious decrease of fisheries production in 1989 occurred following extensive conversion of mangrove area in 1988. Average fisheries production decreased from 16,076.4 tons (1974-1988) to 10,281 tons (1989-1992), a 36.05 % decline worth about 30,762,008 Baht per year.

INTRODUCTION

Since 1985, aquaculture of shrimp has rapidly expanded into semi-intensive and intensive culture techniques for black tiger shrimp (*Penaeus monodon*). Culture shrimp production, accounting for only 13,006.75 tons in 1984, increased tremendously to 190,650 tons in 1994 and is worth 48,109 million Baht (Bank of Thailand, 1995). The rapid expansion of shrimp farms in the coastal areas has been causing serious impact on the ecological system which includes degradation of coastal water and soil quality, acidification, increased risk of coastal erosion from storm surges and wind, salinization of groundwater and agricultural land, as well as social aspects (Tussanee Chantadisai & Wipada Apinan, 1985; Macintosh & Phillips, 1992; Sanit Aksornkoae & Nittharatana Paphavasit, 1990).

One of the important results of increasing shrimp culture is mangrove destruction. Mangroves are often selected as the first sites to be considered for shrimp farming because of ease in salt water supplies to the aquaculture system. It has been reported that 158.72 km^2 of mangrove was cleared during the shrimp culture boom period (1986-1989) (Siri Tookvinas, 1992). Since mangroves have important ecological functions on the coastal zone, large-scale denudation of mangroves might cause many negative impacts on coastal zone ecology, especially on mangroves function in contributing to aquatic productivity of the nearshore. More information on the ecological impact of shrimp farming on coastal ecological systems is urgently needed for proper problem solving and management.

The objectives of this study are to determine the :

1. impact of shrimp farming on mangrove coverage using remote sensing technique,
2. impact of shrimp farming on estuarine fishery production,
3. change, situation, and trend of landuse and coastal resources.

MATERIALS AND METHODS

Study Sites

Welu estuary was selected as the test site for the following reasons:

- this site used to be a large abundant mangrove area, but is now converted to shrimp farms and is a good case to provide sufficient data for learning and testing on shrimp farm expansion,
- past and current satellite data covering the study area are available, including both Landsat-MSS and Landsat-TM images covering the period of the shrimp farm boom.

Welu estuary is a rather large estuary with most of it in the Khlung district of Chantaburi province and the rest in Khao Saming district of Trat province. It is located on the eastern coast of the Gulf of Thailand between latitude 12° 15′ to 12° 30′ N. and longitude 102° 8′ to 102° 25′ E. (Fig. 1) and comprises approximately 290 square kilometers.

In this study, the extent of study area was defined using a coastal line for the lower part of the area with a road lane surrounding the area for the left boundaries (Figure 1).

Software Used

- microBRIAN: This software was jointly developed by Water Resources Division of CSIRO and the MPA Ltd. in Australia. The software consists of more than a hundred modules covering the whole range of the image processing techniques and image statistical analysis.

- IDRISI: This software, developed by a research team at Clark University, USA, provides facilities for image displaying and data manipulation, such as regrouping data and data conversion.

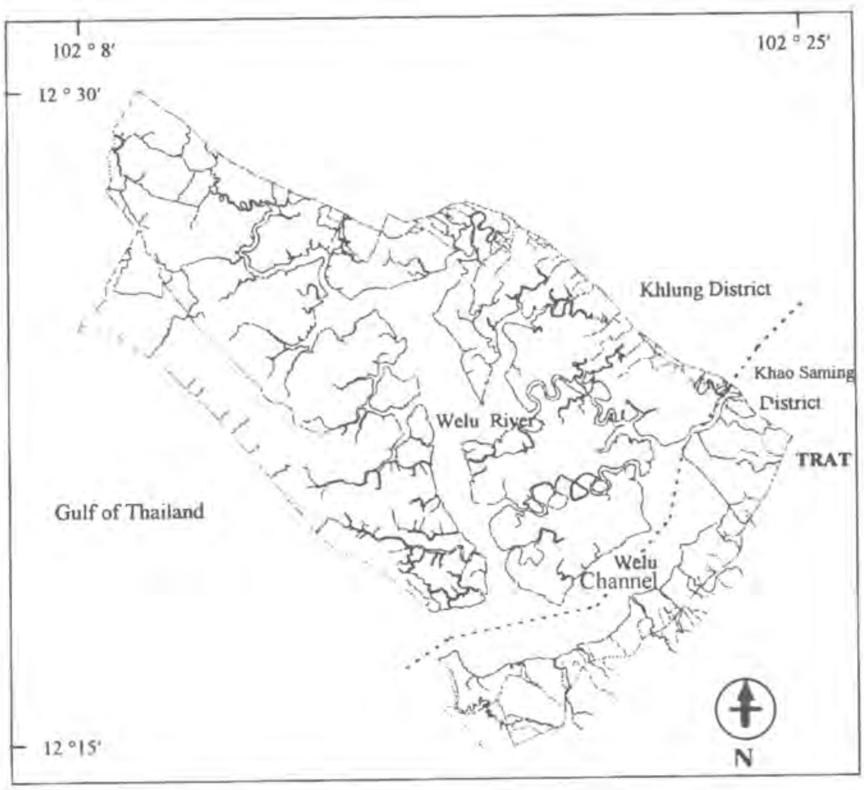

Figure 1. Map of the study area.

Methodology

Remotely sensed data recorded in form of Computer Compatible Tapes (CCTs) received by Thailand Remote Sensing Receiving Station, National Research Council of Thailand were used in the study. Data covering the study area (MSS: path 137, row 51; TM path 128, row 51) were acquired on 21-Jan.-1982 and 02-Mar.-1986 for Landsat-MSS, 20-Feb.-1988, 24-Jan.-1990 and 15-Dec.-1992 for Landsat-TM.

In remotely sensed data processing and classification, the data were processed with version 3.2 of microBRIAN program. This study classified landuse into seven categories related to specific problems referred to in the objectives and resolution of remotely sensed data. The images were classified by using the nearest neighbour classifier technique with semi-supervised classification procedure.

To assess the impact of mangrove depletion due to shrimp farming on coastal fisheries production, data from 'the landing place survey' between 1974-1991 were used to analyze the relationship between the production of the nearshore mangrove-dependent fisheries and the condition of mangrove area. Fish-landing data were recorded by Fisheries Statistics Sub-division, Fisheries Department. The number of registered fishing vessels operating in Chantaburi were also recorded by size and total gross tonnage, but fishing method was not classified by Amphoe. These information were plotted together against the area of mangrove and fish landings to show their relationship.

RESULTS

Impact on Mangrove Landuse Change

Remotely sensed data of the study area during 1982-1992 were classified for measuring the temporal change in landuse. The method attempted to account for the annual rate of change (Table 1, Figure 2). To determine the area where shrimp farms took place, the image (showing locations) of shrimp farms was overlaid with the images of landuse categories in each year by using command OVERLAY in program IDRISI, and then using command AREA to calculate the amount of that area (Table 2).

Table 1. **Rate and extent of changes in landuse of the study area between 1982-1992. (SW/MC = Swamp and/or Mangrove cleared)**

Categories	1982 (km^2)	1986 (km^2)	Annual rate of change 1982-1986	1988 (km^2)	Annual rate of change 1986-1988	1990 (km^2)	Annual rate of change 1988-1990	1992 (km^2)	Annual rate of change 1990-1992	Annual rate of change 1982-1992
Mangrove	190.34	172.32	-2.37%	84.11	-25.59%	63.4	-12.31%	63.23	-.013%	-6.68%
Standing Tree	9.79	9.81	0.05%	12.95	16.00%	20.76	30.15%	27.94	17.29%	18.54%
Paddy Field	49.48	39.32	-5.13%	31.03	-10.54%	35.09	6.54%	39.52	6.31%	-2.01%
SW/MC	18.66	29.44	14.44%	12.99	-27.94%	14.45	5.62%	14.27	-0.62%	-2.35%
Shrimp Farm	16.57	29.98	20.23%	91.04	101.83%	121.31	16.62%	105.48	-6.52%	53.66%
Grassland	5.44	9.41	18.24%	5.74	-19.50%	0.79	-43.12%	2.39	101.27%	-5.61%
Unclassified	0.48	0.46	-1.04%	1.37	98.91%	0.8	-20.80%	0.64	-10.00%	3.33%
Mangrove Cleared	-	-	-	51.22	-	28.18	-22.49%	32.63	7.90%	-

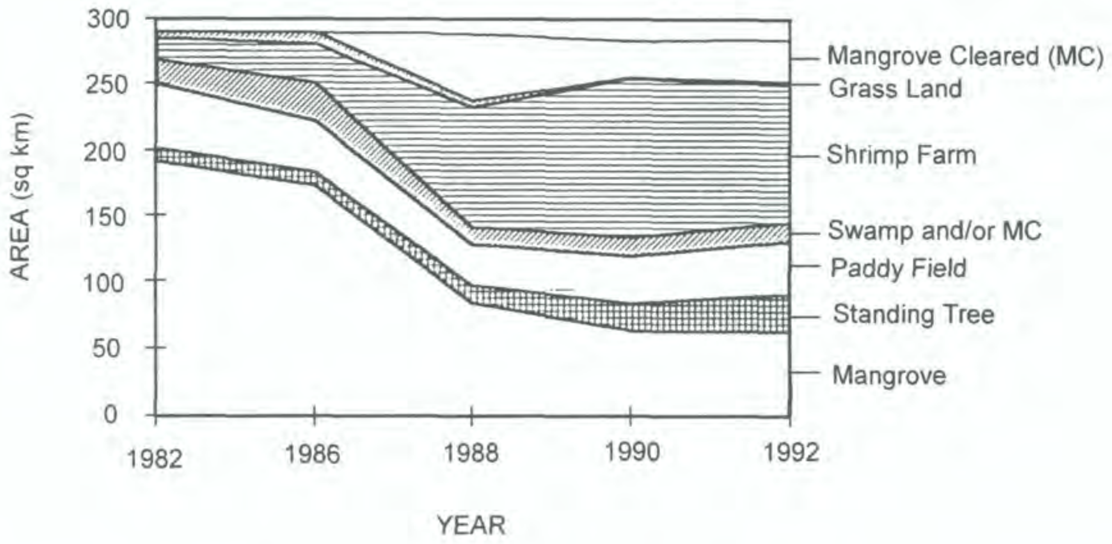

Figure 2. Change of landuse in the study area between 1982-1992.

Table 1. Rate and extent of changes in landuse of the study area between 1982-1992. (SW/MC = Swamp and/or Mangrove cleared)

Categories	Landuse '82 & SF '86		Landuse '86 &SF '88		Landuse '88 &SF '90		Landuse '90 &SF '92		Landuse '82 &SF '92	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Mangrove	16.23	54.14	53.16	58.39	28.23	23.27	12.33	11.69	82.62	78.33
Standing Tree	0.07	0.23	0.02	0.02	0.14	0.12	0.67	0.64	0.22	0.21
Paddy Field	1.26	4.20	3.37	3.70	0.34	0.28	1.17	1.11	4.93	4.67
SW/MC	4.14	13.81	7.61	8.36	0.79	0.65	0.85	0.81	7.09	6.72
Shrimp Farm	8.25	27.52	26.24	28.82	71.96	59.32	82.41	78.13	10.31	9.77
Grassland	0.03	0.10	0.47	0.52	0.27	0.22	0.13	0.12	0.12	0.11
Unclassified	-		0.17	0.19	0.36	0.30	0.16	0.15	0.19	0.18
MC	-		-		19.22	15.84	7.76	7.36	-	
Total	29.98	100	91.04	100	121.31	100	105.48	100	105.48	100

Data from Table 1 and Figure 2 show that tremendous expansion of shrimp farms began in 1986. Between 1986 and 1988, the rate of expansion increased to the level of 101.83%, five times the rate during 1982-1986. During the same period of shrimp farms expansion, there was a 25.9% decrease in mangrove which is obvious from Table 2 as most of the shrimp farms located in the area used to be mangrove. Clearly, this is the dominant factor of change in mangrove.

After 1988, the rate of shrimp farm expansion decreased to 16.62%, but in 1990, reversed by -6.52%. This was because many shrimp farms faced the problem ofwater quality and disease of shrimps due to improper farm management. A number of farms have ceased activities and left the converted land abandoned. Part of these areas might be classified as mangrove cleared area, hence causing the rate of mangrove cleared to increase after 1990 (7.90%).

Mangrove cleared are the areas where the mangrove had been cleared in preparation for shrimp farming. Change of this area depended on time when investors began their farming activities. Swamps also showed this similar pattern as they were regarded as wasteland which could be converted to shrimp farms.

To assess the major causes of mangrove destruction, the image of mangrove in 1982 was overlaid with the images of each landuse category in 1992. The outcome indicated the portion of each activity which took place in mangrove area during 1982-1992 period (Table 3). Obviously, most of the change resulted from the shrimp farms (65.00%). If assumed also that half of the area of swamp and/or mangrove cleared would be converted to shrimp farms, mangrove depletion due to shrimp farms would rise to 74.12%.

Table 3. Summarized causes of mangrove depletion in the study area.

Mangrove area (km^2)			Activities in depletion area	Area (km^2)	%
1982	1992	Depletion			
			Shrimp farm (SF)	82.62	65.00
			Mangrove cleared (MC)	18.61	14.64
			Standing tree (ST)	15.85	12.47
190.34	63.23	127.11	Swamp and/or Mangrove cleared (SW/MC)	4.71	3.71
			Paddy field (PF)	4.54	3.57
			Grassland (GL)	0.61	0.48
			Unclassified	0.17	0.13
				127.11	100.00

Impact on Coastal Fisheries Production

The relationship was assessed based on 12 fish groups, 2 shrimp species and 1 of crab (Table 4). Ten groups of fishes are listed in Table 4 (not on the list are one 'trash fish' and one 'other food fish'). Numerous studies of fish and prawn communities in mangrove of ASEAN countries confirmed that these selected aquatic animals associated with mangroves at least during some stages of their life history either as nursery grounds or feeding grounds.

The relationship showed that obvious decrease in local fisheries production in 1989 occurred after the mangrove area had been reduced. Average fisheries production decreased from 16,076.4 tons (1974-1988) to 10,281 tons (1989-1992) or a 36.05 % decline. The amount of fish landed decreased, even though the number of fishing vessels increased.

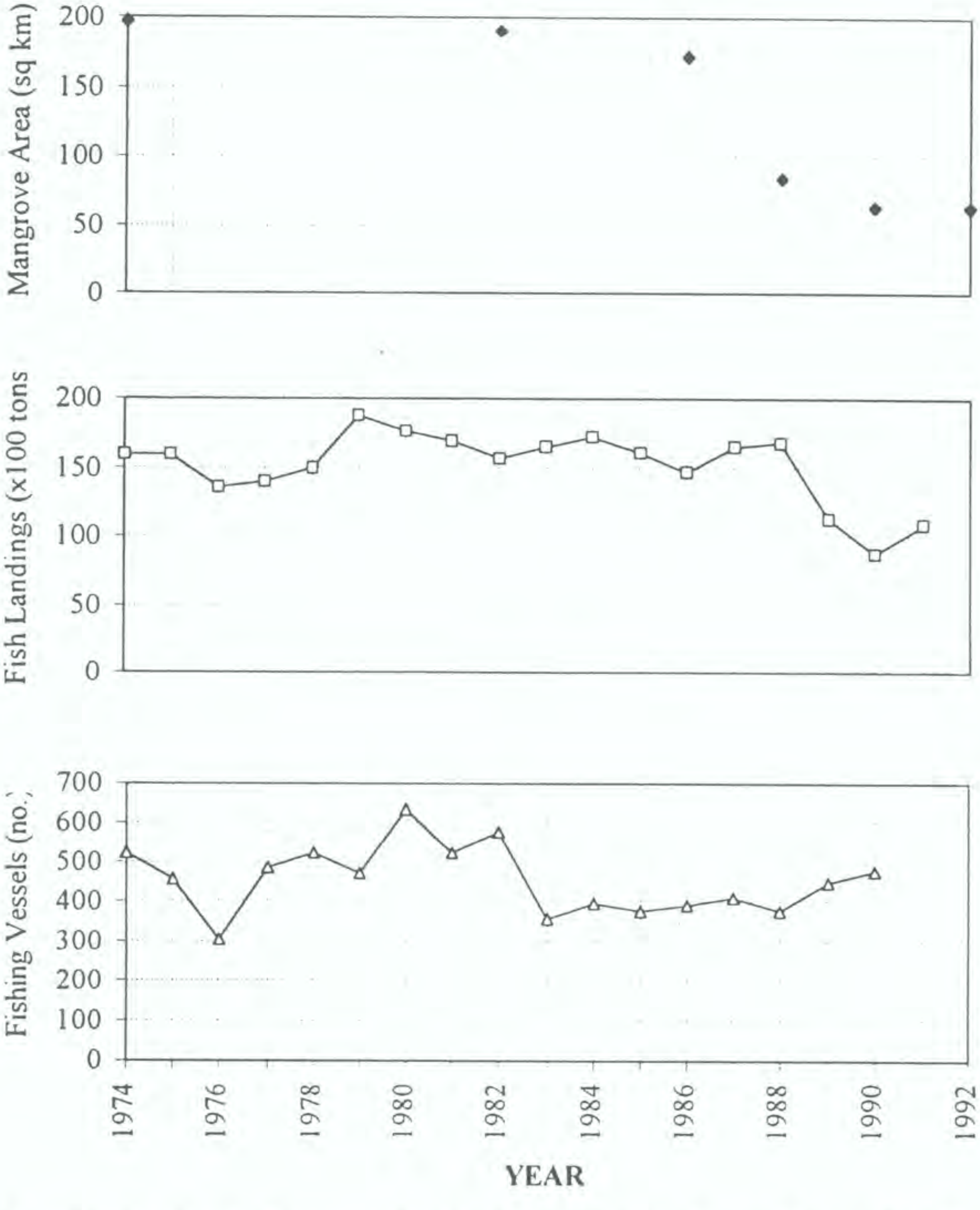

Figure 3. Fish landings, mangrove area and number of fishing vessels between 1974-1992.

DISCUSSION

Although the result showed that average annual rate of mangrove change was declining (6.68 %), it is difficult to expect that the trend would continue. Activity of shrimp farming relies on several external factors such as shrimp sale price which relates to consumption demand in the world market, environmental quality, feed price, disease and also the policy of the government. Therefore, to predict the future trend of each landuse category is rather difficult. However, from field survey at the study area, in November, 1993 and January, 1994, it was noticed that a number of paddy fields have been converted to shrimp farms. If this pattern is still continued, the conflict in landuse between shrimp farming and rice cultivation will be an increasingly serious problem in the future, particularly salt contamination of land suitable for rice cultivation.

For impact on fisheries production, there are at least two points of controversy in the analysis. Firstly, data of fish landings might include fisheries production from other areas, not only from Chantaburi. It was impossible to exclude this error due to the way records are collected. From data of Fisheries Statistics Sub-division, during 1974-1990 the size of fishing vessels in Chantaburi did not exceed 25 meters in length. With this size, fishermen are not able to go too far from their villages since their vessels did not have special freezing room for preserving fishes on a longer trip. If they fished in distant places, they could land their captured production at the nearest landing site i.e. at Trat or Rayong provinces. Also, if they fished in distant places, they had to face higher cost. In addition, if the captured production from longer distances was added to those landed at Muang or Lamsing site, the quantity still showed a decline, indicating that fisheries production in the study area had been seriously affected.

Secondly, there might be other factors that can influence the decline of fisheries production such as, the problem of capturing aquatic animals over their rate of recruitment, called overfishing, or the problem of coastal water degradation. From evaluation of the Maximum Sustainable Yield (MSY) of Chantaburi (Muang and Lamsing) by Fox model (1974), the captured fisheries production was over the MSY (22,355.24 tons) since 1984. The production appeared rather stable and even increased in 1988 before rapid decline following a year of extensive mangrove depletion. This circumstance expressed that destruction of mangrove might be highly affect the availability of fries, brood stock and also the near-shore food web, which consequently affected production of mangrove-dependent species. For water quality problem, a large number of suspended solids from precious stone mining at Khao Saming district might have drained into Welu River, then finally affected nearshore primary productivity. However, analysis of impact of suspended solids cannot be determined because water quality monitoring in Chantaburi had not been regularly.

Table 4. Summary of reports on fish and crustacean communities of mangrove.

Species	Family	References
Fish		
Marine catfish (*Arius* spp)	Arridae	2, 7, 9, 10, 11
Trevallie (*Caranx* spp)	Carangidae	1, 2, 6, 8, 9, 13
Anchovie (*Stolephorus* spp)	Engraulidae	1, 2, 4, 6, 8, 9, 10
Mullet (*Liza* spp)	Mugilidae	1, 2, 3, 6, 8, 10, 12, 13
Snapper (*Lutjanus* spp)	Lutjanidae	1, 2, 3, 6, 8, 9, 11, 12, 13
Barbel eel (*Plotosus* spp)	Plotosidae	2, 6, 8, 9, 11, 12, 13
Crocker (*Johnius* spp)	Sciaenidae	1, 2, 5, 6, 9, 10, 11
Grouper (*Ephinephelus* spp)	Serranidae	1, 2, 4, 6, 9, 11, 12, 13
Sand whiting (*Sillago* spp)	Silaginidae	1, 2, 8, 9, 13
Barracuda (*Spnyraena* spp)	Sphyraenidae	1, 2, 6, 8, 9, 10, 12, 13
Crustacean		
Giant tiger prawn (*Penaeus monodon*)	Penaeidae	9
Banana shrimp (*P. Merguiensis*)	Penaeidae	2, 6, 9
Mud crab (*Scylla serrata*)	Portunidae	6

Source :
1 = Martosewojo and Soedibjo, 1991
2 = Chong, Wee and Sasekumar, 1991
3 = Dolar, Alcala and Nuigue, 1991
4 = Low and Chou, 1994
5 = Yap, Sasekumar and Chong, 1994
6 = Sasekumar, Chong and Leh, 1991
7 = Singh and Sasekumar, 1994
8 = Leh and Sasekumar, 1991
9 = Suphap Monkolprasit, 1994
10 = Sasekumar *et al.*, 1994
11 = Low and Chou, 1991
12 = Dolar and Lepiten, 1991
13 = Burhanuddin, 1991

REFERENCES

Burhanuddin, 1991. A study on mangrove fish at Handeuleum Group and Panaitan Island of Ujung Kulon National Park. In A. Sasekumar (ed.), Mangrove Fisheries and Connections. Malaysia: ASEAN-Australia Marine Science Project Press, pp 173-182.

Chong, V.C., Wee, G.H. & A. Sasekumar, 1991. Inshore fish and prawn communities off a mangrove shore in Selangor, Malaysia. In A.C. Alcala (eds.), Proceeding of the Regional Symposium on: Living Resources in Coastal Areas. Philippines: University of Philippines Press, pp 503-512.

Dolar, L.L., & M.V. Lepiten, 1991. A study on the mangrove, seagrass and coral reef fishes of North Bais Bay, Central Philippines. In A. Sasekumar (ed.), Mangrove Fisheries and Connections. Malaysia: ASEAN-Australia Marine Science Project Press, pp 137-172.

_______., Alcala, A.C. & J. Nuique, 1991. A survey on Fish and Crustaceans of the mangroves of the North Bais Bay, Philippines. In A.C. Alcala (eds.), Proceeding of the Regional Symposium on: Living Resources in Coastal Areas. Philippines: University of Philippines Press, pp 513-520.

Fox, W., 1974. An overview of production modeling. Collect Val. Sci., Pap. ICCAT 3. Cited by Gulland, J.A., 1988. Fish population dynamics. 2nd ed. New York: John Wiley & Sons, pp 142-156.

Leh, M.U.C. & A. Sasekumar, 1991. Ingression of fish into mangrove creeks in Selangor, Malaysia. In A.C. Alcala (eds.), Proceeding of the Regional Symposium on: Living Resources in Coastal Areas, pp. 495-502. Philippines: University of Philippines Press, pp 495-502.

Low, J.K.Y. & L.M. Chou, 1991. Fish fauna of some Singapore mangrove and near-shore habitats. In A. Sasekumar (ed.), Mangrove Fisheries and Connections. Malaysia: ASEAN-Australia Marine Science Project Press, 94-113.

_______. & L.M. Chou, 1994. Fish diversity of Singapore mangroves and the effect of habitat management. ASEAN-Australia Third Symposium on Living Coastal Resources. (in press)

Macintosh, D. J. & M.J. Phillips, 1992. Environmental issues in shrimp farming. In: Saram H. de and T. Singh (Eds) Shrimp 92, Infofish and Eurofish, Hong Kong, pp 118-145.

Martosewojo, S. & B. S. Soedibjo, 1991. Preliminary analysis of the fish community of the mangroves of Grajagan (East Java). In A.C. Alcala (eds.), Proceeding of the Regional Symposium on: Living Resources in Coastal Areas. Philippines: University of Philippines Press, pp 479-484.

Sanit Aksornkoae & Nittharatana Paphavasi, 1990. Research status on ecology and distribution of population and communities in marine habitats. Paperpresented at Workshop 2: Ecology and Distribution of Population and Communities ,April, 3-5. Bangkok: Chulalongkorn University. (Mimeographed)

Sasekumar, A., V.C. Chong & M.U.C. Leh, 1991. Fish and Prawn Communities in mangrove estuaries and mudflats in Selangor (Malaysia). In A.C. Alcala (eds.), Proceeding of the Regional Symposium on: Living Resources in Coastal Areas. Philippines: University of Philippines Press, pp 485-494.

______., V.C. Chong, K.H. Lim & H.R. Singh, 1994. The fish community of Matang mangrove water, Malaysia. ASEAN-Australia third Symposium on Living Coastal Resources. (in press)

Singh, H.R. & A. Sasekumar, 1994. Distribution and abundance of marine catfish (FAM: ARRIDAE) in the Matang mangrove waters. ASEAN-Australia third Symposium on Living Coastal Resources. (in press)

Siri Tookvinas, 1992. Shrimp aquaculture and mangrove. Division of Coastal Aquaculture, Fisheries Department, Ministry of Agriculture and Cooperatives.(Mimeographed)

Suphap Monkolprasit, 1994. Fish composition and food habitat in mangrove forests at Phang-nga Bay and Ban Don Bay, Thailand. ASEAN-Australia third Symposium on Living Coastal Resources. (in press)

Tussanee Chantadisai & Wipada Apinan, 1985. Impact on environment from development in mangrove area. Paper presented in the 5th National Seminar on Mangrove Ecosystem, 26-29 July, 1986. (Mimeographed)

Yap, Y.N., A. Sasekumar & V.C. Chong, 1994. Sciaenid Fish of the Matang mangrove waters . ASEAN-Australia third Symposium on Living Coastal Resources.(in press)

SPATIAL DISTRIBUTION OF SOFT CORALS (OCTOCORALLIA) IN MERAK ISLANDS, WEST JAVA

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ABSTRACT

The objective of this study was to identify the spatial distribution of the soft corals in Merak islands, and interactions between depth and colony size. Data on the distribution of soft corals was collected by using SCUBA in April 1993, using a combination of line and belt transects. The spatial distribution of soft corals and its interactions was analyzed using correspondence analysis. The greatest number of soft coral species, and the best growth were found at sites 3 and 4. The most abundant species observed was *Sinularia polydactyla*, while *Sinularia flexibilis* was uncommon, This species contains toxic compounds and can be found from a depth of 1.5m, with the biggest diameter measured from a colony occurring at 4m. The water clarity in the area studied was low, and visibility was recorded to be between 2-4 m. A possible explanation for this is the high accumulation of sediments in the area.

INTRODUCTION

There is little information on the soft coral communities of the coastal regions of Indonesia. Some studies have been carried out on the taxonomy and ecology of soft corals in Seribu Islands (Manuputty, 1989; 1992a), while the soft coral abundance, major genera, the relationship of soft coral distribution with water conditions and distance from Jakarta have been studied in the Seribu Islands (Manuputty, 1992b). From the latter study, it was stated that the abundance of soft corals was inversely proportional to distance from Jakarta.

Along the coast of Java in the Sunda Strait, the waters are shallow and turbid. The reefs around several islands in the Sunda Strait have been reported to be in a fair condition. In some places where fringing reefs are present, such as Anyer, Carita and Merak, reef conditions are poor, with living coral cover less than 25% (Soekarno *et al.*,1986).

Merak islands are situated in the Sunda Strait, West Java, located close to the mainland. A small ferry port in Merak village faces the islands, which is used to ferry passenges to and from Sumatra across the Sunda Strait. The water surrounding the islands is very turbid.

The objective of this study of soft corals around these islands is to identify the spatial distribution of species, and possible interactions between depth and colony size.

MATERIALS AND METHODS

Merak islands consist of Merak Besar and Merak Kecil, separated from the mainland by a narrow strait which functions as a channel for ferries every half an hour. Five sites were selected for study, three located in Merak Besar and two in Merak Kecil (Figure 1).

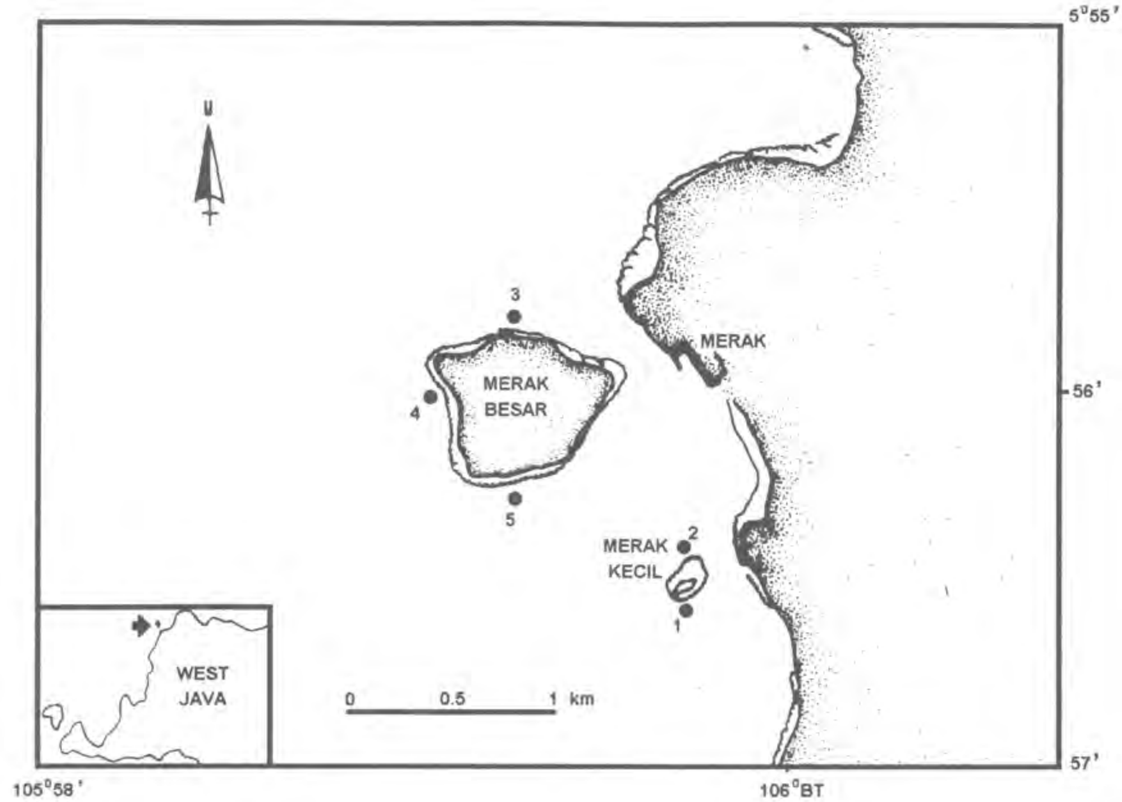


Figure 1. Map of Merak Islands, showing sampling sites.

In addition to general observations, an attempt was also made to assess soft coral conditions quantitatively. The method used was a combination of line and belt transects. A location on a reef was selected, then a marked line and belt were laid from the shore to the end of the reef in deep water. Along the 10m line, a belt transect was made parallel to the shore at 1m intervals. The total line and belt transect area were grouped vertically into five groups, based on the depth distribution. The first was for colonies distributed at the reef flat between a depth of 0.5 -1m, the second between 1-3m, the third between 3-7m in the upper reef slope, and the forth between 7-10m, and finally colonies from a 10m depth to the end of the reef. The diameter and profile of each colony was recorded, as well as the zonation of soft corals. The sizes of the colonies were also divided into three groups, ranging between 1-50cm, from 50-100cm, and those that were more than 100cm. This study was mainly carried out using SCUBA. Soft coral samples were preserved in 70% alkohol for identification, by the observation of scleritesunder the microscope.

The spatial distribution of soft corals and the interactions between depth and colony size were analyzed using correspondence analysis (Legendre & Legendre,1983; Digby & Kempton,1987; Bengen *et al.*, 1992). The results are presented in the form of graphs (Figures 2 and 3). Because of the difficulties associated with octocoral systematics at the specific level, some sinularid species were not identified and simply noted as spp. This study also included gorgonians and pennatulids.

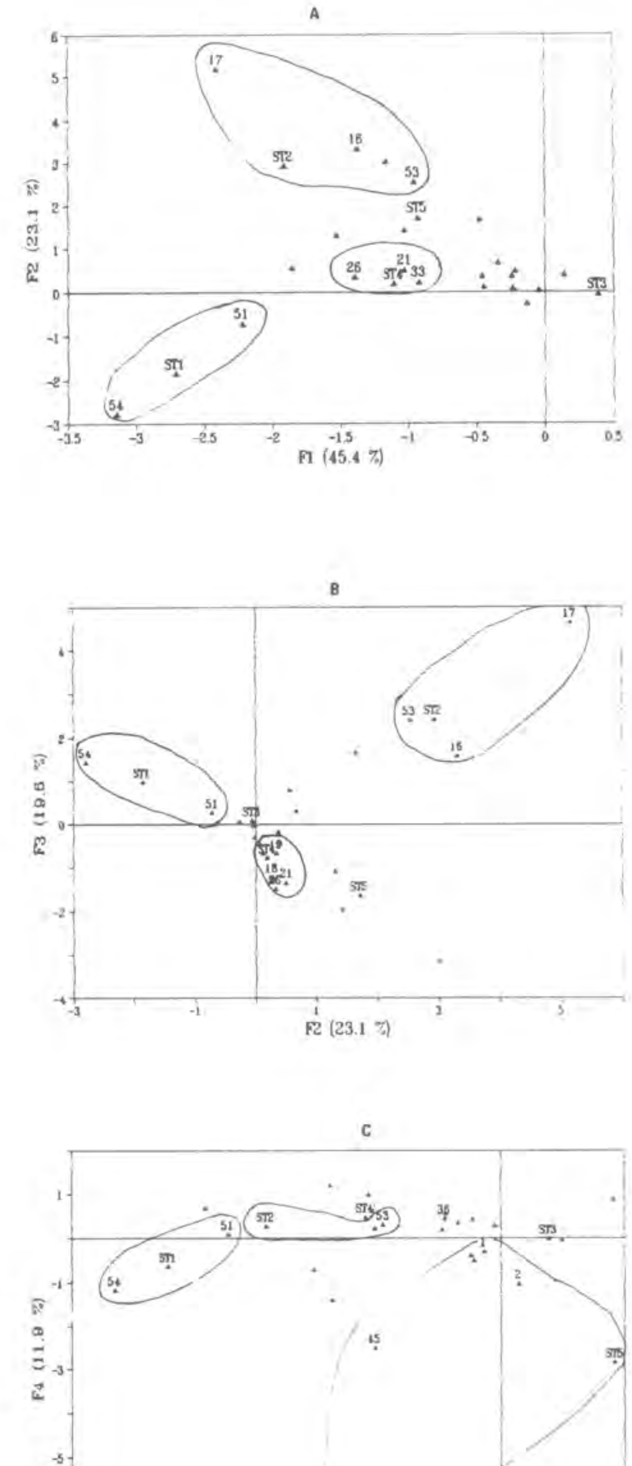
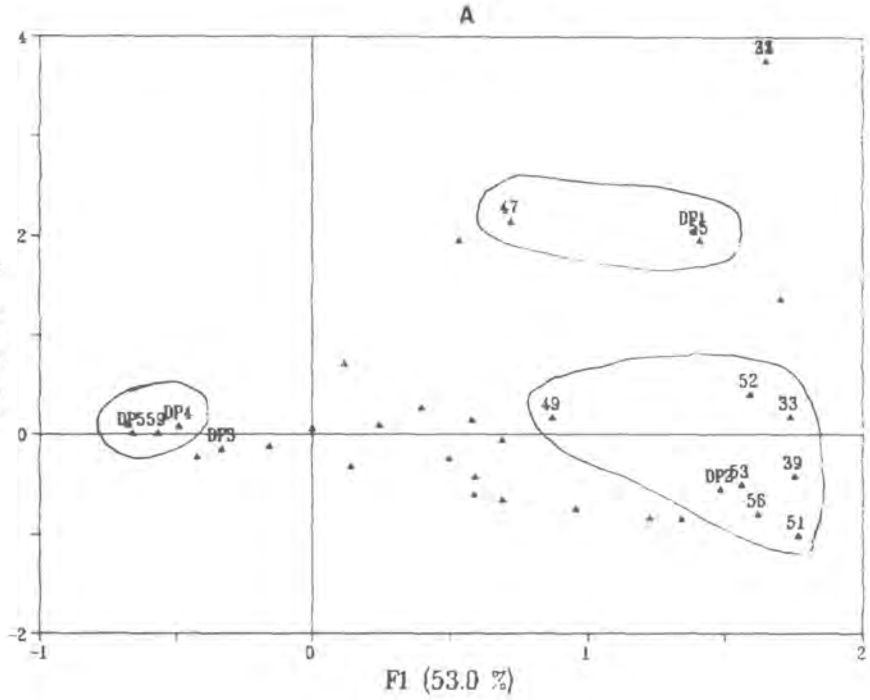


Figure 2. **Graphic results for correspondence analysis on site-species interaction. A) axes 1 and axes 2 (F1 x F2); B) axes 2 and axes 3 (F2 x F3); c) axes 1 and axes 4 (F1 x F4).**



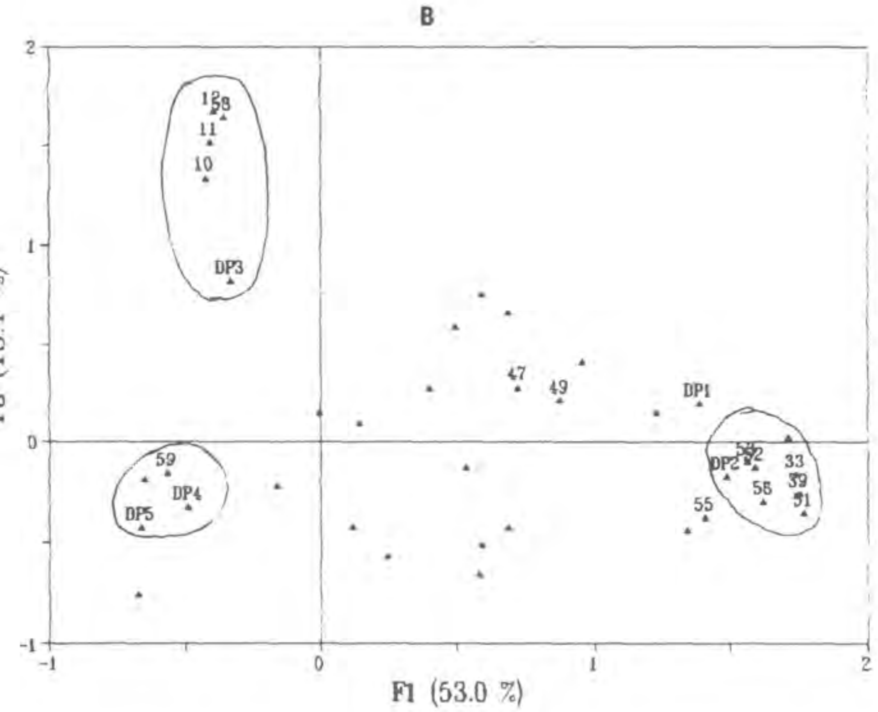


Figure 3. Graphic results for correspondence analysis on sites-depth interaction. A) axes 1 and 2 (F1 x F2); B) axes 1 and axes 3 (F1 x F3).

RESULTS

A total of 34 genera belonging to six families of the order Alcyonacea (excluding gorgonians and pennatulids) were found. The list of species is presented in Table 1. The greatest number of species and also the best colony growth were found in sites 3 and 4. Results for the lower reef slopes were different from observations of the upper reef slopes and reef flats in terms of growth form, relief and species composition. *Sinularia querciformis* was the most common species found in deep waters, followed by *Sarcophyton trocheliophorum* at the upper slope. *Sinularia polydactyla* successfully colonized the depths between 1-7 m. The soft coral cover of each individual species was low at sites 1 and 2. At site 1, the zonation pattern was not as clear as that observed at the other sites. The soft coral cover of each individual species was low, and *Xenia* sp. was observed with colony diameter varying between 3-50cm. *Sinularia flexibilis* was recorded at site 3, found from a depth of 7m up to 1m on the reef flat, with the biggest colony occurring at 4m.

The results of the correspondence analysis show that the main information is centered in axes 1, 2 and 3 (Table 1). Graphical representation of the first and the second axes (F1 X F2) in Figure 2A shows that there are three groups of species-site inter-relationships. The first group represents the inter-relationships at site 1 (ST1) with *Hicksonia kollikeri* (54) and *Xenia* sp. (51), the second group at site 2 (ST2) with *Sinularia* sp.1 (16,17-big-sized) and big colonies of *Xenia* sp.(53). The last group indicates the inter-relationships at site 4 (ST4) with *Sinularia* sp.10 (33), *Sinularia* sp.1 (18), *Sinularia* sp.3 (21) and *Sinularia* sp.6 (26). In Figure 2B (F2 X F3), there are also three groups, the first and the second similar to that described in Figure 2A. The last group represents the inter-relationships at site 4 (ST4) with *Sinularia* sp.1 (18), sp.3 (21), and *Sinularia* sp.2 (19). The inter-relationships at site 5 (ST5) with *Sinularia polydactyla* (1,2),*Cladiella ceylonicum* (45) and *Clavularia* sp. (47) are presented in Figure 2C (F1 X F4).

Table 1. Eigenvalues (variances on principal axes) and contribution to total variance of species-sites (A), illustrating the species-depth inter-relationships of soft corals in Merak Islands.

	Axes 1	Axes 2	Axes 3	Axes 4
A.				
Eigenvalues	0.6306	0.3210	0.2713	0.1647
Contribution to total variance	45.4%	23.1%	19.60%	11.9%
B				
Eigenvalues	0.7058	0.2949	0.2416	0.0900
Contribution to total variance	53.0%	22.1%	18.1%	6.8%

Figure 3A represents the species-depth inter-relationship of axes 1 and 2 (F1 X F2). There are three groups here, namely, depth 1 (DP1) with *Xenia* sp. ((55) and *Cladiella ceylonicum* (47), depth 2 (DP2) with *Xenia* sp. (56), *Clavularia* sp. (51,52,53),*Sinularia* sp.10 (33), *Sarcophytum trocheliophorum* (39) and *Cladiella* sp. (49), and depths 4 (DP4) and 5 (DP5) with gorgonians (59). F1 X F3 shown in Figure 3B indicates that the relationship among groups is similar to the second and the third groups of Figure 3A. The other group identified here shows a close relationship at depth 3 (DP3) with *Lithophyton arboreum* (58), *Sinularia fungoides* (10) and *Sinularia lochmodes* (11,12 big-sized). The species-station and species-depth distribution is listed in the appendices.

DISCUSSION

This study indicates the existance of some sort of spatial pattern in the distribution of soft corals at Merak Islands. The most important of the environmental factors affecting the distribution and abundance of soft corals is the interaction of biological and physical factors. In shallow waters, wave action is a limiting factor for the colonization of soft corals (Tursch & Tursch, 1982). This study indicates that the coral reefs of Merak Islands contain a diverse alcyonacean fauna.

Another factor affecting the distribution of shallow water soft corals is substratum type. Encrusting *Sinularia* spp. are usually abundant on dead corals and on a rocky bottom substratum. They need large spaces and a stable substratum to hold on to (Dinesen, 1983; Satapoomin & Sudara, 1991). The shallow water species found were scattered over the reef flat at site 3. Also in shallow waters where the substratum is mud-sand and broken corals, the soft coral population is dominated by *Xenia* sp. and *Hicksonia kollikeri* (site 1; Figure 3A). *Sinularia polydactyla* dominated deeper areas down to a depth of 10m. The substratum at this depth is covered by sand-silt which is known to be preferred by this species, and the species is also able to survive in waters with low clarity (Tursch & Tursch,1982; Benayahu, 1985; Manuputty,1992b). This species was however not shown graphically as a group because of its scattered distribution from a depth of 1 to 10m. It was also observed that steep reef slopes were dominated by *Sinularia querciformis* and *Sarcophyton trocheliophorum*.

It is known that many soft corals produce toxic compounds (Tursch *et al.*, 1978; Coll *et al.*,1980), and these compounds can be released into the water column. This strategy makes soft corals good competitors for space against hard corals. Coll *et al.* (1982a) isolated toxic terpenes in the sea water surrounding *Sinularia flexibilis*, and noted growth inhibition and mortality of the hard coral *Pavona cactus* in the vicinity of this soft coral. *Sinularia flexibilis* was recorded in this study to stand in big colonies from depths of between 1 and 7m. In general, this species is recognized as a deep water soft coral and can be found at a depth of more than 10m, and where the water is turbid. No hard coral colonies were observed growing in the vicinity of this species of soft coral.

Groups of species-sites and species-depths as shown in Figures 2 and 3 indicate a close relationship between soft corals species and their environment. The correspondence analysis used in this study indicated that the variation seen could point to differences in distribution observed. In general, hard corals occurred mainly in the region of highest water transparency, and were distributed from the low water tide level to a maximum depth of 4 - 5m. The lowest hard coral cover was recorded at a site nearest the mainland (Chua & Chou, 1991). This is contrary to soft coral cover observed in Seribu Islands, where the highest soft coral cover was recorded at the site nearest the mainland, and where the water clarity was low (Manuputty, 1992b). Water clarity surrounding Merak Islands was between 2-4m. This may be due in part to the proximity of this location to the busy shipping lanes for ferrys. Waves in the wake of passing ferrys at half hour freqencies probably increase the turbidity of the water in this area.

ACKNOWLEDGEMENTS

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REFERENCES

Benayahu, Y., 1985. Faunastic composition and patterns in the distribution of soft corals (Octocorallia, Alcyonacea) along the coral reefs of Sinai Peninsula. Proc. 5th Int. Coral Reef Congr., Tahiti 6.

Bengen, D.G., A. Belaud & P. Lim, 1992. Structure et typology ichtyenne de trois bras morts de la Garonne. Annls. Limnol. 28(1) : 35-56.

Chua, C.Y.Y. & L.M. Chou, 1991. The sclerectinian community of southern island's reef,Singapore. Proc. Regional Symp. on Living Coastal Resources in Coastal Areas, Manila, pp.41- 46.

Coll, J.C., B.F. Bowdwen, & S.J. Mitchell, 1980. Marine natural products chemistry at the James Cook University of North Queensland. Chem. Aust. 47: 259-263.

Coll, J.C., B.F. Bowden, D.M. Tapiolas & W.C. Dunlap, 1982a. In situ isolation of allelochemicals released from soft corals (Coelenterata, Octocorallia): a totally submersible apparatus. J. Exp. Mar. Biol. Ecol. 60: 293-299.

Digby, P.G.N. & R.A. Kempton, 1987. Multivariate Analysis of Ecological Communities. Chapman & Hal Ltd. London, 206 pp.

Dinesen, Z.D., 1983. Patterns in the distribution of soft corals across the central Great Barrier Reef. Coral Reefs 1: 229-236.

Legendre, L. & P. Legendre, 1983. Numerical Ecology. Elsevier Scientific Publishing Company. New York, 419 pp.

Manuputty, A.E.W., 1989. Karang lunak marga *Lobophytum* von Marenzeller dari selatan Pulau Pari, Pulau-Pulau Seribu. Makalah dibacakan dalam Seminar Nasional Biologi ke IX, Padang 10-12 Juli 1989.

Manuputty, A.E.W., 1992a. Sebaran, keanekaragaman dan komposisi jenis karang lunak di Teluk Jakarta. Pros.Seminar Ekologi Laut dan Pesisir I, Jakarta, hal: 287-295.

Manuputty, A.E.W., 1992b. The soft coral cover in the Seribu Islands. Proc. 3rd. Asean Science and Technology Week. Marine Science: Living Coastal Resources, 6: 87-94.

Satapoomin, U. & S. Sudara, 1991. Preliminary survey of soft corals in the Gulf of Thailand. Proc. Regional Symp. on Living Resources in Coastal Areas, Manila, pp. 27-31.

Soekarno, N. Naamin & M. Hutomo, 1986. The status of coral reefs in Indonesia. Proc. MAB-COMAR Reg. Workshop on Coral Reef Ecosystem: Their Management Practices and Research/Training Needs, Bogor,Indonesia, pp. 24-33.

Tursch, B., J.C. Braekman, D. Daloze & M. Kaisin, 1978. Terpenoids from Coelenterates.In: Scheuer P.J. (ed.) Marine Natural Products: Chemical and Biological Perspectives, Academic Press,New York, 2: 247-296.

Tursch, B., & A.Tursch, 1982. The soft coral community on a sheltered reef quadrate at Laing Island (Papua New Guinea). Mar. Biol. 68: 321-332.

Appendix 1. List of abundance of soft coral genera / species at each site

Genus/Species/Sizes		Sites				
		1	2	3	4	5
Sinularia polydactylla	1	6	-	47	6	2
	2	-	-	16	1	3
	3	-	-	1	1	-
Sinularia querciformis	1	-	-	41	5	-
	2	-	-	5	-	-
Sinularia flexibilis	1	-	-	9	1	-
	2	-	-	9	-	-
	3	-	-	5	-	-
Sinularia fungoides	1	-	-	5	2	-
Sinularia lochmodes	1	-	-	22	-	-
	2	-	-	7	-	-
	3	-	-	1	-	-
Sinularia gravis	1	-	-	1	-	-
Sinularia dura	1	-	-	2	-	-
Sinularia sp.1	1	1	3	-	18	6
	2	-	2	1	-	1
	3	-	2	-	-	-
Sinularia sp.2	1	-	-	1	5	-
Sinularia sp.3	1	-	-	6	3	-
	3	-	-	2	-	-
Sinularia sp.4	1	-	-	2	8	1
	2	-	-	2	-	-
	3	-	-	1	-	-
Sinularia sp.5	1	-	-	1	-	-
	2	-	-	2	-	-
Sinularia sp.6	1	-	-	-	4	-
Sinularia sp.7	1	-	1	-	-	-
	2	-	-	1	-	-
Sinularia sp.8	1	-	-	2	-	-
	2	-	-	1	-	-
Sinularia sp.9	1	-	-	1	-	-
Sinularia sp.10	1	-	-	-	6	-
Sinularia sp.11	1	-	-	2	6	-
Sinularia sp.12	1	-	-	-	2	-
Sarcophyton trocheliophorum	1	1	5	42	29	-
	2	-	-	6	2	-
Sarcophyton sp.	1	-	-	-	2	-
Lobophytum strictum	1	-	1	5	2	-
	2	-	1	-	-	-

Appendix 1. (Cont.)

Genus/Species/Sizes		Sites				
		1	2	3	4	5
Lobophytum pauciflorum	1	-	2	-	-	-
	3	-	-	1	-	-
Lobophytum crassum	1	-	1	2	-	-
Lobophytum sp.	1	-	-	-	4	-
Cladiella ceylonicum	1	-	-	1	3	3
	2	-	-	1	-	-
Cladiella sp.	1	-	-	-	-	1
Clavularia sp.	1	-	1	28	11	5
	2	-	-	1	7	-
	3	-	-	4	-	-
Xenia sp.	1	32	6	1	44	-
	2	2	2	1	4	-
	3	-	2	2	-	-
Hicksonia kollikeri	1	13	-	-	2	-
	2	1	-	-	-	-
Litophyton arboreum	1	-	-	56	35	-
	2	-	-	4	2	-
Dendronephthya sp.	1	-	-	-	1	-
Junceilla sp.	1	-	-	814	22	-
Gorgonian	1	-	-	96	2	-

Legend : 1 - size of colony (1 - 50cm)
2 - size of colony (50 - 100cm)
3 - size of colony (> 100cm)

Appendix 2. List of abundance of soft coral genera / species at each depth

Genus/Species/Sizes		Depth				
		1	2	3	4	5
Sinularia polydactylla	1	4	22	28	7	-
	2	3	5	6	6	-
	3	-	1	1	-	-
Sinularia querciformis	1	-	-	-	25	21
	2	-	-	-	5	-
Sinularia flexibilis	1	-	5	3	-	-
	2	-	5	6	-	-
	3	-	5	-	-	-
Sinularia fungoides	1	-	-	6	1	-
Sinularia lochmodes	1	-	-	29	2	-
	2	-	-	7	-	-
	3	1	-	-	-	-
Sinularia gravis	1	-	-	1	-	-
Sinularia dura	1	-	-	-	2	-
Sinularia sp.1	1	5	3	-	18	-
	2	1	-	-	-	1
	3	-	1	-	-	-
Sinularia sp.2	1	-	5	-	-	1
Sinularia sp.3	1	1	3	-	1	5
	3	-	2	-	-	-
Sinularia sp.4	1	1	5	-	5	-
	2	2	-	-	-	-
	3	1	-	-	-	-
Sinularia sp.5	1	-	1	-	1	-
	2	-	-	-	1	-
Sinularia sp.6	1	-	-	-	4	-
Sinularia sp.7	1	1	-	-	-	-
	2	-	-	-	1	-
Sinularia sp.8	1	-	2	-	-	-
	2	1	-	-	-	-
Sinularia sp.9	1	2	-	-	-	-
Sinularia sp.10	1	-	6	-	-	-
Sinularia sp.11	1	2	6	-	-	-
Sinularia sp.12	1	2	-	-	-	-
Sarcophyton trocheliophorum	1	6	15	27	35	7
	2	1	1	1	4	-
Sarcophyton sp.	1	-	2	-	-	-
Lobophytum strictum	1	1	7	-	-	-
	2	-	1	-	-	-

Appendix 2. (Cont.)

Genus/Species/Sizes		Sites				
		1	2	3	4	5
Lobophytum pauciflorum	1	-	2	-	-	-
	3	1	-	-	-	-
Lobophytum crassum	1	2	1	-	-	-
Lobophytum sp.	1	-	4	-	-	-
Cladiella ceylonicum	1	4	-	1	2	-
	2	1	-	-	-	-
Cladiella sp.	1	1	-	-	-	-
Clavularia sp.	1	8	20	11	7	-
	2	-	2	3	3	-
	3	-	4	-	-	-
Xenia sp.	1	23	53	1	4	-
	2	1	9	1	-	-
	3	-	4	-	-	-
Hicksonia kollikeri	1	9	4	2	-	-
	2	1	-	-	-	-
Litophyton arboreum	1	3	86	2	4	-
	2	-	-	3	1	-
Dendronephthya sp.	1	-	1	-	-	-
Junceilla sp.	1	-	6	174	385	171
Gorgonian	1	-	-	27	20	59

Legend : 1 - size of colony (1-50cm)
2 - size of colony (50-100cm)
3 - size of colony (> 100cm)
Depth 1 : < 1m
Depth 2 : 1-3m
Depth 3 : 3-7m
Depth 4 : 7-10m
Depth 5 : > 10m

GROWTH AND POPULATION DYNAMICS OF THE SLIPMOUTH *LEIOGNATHUS BINDUS* IN BRUNEI DARUSSALAM

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ABSTRACT

The growth and population dynamics of *Leiognathus bindus* in the waters of Brunei Darussalam were investigated based on trawl samples obtained between July 1989 and June 1990. The Von Bertalanffy Growth Function for the species is given as: $L_t = 11.5\ (1\text{-}e^{-0.85\ (t + 0.25)})$. The species has been only lightly exploited to date, and there is scope for an increase in Exploitation Rate to between 0.35 and 0.45.

INTRODUCTION

Fisheries

In terms of contribution to the Gross Domestic Product of the Brunei National Economy, the percentage from fisheries is very low, in particular when compared with the contribution of the giant oil and gas industry. Against this apparent limitation however, one should note the importance of fish and fisheries in the diet and culture of the population. Fish is a very popular item in the diet of Bruneians. In fact, the per capita consumption of 40kg/annum is among the highest in the region.

Besides this, Brunei has had a long tradition of fishing. Records of the early Chronicler, Pigafetta mention the presence of fishing boats in Brunei in 1521 (Nicholl, 1975). In the past, fishing was a very important occupation. At present however, with the availability of comfortable land based vocations, fishing as a livelihood for Bruneians has dwindled in importance.

However, it should be emphasized that fishing remains a popular recreational pursuit of the Bruneian, as evidenced by the number of part-time fishermen (those who hold regular Public or Private Sector vocations but engage in fishing during week-ends, holidays).

Fishing Gear

A variety of fishing gear is operated in Brunei. Gear may be classified as artisanal or industrial, the latter category comprising only trawlers and purse-seiners at present. Artisanal gear may be divided into the categories of traps, hooks and nets.

The majority of the fishing gears operated in Brunei would be classified as artisanal. However, one needs to exercise caution in the use of the term 'artisanal' in Brunei, because whilst the fishing methods may be traditional, many of the fishing gear have themselves undergone changes in configuration and now modern synthetic materials are employed in their construction. Hence the observation by Tubb (1964) that the fishing gear has undergone little or no modification other than the use of nylon for drift, drag and cast nets and the use of wire mesh for traps would not be strictly true today.

Fishing Grounds

The fishing grounds for the artisanal fishermen is largely within the near shore coastal waters. Some fishermen who operate traps (bubu) and longline have operations which are further out to sea (Beales *et al*, 1982), but nevertheless generally within approximately 20 miles from shore.

The Brunei River estuarine system is also an important area for fishing, especially for shrimp. Shrimp is also caught seasonally off the coast in the South China Sea especially near Berakas and Jerudong.

Trawlers and Purse-Seiners, being larger vessels and equipped with inboard engines are able to go further out to sea. At present these vessels generally do not go beyond 20 nautical miles off the coast. This is because fish productivity is generally greater in areas nearer the coast due to several factors, including nutrient enrichment from the rivers. In addition, as most of these vessels operate on a daily basis, ie leaving and returning to port within 24 hours, proximity of the fishing area to the fishing port facilitates their mode of fishing operation.

Khoo *et al.* (1987) have provided detailed maps of the fishing areas for the various types of fishing gear employed in Brunei Darussalam.

The Slipmouth Fishery in Brunei

Slipmouths (Leiognathidae) are found in abundance in the coastal waters of Brunei (Beales *et al.*, 1982). Leiognathids are a not a highly preferred food fish in Brunei, but it must be emphasised that this is not true for all species. The species commonly found in the commercial markets are *Leiognathus splendens* and *Leiognathus equulus* which are the bigger members of the Family. It is also worth mentioning that *Leiognathus splendens* caught in a juvenile or sub-adult stage with the characteristic slime is very popular in Brunei for a local food preparation. The other species of Leiognathids are generally not marketable as food fish. The low marketability of these latter species has not posed a problem in Brunei as yet, because catches have not been substantial. With the expansion of the trawling fleet however, it is anticipated that the volume of Leiognathid landed would increase. Serious attention would then have to be paid as to their effective usage.

If the production potentially available from trawlers were included, it is suggested that local production would be more than sufficient to meet local demand. Trawlers however have been of very recent introduction in Brunei, having been actively initiated only in 1984, and at present their contribution to local production is not very significant. Besides this, in view of the difficulty of breaking into the market with its limited demand for Leiognathids, the trawler fishermen have generally tended to discard the smaller Leiognathids at sea.

There have not been many studies on the Leiognathids in Brunei Darussalam. In Brunei, Lindley (1982) conducted cod-end escapements from demersal trawls with special reference to Leiognathidae. Beales *et al.* (1982) gave abundance patterns, catch-rates and biomass estimates for the Leiognathids with a comment as to their significance in off-shore demersal fisheries development. Khoo *et al.* (1987) reported on the apparent relationship between Leiognathid and Lutjanid catches. However, studies on the biology of Leiognathid species in Brunei are few.

MATERIALS AND METHODS

This study was part of a wider survey on the demersal resources of Brunei Darussalam conducted between July 1989 and June 1990. Samples of the fish were collected during cruises over the survey period.

Survey Area

The survey area stretches from the coast to the 100 fathom (200m) depth isobath, though in practice, the areas within three nautical miles from the coast were avoided to take account of navigational safety. The trawl stations are shown in Fig 1. As indicated in this figure, the trawl stations were spread across the area to account for depth stratifications. The majority of Stations were established in depths less than 50 metres as these areas were known to have higher fish densities than areas with greater depths (Table 1).

The survey area was divided into two strata, stratum 1 from depths approximately 50 metres and less and stratum 2 from 50 metres to the 100 metre isobath, corresponding broadly to the stratification employed by Beales *et al.* (1982).

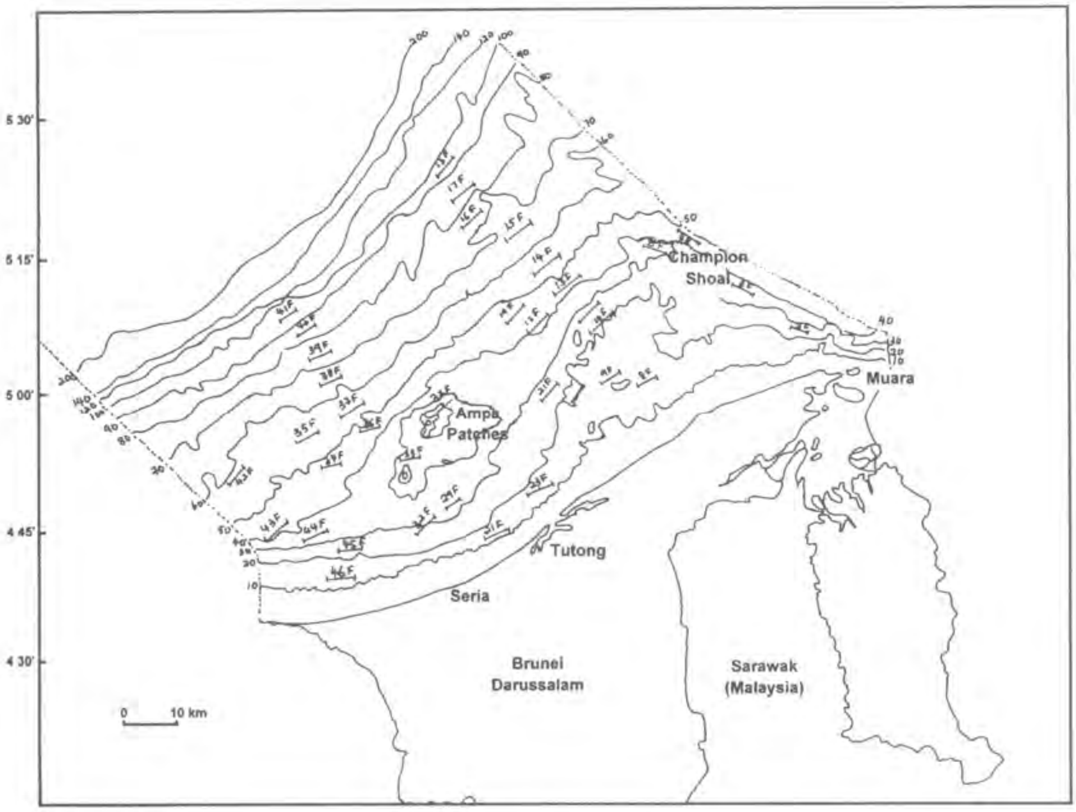

Figure 1. Trawl survey stations, 1989-1990 survey.

Table 1. **Trawl survey stations from 1980-90. Survey by depth and distribution.**

Depth Range (metre)	Trawl Station Number
10 - 20	7, 8, 9, 10, 22, 23
20 - 30	2, 6, 11, 21, 30, 27
30 - 40	1, 3, 5, 12, 20, 25, 26, 29, 32, 33, 34
40 - 50	4, 13, 19, 36
50 - 60	14, 37
60 - 70	15, 38
70 - 80	16, 39
80 - 90	17, 40
90 - 100	18, 41

Survey Period

The survey was conducted over a period of one year between July 1989 and June 1990 as shown in Table 2.

Table 2. **1989 - 90 trawl stations by periods**

Cruise	Dates	Number of valid hauls		
		Stratum 1	Stratum 2	Total
1	1 - 15 July 1989	26	9	35
2	15 - 29 August 1989	14	3	17
3	13 - 26 September 1989	16	4	20
4	29 November - 20 December 1989	11	4	15
5	26 February - 7 March 1990	11	4	15
6	8 - 15 March 1990	12	4	16
7	18 - 28 June 1990	21	4	25
	Total	111	32	143

Survey Vessel and Gear

The Survey was conducted from the Research Vessel `K/P LUMBA-LUMBA'. This is a steel hulled, stern trawler of 15 metre LOA.

Survey Methodology

At each trawl station, trawling was performed for 30 minutes with the vessel travelling at an average speed of three knots. Length frequency analysis was carried out on samples of *Leiognathus bindus*.

Individual specimens were measured for Total Length (TL) defined as the length from the tip of the snout to the tip of the longest caudal fin ray (See Fig. 2). Measurements were taken in centimeters using a class interval of 1cm.

Treatment of Length Frequency and Derivation of Parameters

Length Frequency

ELEFAN 1.1 (Electronic Length Frequency Analysis), a computer program for the analysis of fish length frequencies was utilised for the treatment and analysis of length frequency data. This program allows for a more objective treatment of the data compared to earlier methods which tended to be influenced by the subjective judgement of the worker. Further details of this programme can be obtained from Gayanilo *et al.* (1989).

Data Entry

The length-frequency data was entered into the Data Storage Programme of ELEFAN, ie. ELEFAN 0. ELEFAN 0 creates and modifies length-frequency data files.

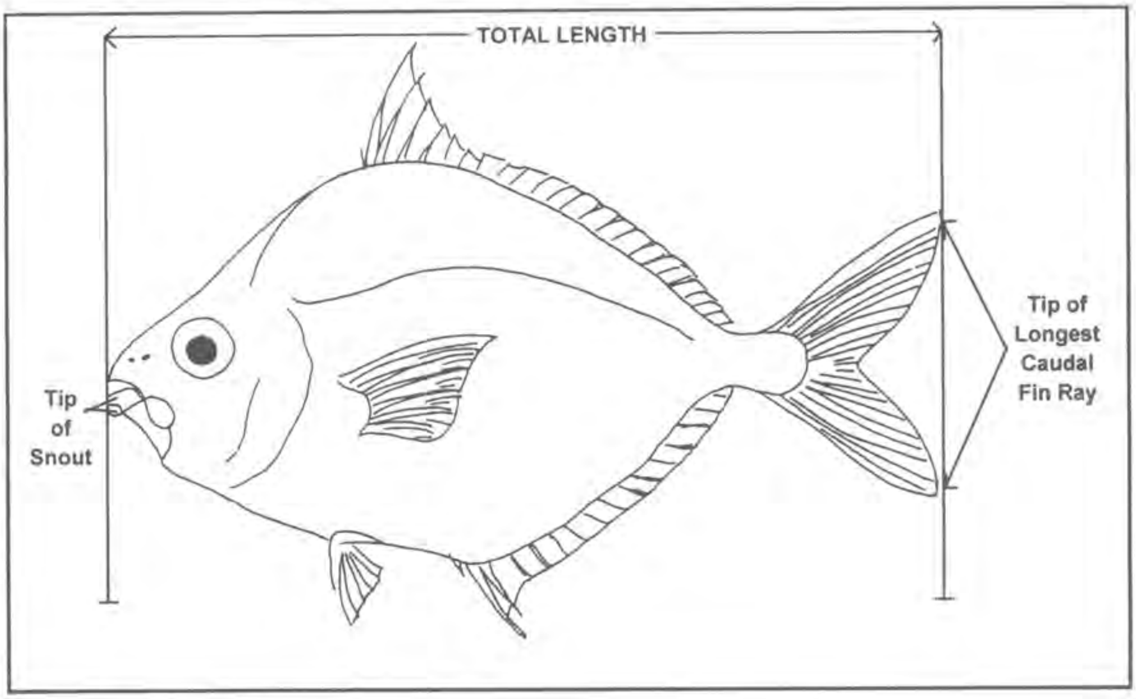

Figure 2. Total length measurement (TL)

Initial Estimates

An initial value of L was obtained from the Wetherall method in ELEFAN II. In addition, a literature search was also undertaken to extract seed population parameters of the species of *Leiognathus* being studied from adjacent waters.

Estimation of L_{∞}, K

Using the initial estimates of available population parameters, either from the Wetherall Method or from other sources as seed values, the data was run through ELEFAN I to obtain growth curves from the restructured data. Restructuring in ELEFAN is by means of a Running Average method resulting in a series of peaks and troughs. The best fit to the length-frequency data is that which connects the most number of peaks.

Estimates of Z, M, F, E

The growth parameters obtained from the ELEFAN I routine were used as inputs into ELEFAN II to obtain Z (Total Mortality Rate) using the length converted catch curve routine. Correction for non-linearity of the growth model and within length class mortality is afforded by the iteration procedure of Sparre.

M (Natural Mortality Rate) was estimated using the empirical formula (Pauly, 1980).

$\text{Log}_{10}M = -0.0066 - 0.279\log_{10}L + 0.6543\log_{10}K + 0.4634$

$\log_{10}T$. T was set equal to 28°C. Once Z was estimated from the catch curve, and M from Pauly's equation, F (Fishing Mortality Rate) was obtained from the relationship, F = Z - M.

Exploitation rate E was then derived from the relationship,

$$E = \frac{F}{F + M} = \frac{F}{Z}$$

Resultant Curve, Probability of Capture

Resultant Curves, being the net effect of mesh selection and recruitment was derived from the catch curve. Projection of the descending limb if the catch curve backwards will produce a series of expected values corresponding to the actual or observed values. The ratios of observed to expected values, i.e probabilities of capture at stated length intervals can then be used to elaborate an ogive.

The probabilities of capture estimated by ELEFAN II were used to correct the original length-frequency files in ELEFAN 0 and subsequently used to attempt obtaining improved growth parameter estimates in ELEFAN I. Where this exercise did not lead to improved growth parameter values eg. a lower value of L_∞, the original values obtained were used.

L_{50} values were calculated by ELEFAN II. L_{50} is the length at which 50% of the fish entering the trawl are retained or is the mean length at first capture (Lc). Lc can be taken to be proportional to the cod end mesh size, ie. Lc = 'a' x mesh size, where 'a' is a proportionality constant and is termed the Selection Factor (SF).

Recruitment Pattern

Recruitment patterns were derived using ELEFAN II. Where it was not possible to derive sensible recruitment patterns using ELEFAN II, the Bhattacharya method as provided in the Modal Progression Analysis (MPA) of the ELEFAN programme was used.

Relative Yield Per Recruit and Relative Biomass Per Recruit

Relative Yield Per Recruit and Relative Biomass Per Recruit were computed using the routines in ELEFAN II. Beverton and Holt's (1966) Relative Yield Per Recruit Model as modified by Pauly and Soriano (1986) was used to obtain plots of Relative Yield Per Recruit (Y'/R) and Relative Biomass Per Recruit (B'/R) against Exploitation rate using the probability of capture routine.

RESULTS

DISTRIBUTION

Spatial

Whilst *L. bindus* is also found in shallow waters, it appears to be particularly represented in the deeper waters in an area seemingly in a line off the Tutong River, (Fig 3). The reason for this is not apparent. It may be significant that the 'deeper' waters indicate an absence of the bigger *Leiognathus* species. This may then provide a niche for this smaller sized species to proliferate due to reduced competitive pressure. Further investigation would however be necessary to vertify this.

Temporal (Table 3)

In general, it was observed that the greatest abundances occurred during the transition period after the Northeast (NE) Monsoon. This agrees with the observation by Khoo et al (1987) who suggested that churning and turbidity associated with the NE Monsoon have a positive effect on recruitment processes, and hence subsequent increased abundance of fishes.

Table 3. CPUE (kg/hr) by monsoon regime

Species	Monsoon regime			
	SW	TP_1	NE	TP_2
L. bindus	7.39	6.42	5.62	41.02

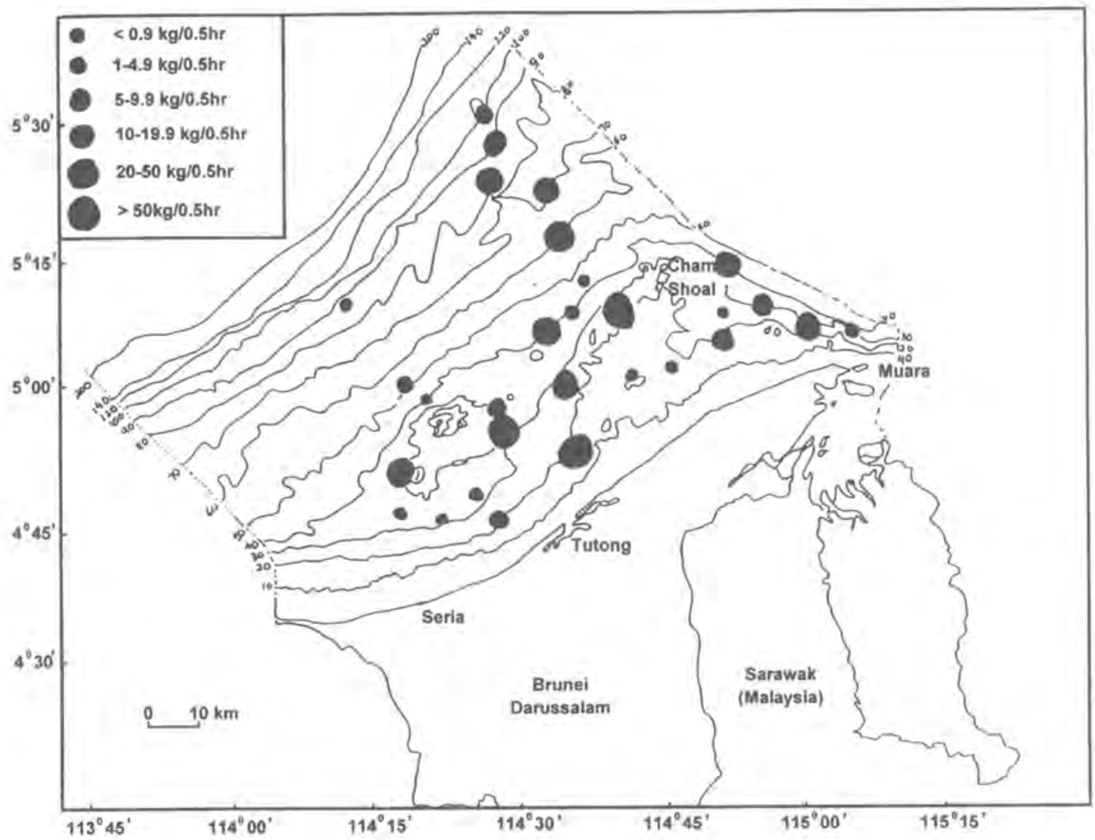

Figure 3. Distribution of *Leiognathus bindus* (kg/0.5hr) by depth

Population Parameters (Table 4)

Use of L of 11.50 and K of 0.85 provided a good fit to the length frequencies.

Attempts to correct for the effects of gear selection and/or incomplete recruitment did not lead to improved values of L or K. Thus the values mentioned above were used for subsequent analysis. The values obtained by other authors are shown in Table 4.

The Von Bertalanffy Growth Function for *Leiognathus bindus* obtained was found to be:

$$L_t = 11.5\ (1-e^{-0.85\ (t + 0.25)})$$

t_o was obtained by backward projection of the Growth Curve. In Fig. 4, t_o derived in this manner was -0.25 which is in agreement with the value obtained from the Pauly (1979) formula. $Log_{10}\ (t_o) = -0.3922 - 0.2752\ Log_{10}\ L - 1.038\ Log_{10}K$.

Longevity of the fish estimated from $tmax = t_o + 3/K$ is approximately 3.3 years at which time it is about 11^{K}cm in total length.

Using the Catch Curve Method to obtain values of Total mortality, Z gave a value of 2.70. Natural Mortality, M obtained by using a temperature of 28°C in Pauly's equation was found to be 2.10, hence F, by subtraction of M from Z is 0.60.

Exploitation Rate (E) calculated from these values of F and Z, i.e., $\frac{E}{F+M}$ or $\frac{E}{Z}$ was 0.22.

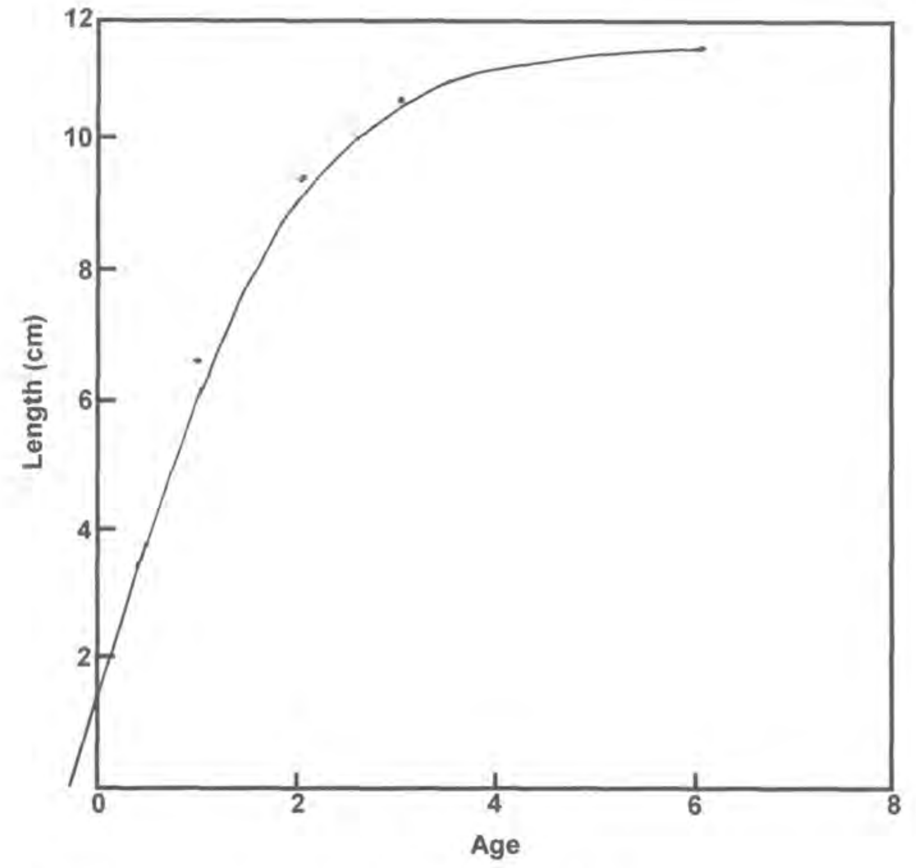

Figure 4. Growth curve of *Leiognathus bindus*

Table 4. Summary of population parameters

Species	L	K	ARP	0'	F	M	Z	E	t_0
Leiognathus bindus	11.5	0.85	2	2.05	0.60	2.10	2.70	0.22	-0.25

The mean length at first capture (L_{50}) was calculated to be 7.19cm at an age over 1.1 years. There is a very narrow band of probabilities of capture between L_{25} and L_{75} ie. between 6.58 cm to 7.66 cm. Fish less than 5.0 cm have a very low probability of capture. Barring the clogging effects in the trawl, fish smaller than 5.0cm are able to escape through the 3.8cm meshes of the cod-end. Recruitment pattern could not be obtained from the routine in ELEFAN II. Hence the Bhattacharya Method was employed to derive a recruitment pattern for *Leiognathus bindus*. The result of this latter exercise showed that there are two recruitment pulses, one of a greater intensity than the other.

Relative Yield Per Recruit was maximised at an Exploitation Level of 0.5956, and $E_{0.1}$ was at 0.5663.

DISCUSSION

The value of L_∞ obtained in Brunei is in fairly good agreement with the values obtained by various authors as shown in Table 5.

Table 5. Population parameter values of *Leiognathus bindus*

References	L_∞	K	ϕ'	ARP	Area
Ingles and Pauly (1984)	10.3	1.25	2.12	2	Manila Bay (1957 - 58)
-ibid-	8.2	1.25	1.92	2	Manila Bay
-ibid-	8.2	1.30	1.93	1	Manila Bay
Pauly (1978) from Tiews *et al.* (1965)					
February brood	11.3	2.06	2.41	-	Manila Bay
May brood	10.5	2.24	2.39	-	- do -
September brood	10.2	2.63	2.44	-	- do -
December brood	10.3	2.58	2.43	-	- do -
March brood	9.5	2.42	2.34	-	- do -
Corpuz *et al.* (1985)	13.6	1.03	2.27	2	Ragay Gulf (1981)
-ibid-	13.2	0.96	2.24	2	Burias Sea
-ibid-	13.75	0.88	2.22	2	Samar Sea
Silvestre (1986)	12.1	0.98	2.15	2	Samar Sea
Pauly (1978) from Balan (1967)	12.7	2.04	2.51	-	Calicut (India)

The K value of 0.75 shown by *Leiognathus bindus* in Brunei Darussalam appears to be low compared to many of the other authors in Table 5. However, it is in close agreement with the values obtained by Corpuz *et al.* (1985) in Burias Pass and Samar Sea as well as that of Silvestre (1986) in the Samar Sea.

The very high K values obtained by the other workers do not seem to be representative of the growth rate of *Leiognathus bindus* in Brunei.

Total Mortality (Z) estimated from the catch curve routine was 2.70 and with a Natural Mortality value 'M' of 2.10 estimated using Pauly's empirical equation leads to a Fishing Mortality (F) of 0.60. Silvestre (1986) derived an M value of 2.21 for *Leiognathus bindus* in the Samar Sea and this corresponds to the figure obtained in Brunei.

Using the above mentioned mortality values, an Exploitation Rate 'E' of 0.22 was obtained for *Leiognathus bindus* in Brunei. It is obvious that this species is only lightly exploited at present.

Two annual recruitment pulses were observed with one more pronounced than the other. As shown in Table 5, this condition is reflected in the observations of the other workers too with the exception of Ingles and Pauly (1984) using data from Manila Bay 1960. *Leiognathus bindus* is probably a multiple spawner in Brunei with a major spawning and a minor spawning activity period. Balan (1967) reported the spawning season of *Leiognathus bindus* to be from December to February whilst Murty (1983) working off Kakinada, India described the species to be a fractional spawner, spawning almost throughout the year.

Relative Yield Per Recruit Y/R' is maximised at E = 0.5956, and $E_{0.1}$ is 0.5663. It is not considered advisable to raise exploitation to these levels, and in general, it is best to keep exploitation levels below 0.5.

However, in view of the fact that the current Exploitation Rate is only 0.22, there is a faily large room for an increase in exploitation without any immediate danger of growth overfishing. Whilst paying attention to the cautions expressed by Pauly and Soriano (1986), i.e. high M/K values in the tropics with small animals leading to Y/R' maxima at E levels beyond 0.5, a fair compromise would appear to be to increase Exploitation levels to between 0.35 and 0.45. At these levels, Relative Biomass Per Recruit B/R' would be about 49% and 37% of Virgin Biomass, respectively.

This is considered to be tenable advice if one notes that MSY is generated when relative biomass is 50% (Schaefer) or 37% (Fox) of virgin stocks. At the exploitation levels suggested above, there appears to be little danger of the parent stock being reduced so drastically so as to lead to recruitment overfishing.

REFERENCES

Beales, R.W., D.J. Currie & R.H. Lindley, 1982. Investigations into fisheries resources in Brunei.

Beverton, R.J.H. & S.J. Holt, 1966. Manual of methods for fish stock assessment. Part 2. Tables of Yield functions FAO Fish Tech. Pap. (38) Rev.1.

Balan, V., 1967. Biology of the Silver-belly, *Leiognathus bindus* (Val.) of the Calicut Coast. Ind. J. Fish. 10 (1).

Corpuz, A., J. Saeger & V.J. Sambilay, 1985. Population parameters of commercially important fishes in Philippine waters. Tech. Rep. No. 6. Dept. of Marine Fisheries, Univ. of the Philippines.

Gayanilo, F.C., M. Soriano & D. Pauly, 1989. A draft guide to the Complete ELEFAN. ICLARM Software 2.70. International Center for Living Aquatic Resources Management, Philippines.

Ingles, J. & D. Pauly, 1984. An atlas of the growth, mortality and recruitment of Philippines fishes. ICLARM Tech. Rep. 17.

Khoo, H.W., S. Subramaniam & A.H.M. Salleh, 1987. Capture fisheries. In: Chua, T. E., L.M. Chou & M.S.M. Sadorra (eds.), The Coastral Environmental Profile of Brunei Darussalam: Resource Assessment and Management Issues. ICLARM Tech. Rep. 18.

Lindley, R.H., 1982. Cod-end escapement from a demersal trawl with particular reference to the Leiognathidae. In: Beales, R. W., D.J. Currie & R.H. Lindley (eds.), Investigations into Fisheries Resources in Brunei. Brunei Museum Journal No. 5.

Murthy, V.S., 1983. Observations on some aspects of biology of the Silverbelly, *Leiognathus bindus* (Val.) from Kakinada. Indian J. Fish. 30.

Nicholl, R. (ed.), 1975. European sources for the history of the Sultanate of Brunei in the sixteenth century. Brunei Museum, Bandar Seri Begawan, Brunei Darussalam.

Pauly, D. & M.L. Soriano, 1986. Some practical extensions to Beverton and Holt's Relative Yield Per Recruit Model. First Asian Fisheries Forum. Asian Fisheries Society.

Silvestre, G., 1986. Preliminary analysis of the growth, mortality and Yield-Per-Recruit of ten trawl-caught species from the Samar Sea, Philippines. Tech. Rep. Dept. of Marine Fisheries, Univ. of the Philippines.

Tubb, J.A., 1964. Preliminary report on the fisheries industry - State of Brunei. Unpublished Report.

RESPONSES OF BENTHIC MICROALGAL COMMUNITIES TO ELEVATED NITROGEN AND PHOSPHORUS LEVELS: PRELIMINARY RESULTS

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ABSTRACT

Sediment plates were prepared using the upper 1cm layer of sand samples from the Lucero reef flat in the northwestern Philippines. These were acclimated for 7 days in outdoor aquaria under 3 treatments: ambient, nitrogen-elevated, and phosphorus-elevated sea water. A total of three such acclimation experiments were conducted within a period of one year. The sediment plates were subjected to Photosynthesis-Irradiance (P-I) response experiments before and after the acclimations and were sampled for chlorophyll *a* content. N-treated plates had the highest chlorophyll content while the P-plates showed the highest metabolic rates. Statistical tests yielded significant results in the comparison of chl *a* levels while significantly high P-I profiles were detected for the P-treated plates in one batch of experiments. Results suggest N-limitation in sediment communities of the reef flat when considering biomass responses and P-limitation for metabolism. These preliminary results show that nutrient limitation is dependent on the community response parameter being measured.

INTRODUCTION

Apparently bare coral reef sands harbor assemblages of microalgae responsible for the metabolic activity measured in these substrates (see, for example, Daehnick *et al.*, 1992; Yap *et al.*, 1994). These communities typically consist of blue green algae and both motile and attached forms of diatoms inhabiting the interstitial spaces and crevices of sand particles. The ecological significance of these communities can be readily seen in both their role in the trophic hierarchy of the reef (e.g., Blanchard, 1991) and their energetic contribution to overall system productivity (Yap *et al.*, 1994).

The metabolic responses of benthic algal communities can vary with changes in ambient physico-chemical factors that directly influence physiological functions. Factors affecting microphytobenthic productivity typically include biotic activity (e.g., Moriarty *et al.*, 1985 in Hansen *et al.*, 1987; Blanchard, 1991), light (Daehnick *et al.*, 1992; Yap *et al.*, 1994), tidal stages and sun angles (Pinckney & Zingmark, 1991; Metaxas & Lewis, 1992), particle abrasion due to sand movement (Delgado *et al.*, 1991) and nutrients (Nilsson & Sundbäck, 1991; Nilsson *et al.*, 1991).

In tropical environments where light does not seem to be limiting, nutrient availability is probably the most vital factor controlling benthic primary productivity (Sorokin, 1981) since reefs do not normally experience high nutrient conditions typically associated with other high productivity systems. It would be important to determine which nutrient is limiting in these microalgal systems, if any. Two approaches in determining the primary limiting nutrient are considered in this study, namely, measurements of biomass increase as reflected by chlorophyll *a* concentrations and physiological responses in terms of photosynthetic performance across a range of light intensities. Due to the physiological approach of this study, nitrogen and phosphorus, which are soft tissue formers, are considered and not the hard tissue former, silicon.

MATERIALS AND METHODS

Sample collection and preparation

The upper 1cm layer of coralline sand in the Lucero reef flat in Bolinao, Pangasinan (northwestern Philippines) was collected with a flat metal scoop taking great care to avoid loss of any components. A number of samples were pooled together and made up a volume of about 15 l. The collection sites for the sand samples were haphazardly chosen over the reef flat. The sediment samples were transported to the laboratory where they were sieved through a 1 mm mesh to remove both the large grain fractions (to achieve uniformity of grain size) and the macroinfauna from the sediment fraction that was to be used for the experiment. Particles retained on the sieve were immersed for 10 min in a sonic bath to dislodge and resuspend attached microalgae. The suspension was then poured through a 1mm sieve (to remove suspended macrofauna and large particles) and collected for use in the settlement phase of sample preparation.

Sediment plates were prepared by carefully packing the <1mm sand fraction into glass petri dishes (dia = 7cm) up to a depth of about 1cm. The plates were then left for three days in two outdoor settlement tanks containing the sonicated seawater suspension (see above) to allow for the resettlement of detached microalgae (from the larger sediment particles which had been discarded) on the prepared media.

Nutrient acclimations

Six glass aquaria were filled with serially filtered (10, 1, and 0.2 μm) sea water and maintained in an outdoor set-up. The aquaria were sequentially designated as "Control" (CTRL), "Nitrogen" (N) and "Phosphorus" (P) treatments following an interspersed design. There were thus 2 replicate aquaria allocated per treatment. Sediment plates were transferred to the aquaria after the settlement phase. The N aquaria were spiked with $NaNO_3$ up to a final NO_3 concentration of 100μM while the P aquaria were given KH_2PO_4 for a resultant PO_4 concentration of 10μM. The CTRL aquaria, on the other hand, were maintained with the ambient nutrient concentrations. Throughout the acclimation period which lasted 7 days, all tanks were provided with a motor-driven paddle system (described in Montebon, 1993) to homogenize the sea water medium and to minimize the thickness of the diffusive boundary layers over the sediment plates. Actual nutrient concentrations achieved in the treatment aquaria were slightly lower than the calculated levels.

Salinity, temperature, light levels and DO concentrations were periodically monitored in the acclimation aquaria during the experiment to ensure that ambient environmental conditions in the set-up were comparable with *in situ* conditions. Allochthonous material input and intense irradiance levels were minimized by covering the entire outdoor set-up with screens and clear polyethylene sheets.

Photosynthesis-Irradiance experiments

Three sediment plates from each of the 2 settlement tanks were collected in a haphazard manner for photosynthesis-irradiance (P-I) measurements before being acclimated to the elevated nutrient levels ("Initial" plates = 6). The P-I set-up, described in detail in Montebon (1993) and Montebon and Yap (1995), consists of a halogen light source, a series of black screens, 4 clear acrylic respiration chambers (StrathKelvin Instruments RC 400) incorporated in a flowthrough system, a magnetic stirring plate, and a polarographic dissolved oxygen meter (StrathKelvin Instruments Model 781b). The flow rate was regulated by a peristaltic pump at a range of 8-50 ml min^{-1}. Metabolic activity was measured using 6 light levels inclusive of a 0$\mu Em^{-2}s^{-1}$ level to determine the respiration rate in the dark and a maximum irradiance level of 2100$\mu E\ m^{-2}\ s^{-1}$. Samples from each acclimation aquarium (CTRL, N and P) were also subjected to the same P-I measurements at the end of the 7-day acclimation. A total of three replicate plates were taken from each treatment aquarium (total replicates per treatment = 6) for each P-I run.

Subsamples from each of the sediment plates were taken for chlorophyll *a* analyses and stored in liquid nitrogen prior to pigment extraction. The rest of the sediment samples were preserved in stained 10% formalin for subsequent meiofaunal analyses while randomly selected plates (n = 2) from each aquarium were collected before and after the nutrient acclimations and preserved in Lugol's solution for microalgal analyses.

Chlorophyll *a* analyses

Sediment subsamples were extracted of chlorophyll with cold 90% acetone over 24 h with an additional 5 min sonication step (Cole Parmer Ultrasonic Homogenizer) to physically disrupt the algal cells. Pigment extracts were then determined spectrophotometrically (Hitachi UV-VIS 200-20) using the equations of Lorenzen (1967).

Statistical and curve-fitting analyses

In the P-I measurements, the same sediment plates were subjected to a series of light levels, constituting a repeated measures experimental design. Metabolic rates were thus subjected to Repeated Measures Analysis of Variance (ANOVAR and MANOVAR) to test for differences due to light level (as well as nutrient treatment) using SPSS v.6 (Norusis). Chlorophyll-normalized metabolic rates were used in the repeated measures analyses of the data since the area-normalized rates did not conform to the assumption of homoscedasticity necessary for the tests. In performing ANOVAR, Mauchly's sphericity criterion, Huynh-Feldt's epsilon and Greenhouse-Geisser's epsilon fell way below the ideal value of 1.0 for all acclimation batches, thus, the multivariate counterpart of the test, MANOVAR (using Pillai's trace statistic), was resorted to as advised by Potvin *et al.* (1990). Cochran's univariate homogeneity of variance test was applied to the data prior to the multivariate tests.

P-I parameters were estimated using the hyperbolic tangent model by Chalker *et al.* (1983) and generated using the curve-fitting function of SigmaPlot v4.1 (Jandel). Tests of significant differences among P-I parameters due to the various nutrient treatments were done using a 2-way ANOVA after appropiate transformations to ensure normality and homoscedasticity. Differences in chlorophyll content among treatments were examined using a 1-way ANOVA.

Temporal replication

Sediment collection and nutrient limitation experiments were conducted in April, September and December 1994. In this paper, the nutrient limitation experiments will be referred to as Batches 1, 2, and 3, respectively.

RESULTS

Chlorophyll *a* concentrations

Initial chlorophyll *a* concentrations (prior to exposure to elevated nutrient levels) of the sediment plates were measured to be 88.13 (±4.63), 72.98 (±3.03), and 70.78 (±7.27) mg chl *a* m^{-2} for Batches 1, 2 and 3, respectively. In all three batches after the 7-day acclimation, the N plates exhibited the highest chlorophyll concentrations per unit area (1-way ANOVA, $p < 0.05$). P and CTRL plates had comparable pigment concentrations except during the September acclimation (Batch 2) when P-treated plates had higher chlorophyll content than the CTRL plates. CTRL plates showed higher mean pigment concentrations than the initial plates by a range of about 2 - 17 %. Table 1 shows the mean chlorophyll *a* levels for each treatment in all 3 batches.

Table 1. **Mean chlorophyll *a* (S.D.) concentrations of the sediment plates. INITIAL values represent measurements before exposure to elevated nutrient concentrations. CTRL, N and P values are measurements made after 7 days of exposure. Values are in mg chl *a* m^{-2} (n = 6).**

BATCH	INITIAL	CTRL	N	P
1	88.13 (4.63)	96.39 (38.02)	133.84 (7.54)	93.64 (11.38)
2	72.98 (3.03)	85.51 (3.66)*	140.04 (22.51)*	109.47 (4.55)*
3	70.78 (7.27)	72.43 (4.23)*	108.23 (8.54)	71.05 (12.58)

* n = 4

Photosynthesis-Irradiance responses

Despite the consistently high algal biomass in the N plates, metabolic activity was shown to be highest in the P plates - both in terms of area-normalized and chlorophyll-normalized photosynthetic rates. Figure 1 presents the P-I profiles of the treated plates from the three acclimation periods (Batches 1, 2, and 3) on the basis of chlorophyll. The P-I profile of the P-treated plates was consistently highest in all acclimation batches.

P-I parameters generated using the hyperbolic tangent function for all acclimation batches are shown in Table 2. A two-way analysis of variance revealed a significant effect of treatment on the maximum gross photosynthesis (P_{max}) of the microalgal communities ($p < 0.05$). Addition of P elicited the highest P_{max} as compared to the other treatments. Little or no effect was detected in the half-saturation constant (I_k) and dark respiration rate (R). P_{max}, I_k, and R were found to be significantly different among Batches 1, 2, and 3.

Table 2. Photosynthesis-Irradiance parameters generated using the hyperbolic tangent function of Chalker et al. (1983). P_{max} and R values are in mg O_2mg chl a^{-1} m^{-2} while I_k values are in µE m^{-2} s^{-1}.

	P_{max}	I_k	R
Batch 1			
INITIAL	0.74	712	-0.14
CTRL	1.05	674	-0.23
N	0.99	689	-0.18
P	1.34	663	-0.37
Batch 2			
INITIAL	1.19	808	-0.22
CTRL	1.75	430	-0.28
N	2.47	523	-0.29
P	4.63	580	-0.48
Batch 3			
INITIAL	2.28	439	-0.65
CTRL	2.40	457	-0.72
N	2.49	475	-0.42
P	3.65	653	-0.75

Table 3 lists the results obtained from application of repeated measures MANOVAR showing consistently significant differences in photosynthetic rates across the light levels used. Interactions between the nutrient treatments and light were not significant. The effect of nutrient treatment was significant only in Batch 2 samples due to the high P-I rates of the P-treated plates.

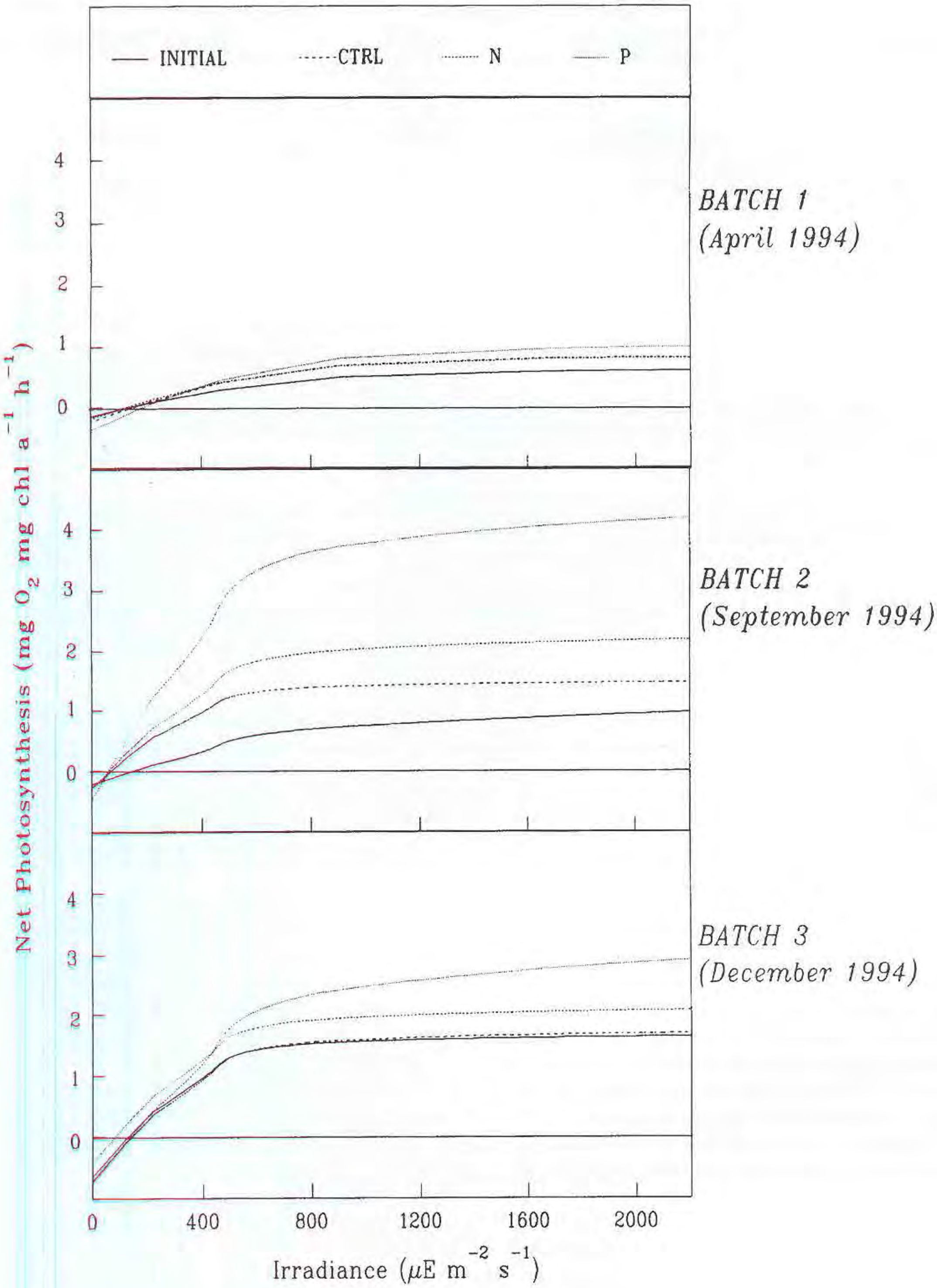

Figure 1. Photosynthesis-Irradiance profiles of INITIAL, CTRL, N and P plates (see Table 2 for P-I parameter values)

Table 3. **Summary of the statistical results (MANOVAR) comparing the effect of nutrient treatment, light levels and the interaction of both factors on the metabolism of microalgal communities acclimated under different nutrient environments. Values are significance values at $p < 0.05$. * = significant.**

BATCH	TREATMENT	LIGHT	TREATMENT x LIGHT
1	0.938	0.000*	0.177
2	0.005*	0.000*	0.439
3	0.306	0.000*	0.054

DISCUSSION

Differences in the chlorophyll content of the sediment between the three batches (collected in April, September and December, respectively) are not as remarkable as when comparing between nutrient treatments. This indicates a relative constancy in the density of benthic microalgae in the reef flat over time as previously noted by Dizon *et al.* (In press) from their *in situ* measurements of sediment chlorophyll. Concentrations of both "Initial" and treatment (CTRL, N and P) plates are within the range reported by Dizon *et al.* (In press).

The question as to which nutrient elicits the greater community response apparently produces divergent answers when considering different aspects of community function, namely, biomass and metabolism, as shown in this study. In defining a limiting nutrient, a nutrient is considered such when an increase in its flux brings about an enhancement in a metabolic response (Parsons *et al.*, 1984). Atkinson (1988) further explains this "metabolic response" as being either net photosynthesis, respiration, gross productivity, net calcification, specific growth rate, cell division, or some other measure of community function.

Biomass data in the sets of experiments in this study indicate a probable N-limitation while P-I profiles show an emerging pattern of P-limitation. N-limitation has been experimentally observed in other algae such as phytoplankton (see review by Turpin, 1991), macroalgae (Dawes & Koch, 1990) and symbiotic zooxanthellae (Hoegh-Guldberg & Smith, 1989; Belda *et al.*, 1993), as well as in other microalgae-dominated benthic systems (Ryther & Dunstan, 1971; Hoegh-Guldberg & Smith, 1989; Muscatine *et al.*, 1989). Other authors maintain that reef systems are primarily P-limited (Redfield, 1958; see Smith, 1984).

Nitrogen, being the second major soft tissue-forming component (next to carbon) in living organisms, is apparently responsible for the observed rise in algal biomass in the N-treated plates. It is an established fact that nitrogen plays a vital role in the production of proteins (e.g., structural forms and enzymes) and pigments (e.g., photosynthetic pigments). The increased availability of nitrogen could have thus provided the necessary structural and enzymatic components for the algal populations to proliferate. Phosphorus availability, on the other hand, may have stimulated community metabolism due to the significant role phosphorus plays in cellular energetics (in the form of ATP), intermediary metabolism and replication (Belda *et al.*, 1993). In community response studies on benthic microalgae, nutrient limitation is thus deemed as dependent on which aspect of community response the assessment is based. As Atkinson (1988) cautions, it is impossible to speak of a probable nutrient limitation in a given system without a definition of the "metabolic response" used for the assessment.

ACKNOWLEDGMENTS

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REFERENCES

Atkinson, M.J., 1988. Are coral reefs nutrient-limited? Proc. 6th Int. Coral Reef Symp., Australia 1: 157-166.

Belda, C.A., J.S. Lucas & D. Yellowlees, 1993. Nutrient limitation in the giant clam-zooxanthellae symbiosis: effects of nutrient supplements on growth of the symbiotic partners. Mar. Biol. 117: 655-664.

Blanchard, G.F., 1991. Measurement of meiofauna grazing rates on microphytobenthos: is primary production a limiting factor? J. Exp. Mar. Biol. Ecol. 147: 37-46.

Chalker, B.E., W.C. Dunlap & J.K. Oliver, 1983. Bathymetric adaptations of reef-building corals at Davies reef, Great Barrier Reef, Australia. II. Light saturation curves for photosynthesis and respiration. J. Exp. Mar. Biol. Ecol. 73: 37-56.

Daehnick, A.E., M.J. Sullivan & C.A. Moncreiff, 1992. Primary production of the sand microflora in seagrass beds of Mississippi Sound. Bot. Mar. 35: 131-139.

Dawes, C.J. & E.W. Koch, 1990. Physiological responses of the red algae *Gracilaria verrucosa* and *G. tikvahiae* before and after nutrient enrichment. Bull. Mar. Sci. 46: 335-334.

Delgado, M., V.N. De Jonge & H. Peletier, 1991. Effect of sand movement on the growth of benthic diatoms. J. Exp. Mar. Biol. Ecol. 145: 221-231.

Dizon, R.M., H.T. Yap & A.R.F. Montebon, (In Press). Temporal stability in function of tropical reef flat sand communities. In: Proceedings of the 3rd Regional Symposium on "Living Coastal Resources", Bangkok, Thailand, 17-20 May 1994. Bangkok: Department of Marine Science, Chulalongkorn University.

Hansen, J.A., D.M. Alongi, D.J.W. Moriarty & P.C. Pollard, 1987. The dynamics of benthic microbial communities at Davies reef, central Great Barrier Reef. Coral Reefs 6: 63-70.

Henley, W.J., 1993. Measurement and interpretation of photosynthetic light-response curves in algae in the context of photoinhibition and diel changes. J. Phycol. 29: 729-739.

Hoegh-Guldberg, O. & G.J. Smith, 1989. Influence of the population density of zooxanthellae and supply of ammonium on the biomass and metabolic characteristics of the reef corals *Seriatopora hystrix* and *Stylophora pistillata*. Mar. Ecol. Prog. Ser. 57: 173-186.

Lorenzen, C.J., 1967. Determination of chlorophyll and pheopigments: spectrophotometric equations. Limnol. Oceanogr. 12: 343-346.

Metaxas A. & A.G. Lewis, 1992. Diatom communities of tidepools: the effect of intertidal height. Bot. Mar. 35: 1-10.

Montebon, A.R.F., 1993. Metabolic responses of *Porites cylindrica* (Anthozoa:Scleractinia) to water motion. M.Sc. thesis. Marine Science Institute, University of the Philippines.

Montebon, A.R.F. & H.T. Yap, 1995. Metabolic responses of the scleractinian coral *Porites cylindrica* Dana to water motion. I. Oxygen flux studies. J. Exp. Mar. Biol. Ecol. 186: 33-52.

Muscatine, L., P.G. Falkowski, Z. Dubinsky, P.A. Cook & L.R. McCloskey, 1989. The effect of external nutrient resources on the population dynamics of zooxanthellae in a reef coral. Proc. R. Soc. Lond. (Ser. B) 236: 311-324.

Nilsson, C. & K. Sundbäck, 1991. Growth and nutrient uptake studied in sand-agar microphytobenthic communities. J. Exp. Mar. Biol. Ecol. 153: 207-226.

Nilsson, P., B. Jönsson, I. Lindström Swanberg & K. Sundbäck, 1991. Response of a marine shallow-water sediment system to an increased load of inorganic nutrients. Mar. Ecol. Prog. Ser. 71: 275-290.

Parsons,T.R., M. Takahashi & B. Hargrave, 1984. Biological Oceanographic Processes. 3rd edition. Pergamon Press, New York, 330 pp.

Pinckney, J. & R.G. Zingmark, 1991. Effects of tidal stage and sun angles on benthic microalgal populations on an intertidal sandflat: scale linkage between consumers and resources. Estuar. Coastal Shelf Sci. 30: 341-353.

Potvin, C., M.J. Lechowicz & S. Tardif, 1990. The statistical analysis of ecophysiological response curves obtained from experiments involving repeated measures. Ecology 71: 1389-1400.

Redfield, A.C., 1958. The biological control of chemical factors in the environment. Am. Sci. 46: 1-18.

Ryther, J.H. & W.M. Dunstan, 1971. Nitrogen, phosphorus and eutrophication in the coastal marine environment. Science 171: 375-380.

Smith, S.V., 1984. Phosphorus versus nitrogen limitation in the marine environment. Limnol. Oceanogr. 29: 1149-1160.

Sorokin, Y.I., 1981. Periphytonic and benthic microflora on the reef: biomass and metabolic rates. Proc. Fourth Int. Coral Reef Symp., Manila 2: 443-451.

Turpin, D.H., 1991. Effects of inorganic N availability on algal photosynthesis and carbon metabolism. J. Phycol. 27: 14-20.

Yap, H.T., A.R.F. Montebon & R.M. Dizon, 1994. Energy flow and seasonality in a tropical coral reef flat. Mar. Ecol. Prog. Ser. 103: 35-43.

EFFECT OF CHEMICAL DISPERSANTS ON THE BIODEGRADATION OF CRUDE OIL IN THE OCEAN

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ABSTRACT

Four chemical dispersants collected randomly among the dozens of dispersants proposed for use in Indonesia were examined for their effects on the rate of biodegradation of crude oil. The degree of degradation of the crude oil measured by calculating n-C_{17}/pristane and n-C_{8} /phytane ratios varied depending upon the dispersant used. Under test conditions, the poorer the dispersing capacity of the dispersant, the slower the biodegradation of crude oil effected by the dispersant. In addition to the effectiveness and toxicity tests of dispersants which are ussualy used for evaluating the performance of chemical dispersants, a test to determine the effect of dispersants on the biodegradation rate of crude oil is proposed.

INTRODUCTION

Chemical dispersants are often used to disperse spilled oils which threaten to pollute shoreline areas. In Indonesia, the use of oil spill dispersants is controlled by the Directorate General of Oil and Gas, and all dispersants produced or marketed undergo a toxicity test. This toxicity test is conducted with regard to certain types of fish to determine the threshold limit, LD_{50}, of dispersants (Prasetyo, pers comm., 1990).

It is generally understood that the criteria for a good oil dispersant is adequate dispersing qualities and low toxicity to marine species. Few reports exist which consider the effect of oil dispersants on microbial species, which may be important, since it is known that biodegradation is the major natural process ultimately responsible for eliminating oceanic oil pollutants.

The physical state of spilled oils has a marked effect on their biodegradation. At very low concentrations, petroleum hydrocarbons are soluble in water. However, most oil spills release petroleum hydrocarbons in concentrations far in excess of the solubility limits. The degree of spread determines in part the surface area of oil available for microbial colonization by hydrocarbon-degrading microorganisms. Hydrocarbon-degrading microorganisms act mainly at the oil-water interface, and dispersing the oil throughout the water column to increase its surface area should accelerate biodegradation. This way, the oil is not only made more readily available to microorganisms, but the movement of emulsion droplets through the water column makes oxygen and nutrients more readily available to the microorganisms.

On the other hand, the type of surface active agent and the solvent used in the dispersant which may increase their dispersing quality might be toxic to bacteria. Several reports have shown that not all dispersing agents promote bacterial growth. Some agents are instead quite toxic, and will retard the rate of oil decomposition. Although some reports state that crude oil degradation could be enhanced by a number of dispersants (Robichaux & Myrick, 1972; Atlas & Bartha, 1973; Mulkins-Phillips & Stewart, 1974), the results to date suggest that many, but not all chemical dispersants increase the rate of degradation of oil.

In addition to the two criteria mentioned above, oil spill dispersants should be tested to ensure that they meet three further criteria (Mulkins-Phillips and Stewart, 1974) : (i) they should be biodegradable; (ii) they must not be preferentially utilized as a carbon source in the presence of oil; and (iii) they must be nontoxic to indigenous bacteria. The experiments discribed in this report were carried out to provide information on some of these points for four chemical dispersants chosen randomly among the dozens of dispersants proposed for use in Indonesia. The type of dispersants, i.e. oil- or water-based, and the ratio of dispersants to crude oil were two parameters which were considered in the experiments.

MATERIALS AND METHODS

The main objective of the laboratory experiments was to determine the dispersants composition and their dispersing quality in order to correlate theese two results with the effect on the rate of biodegradation of crude oil.

Composition of dispersants

The solvent used in the dispersant was separated by distillation. The distilate and the residue were then examined by infrared spectral analysis to determine the surfactant composition, and type of solvent used.

Dispersing quality

The dispersing capacity of the dispersants at room temperature (30°C) was estimated by measuring the turbidity of the oil dispersant mixture in non enriched seawater. The combination was mixed for 1 minute, and percent transmittance of the mixtures was measured at 340nm on a Perkin Elmer lambda 5 spectrophotometer during a 120 minute period, immediately following the mixing step. Low percent transmittance values indicate good dispersing qualities.

Degradation experiments

The seawater used in these experiments was collected offshore about two kilometers from Taman Impian Jaya Ancol, which is a relatively unpolluted area. The mixed culture was obtained from sediment known to be chronically polluted with oil, from the Pertamina Harbour, Teluk Jakarta. Microbial activation was conducted by transferring a portion of the sediment into a sterile flask containing 100 ml of seawater, 0.1gram of pepton and 1gram of the crude oil being tested. The flask was then incubated at 30°C for 3 days.

Portions (1ml) of activated culture were then dispensed into a series of sterile flasks containing 100ml of seawater, 0.1gram pepton and 1gram of crude oil. A sterile solution of KNO_3 was added aseptically to give a ratio of Carbon to Nitrogen of 4:1, 2:1, and 1:1, respectively. The chemical dispersants, namely A and B which are oil-based, and C and D which are water-based, were added to the culture in the following amounts: 0.1, 0.5 and 1.0 grams, respectively. The flasks were then incubated on a rotary shaker at 120rpm and at a temperature of 30 °C. for 7, 14 and 28 days, respectively. Control flasks were identical to the growth flasks but contained no added dispersants. The treatment in the chemical control flasks were identical to the growth flasks, except for an addition of $HgCl_2$ to a final concentration of 1%. Total viable bacterial numbers were determined by the droplate method on agar plates containing broth nutrient.

Analysis of hydrocarbons

The extent of biodegradation was determined by extracting the crude oil in the growth flasks with chloroform after incubation. The chloroform extract was then examined for n-paraffin content using gas liquid chromatography, and carbonyl content using infrared spectrophotometry. Operating conditions for gas liquid chromatography measurements were as follows : the column (SPB-1 CFS-674 25μm x 35m) was programmed to be between 45 and 325 °C at intervals of 5 °C/min. The detector used was FID, and the carrier gas nitrogen, at a rate of 30 ml/min. Normal alkane peak heights as well as those of pristane and phytane were measured using an electronic integrator, and this was used as an indicator of the percent degradation of crude oil.

RESULTS AND DISCUSSION

Since all the products which have been marketed as dispersants could not be tested, an attempt was made to account for the properties of most of these products. Four dispersants which appeared to represent the types currently available were selected. Analysis of the four dispersants was performed using infrared spectrometry in order to identify the type of the surface active agent as well as the solvent used in the dispersants, and results are presented in Tabel 1. Product A is a typical oil-based emulsifier with a non-ionic surface active agent and a petroleum solvent. Product B is similar but with aromatic solvents. Product C and D contain the same surface active agent with a water-based solvent, and short-chained alcohols.

Turbidimetric measurements of the dispersants added to oil plus seawater illustrated their emulsifying or dispersing capacity, which was found to be as follows, in decreasing order of effectiveness: D = C > B > A (Figure 1).

Table 1. **Apparent composition of the dispersants**

Product	Surfactant Ionic Nature	Surfactant Basic Composition	Solvent
A	Nonionic	Alkilphenoxy	Kerosen polyethanol
B	Nonionic	Fatty acid of polyoxy ethylene	Aromatic hydrocarbons
C	Nonionic	Alkyl Aryl poly ether alcohol	Water, ethylene glycol monobutyl ether
D	Nonionic	Alkyl Aryl	Water, diethylene,glycol monobutyl ether

Dispersants C and D formed a very stable emulsion, whereas the dispersing capacity of dispersant B was slightly poorer. Dispersant A produced an emulsion which was only slightly better in quality than that obtained when only the oil was mixed with seawater. As can be observed, the dispersing capacity of the dispersants correspond well with the dispersant composition.

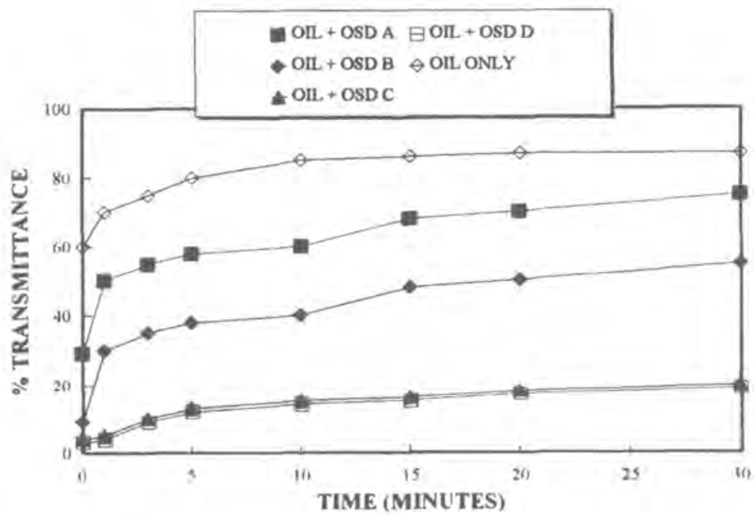

Figure 1. **Effectiveness of the dispersants in forming emulsions with crude oil in seawater at room temperature (ca 30 °C).**

The stability of the dispersion is influenced by the type of surfactant (Canevari, 1969). The surfactant's molecular structure, e.g. ratio of hydrophylic to lipophylic portions, determines the type of dispersion, as well as stability of the dispersion. A surfactant that is principally water soluble disperses oil-in-water and establishes water as the continuous phase, while a surfactant that is principally oil solubleacts in a converse manner. For a more water compatible surfactant, the physical location of the larger hydrophylic group on the outside of the dispersed oil droplets results in a more effective fender, to parry droplet collisions and prevent droplet coalescence. The converse, locating this group on the hydrophilic layer portion of the continuous phase, would be geometrically awkward and unstable.

With regard to the biodegradation capacity of the hydrocarbon-degrading microorganisms used in the experiments, the results show that the mixed culture obtained from the sediments is capable of degrading n- alkanes in the crude oil. The growth curve obtained for microorganisms which grew in the crude oil exhibited a lag phase, which was pronounced after 24 hours (Figure 2).

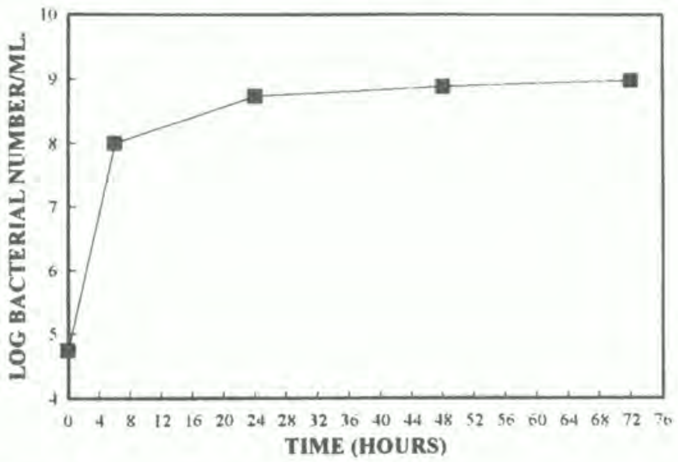

Figure 2. Growth of microorganisms on the crude oil, at 30 °C.

The activated culture which has a lag phase at 24 hours was then used as the bacterial inoculum to test the biodegradation rate of the crude oil in the presence of the four different dispersants and of the crude oil alone.

Analysis of the bacterial populations which grew in the presence of oil and treatments containing oil and dispersants showed that the bacterial numbers varied for each dispersant. This indicates that the dispersants have an effect on the indigeneous microbial population. Nutritional composition, i.e. C and N ratios, as well as the crude oil-dispersant ratio also influenced the bacterial growth (Table 2). A carbon and nitrogen ratio of 2:1 was apparently the optimum ratio for all systems. In this regard we noted that there was a good correlation in which the dispersant with the poorest dispersing capacity, i.e. dispersant A, produced the smallest growth in bacterial population.

Measurements of the disappearence of the n-alkanes as well as pristane and phytane contained in the crude oil incubated with the different dispersants, showed the extent to which degradation was affected by these dispersants (Figure 3). Assuming that pristane and phytane are persistant hydrocarbons, the percentages of biodegradation of the crude oil could be calculated from the ratio of n-C_{17} to pristane and of n-C_{18} to phytane (Table 3). Again, the results show that the poorer the dispersing capacity of the dispersant, the smaller the percentage of crude oil biodegradation. Our findings are contratry to those obtained by other authors (Mulkins-Phillips & Stewart, 1974), who reported that dispersants with the poorest emulsification enhanced the biodegradation of the n-alkanes. We predict the biodegradation rate is not influenced solely by the degree of the dispersion of crude oil, but also by the toxic properties, both of the surface active agent and the solvent. In the absence of toxicity however, the degree of the dispersion of crude oil will determine the rate of crude oil biodegradation.

Table 2. Growth of microorganisms on the crude oil plus dispersants. Microbial Population in Log. Bacterial Number x 10^5/mL.

C:N = 4:1

DAYS	OIL + OSD A	OIL + OSD B	OIL + OSD C	OIL + OSD D	OIL ONLY
0	6.58	6.58	6.58	6.58	6.58
7	5.95	6.82	7.43	7.13	6.86
14	7.77	8.23	8.37	8.48	8.15
28	4.55	4.74	6.27	4.73	5.41

C:N = 2:1

DAYS	OIL + OSD A	OIL + OSD B	OIL + OSD C	OIL + OSD D	OIL ONLY
0	6.58	6.58	6.58	6.58	6.58
7	7.84	6.70	7.73	7.82	6.69
14	7.92	8.57	8.70	8.76	8.00
28	5.76	5.41	6.57	5.39	4.51

C:N = 1:1

DAYS	OIL + OSD A	OIL + OSD B	OIL + OSD C	OIL + OSD D	OIL ONLY
0	6.58	6.58	6.58	6.58	6.58
7	6.93	6.76	7.21	6.82	7.85
14	7.72	8.14	8.25	8.25	7.90
28	4.36	4.44	6.08	4.58	4.60

Table 3. n-C17/Pristane and n-C18/Phytane ratios

Days	7		14		28	
SAMPLES	n-C_{17}/Pri	n-C_{18}/Phy	n-C_{17}/Pri	n-C_{18}/Phy	n-C_{17}/Pri	n-C_{18}/Phy
Oil+A	4.07	2.70	3.84	2.43	3.60	2.25
Oil+B	3.97	2.66	3.44	2.12	2.85	1.80
Oil+C	3.17	2.04	2.17	1.46	1.24	0.72
Oil+D	3.12	2.02	2.12	1.42	1.18	0.71
Oil	3.80	2.58	3.45	2.24	2.96	1.95

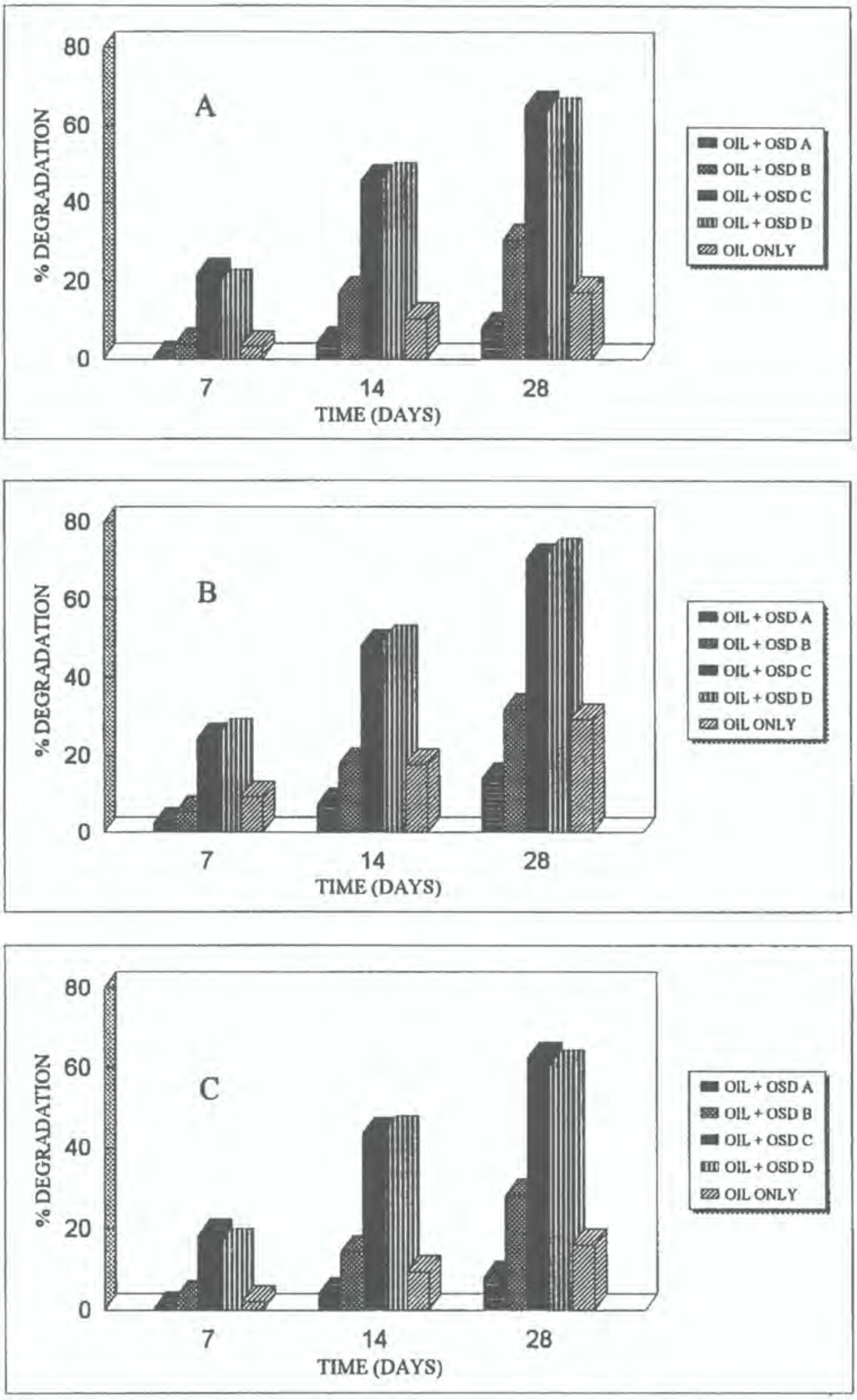

Figure 3. **Percentage of crude oil degradation measured by gas chromatography. (A) C:N = 4:1; (B) C:N = 2:1; (C) C:N = 1:1**

CONCLUSIONS

Chemical dispersants function to carry oil and hydrocarbons into the water column as discrete droplets which can be attacked by bacteria. In the absence of toxicity, the rate of crude oil degradation is influenced by the degree of dispersion, which is a function of dispersing capacity of dispersants. Unless mechanically or chemically dispersed into the water column, hydrocarbons or crude oils are merely oxidized by the natural seawater microbial populations.

In addition to the effectiveness test and toxicity tests generally conducted on dispersants, a biodegradable test of the dispersant and of the oil mixed with dispersant are proposed here as tests that may be used to classify the dispersant.

REFERENCES

Atlas, R.M. & R. Bartha, 1973. Effects of some commercial oil herders, dispersants and bacterial inocula on biodegradation of oil and seawater. In: D.G. Ahearn & S.P. Meyers (eds.), The Microbial Degradation of Oil Pollutants, Louisiana State University publ. no. LSU-SG-73-01, Baton Rouge, La., pp. 283-289

Canevari, G.P., 1969. General dispersant theory. Proc. API/FWPCA. Joint Conference on Prevention and Control of Oil Spills. Publ. no. 4040. America Petroleum Institute, Washington, D.C., pp. 171-177.

Mulkins-Phillips, G.J. & J.E.Stewart, 1974. Effect of four dispersants on biodegradation and growth of bacteria on crude oil. Appl. Microbiol. 28: 547-562.

Robichaux, T.J., & H.N. Myrick, 1972. Chemical and enhancesment of the biodegradation of crude oil pollutants. J. Petrol. Technol. 24: 16-20.

REGIONAL COOPERATION IN PREVENTION AND RESPONSE TO MARINE POLLUTION IN THE SOUTH CHINA SEA

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ABSTRACT

The South China Sea region contains valuable habitats which are rich in terms of diversity and productivity. The nations whose coastlines border the South China Sea are rapidly growing economies with increasing populations. Fast increasing populations, coupled with rapid industrialization and development has resulted in increased stress on the coastal and marine environment. Improper or inadequate pollution prevention, control and management constantly threatens the health of the coastal and marine habitats that the populations in this region heavily depend upon. The growing concern for the degradation of the marine environment has lead the United Nations to formulate the United Nations Convention on the Law of the Sea (UNCLOS). More recently, the 1992 United Nations Conference on Environment and Development (UNCED) also addressed the problem of marine pollution, endorsing an integrated and developmentally sustainable approach to the problem. In addition to national programmes, bilateral and regional cooperation (e.g. among ASEAN nations) also exist in this region to deal with marine pollution. Indeed, regional and international initiatives are required to help stem the growing tide of pollution, in particular the implementation of regulations and standards on discharge levels, and the enforcement of legislation. There remains much to be done, however, as many countries are constrained by the lack of either financial or technical resources to implement regulations on marine pollution. Funding and technical expertise from international and regional counterparts are thus needed if the tide is to be turned in the battle against pollution of the marine environment is to be won.

INTRODUCTION

The South China Sea region is bordered by the six ASEAN nations (Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore and Thailand), Vietnam, Cambodia, China and Taiwan (Fig. 1). Of the total of 89,391 km of coastline in the Southeast Asian region, more than 80% belongs to Indonesia and the Philippines (Chou, 1994). Indonesia comprises more than 13,600 islands which cover only one third of the country (Thayib & Thayib, 1987), while the Philippines has a marine water area 5 times the land area of its 7,000 islands.

The States that share the waters of the South China Sea are rapidly growing economies with increasing populations. The Southeast Asian region's current population of 444 million is projected to grow by 63% to 724 million by the year 2025 (Chou, 1994). An estimated 70% of the population live in the urbanised centres along the coast. In addition, this region contains shipping activity which is amongst the world's busiest, and is also a centre for the production and transport of oil and gas.

The rising population and increasing development of the coastal areas have placed a heavy strain on the coastal and marine environment in the region. Improper waste management has lead to the increased outflow of sewage and industrial effluent to the surrounding waters, increasing the health risks to the population. Elevated pathogenic bacteria levels, high heavy metal concentrations in seafood, occurrences of red tides and oil spills from vessels, oil platforms and underwater pipelines, and land-based petrochemical plants are some of the many pollution concerns of this region.

This paper is intended to be a working document briefly reviewing the marine pollution problems, and international and regional collaborative initiatives relevant to the prevention, control and management of marine pollution in the South China Sea region.

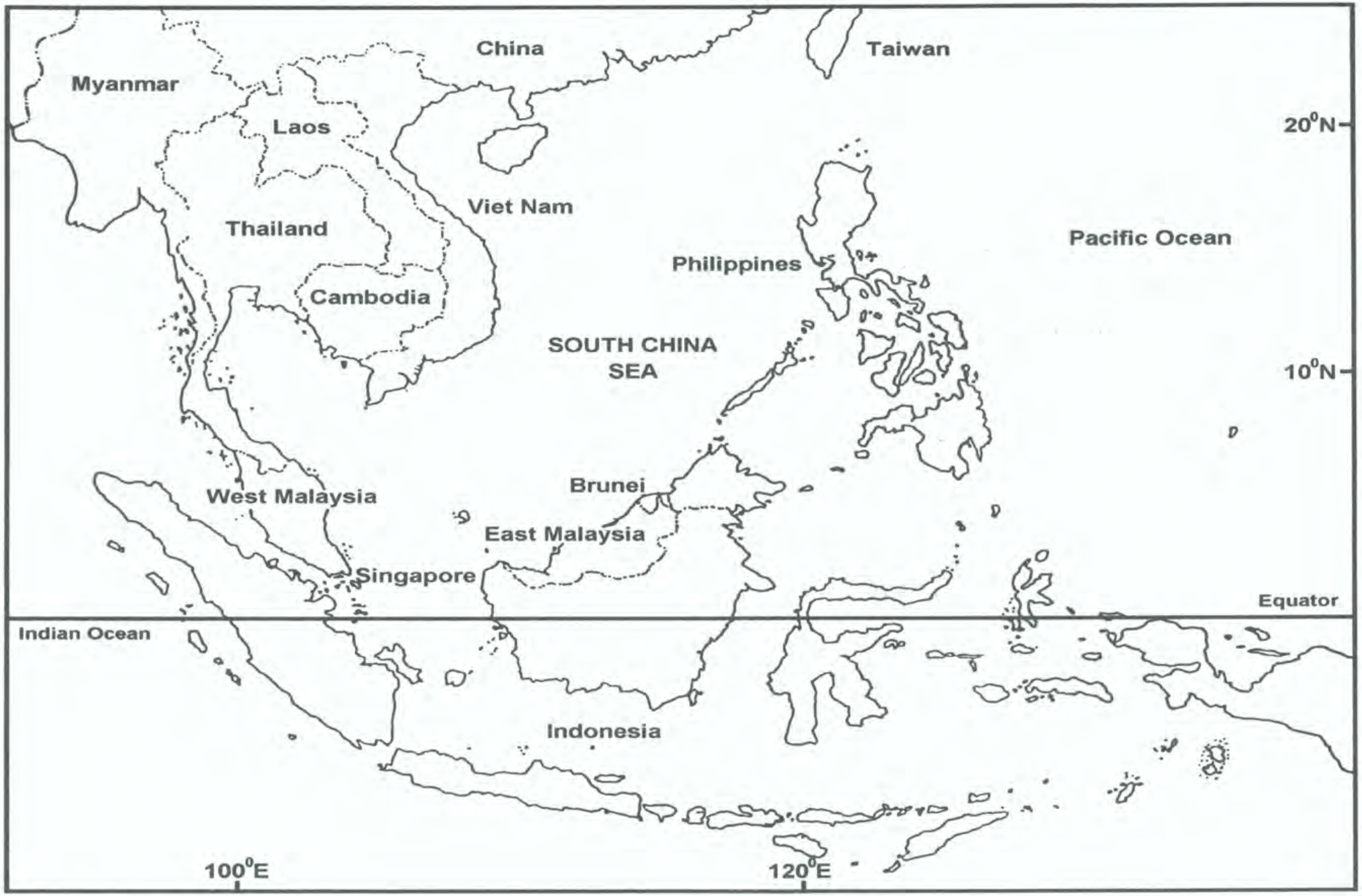

Figure 1. The South China Sea region.

LIVING RESOURCES

The semi-enclosed South China Sea is a very rich resource, with fisheries being a prominent activity. Eleven percent of the world's marine catch comes from this region, with almost 5 million people directly dependent upon fishing for their livelihood (Anon., 1992). A large proportion of the populations in this region depend on the approximately 2,500 species of fish, and many more invertebrates as the major source of protein (Anon., 1992). In Brunei Darussalam, the fish consumption rate per capita is in excess of 40 kg/person/annum, half of which are caught in local waters (Matdanan *et al.*, 1987). Similar consumption rates were reported in the Philippines, with fisheries providing more than half the animal protein intake (Guerrero *et al.*, 1987; Hammond *et al.*, 1994), and employing over one million people. The annual marine catch for the six ASEAN countries alone increased from 1.5 million tons (in 1960s) to 5.5 million tons in the early 1980s.

Thirty percent of the world's coral reefs are found in Southeast Asia (Smith, 1978). Diversity is very high, with coral reef fisheries supplying 12% of the world's total fish catch (Munro & Williams, 1985). In Sabah, East Malaysia, reef fisheries were estimated to contribute more than 30% of East Malaysia's total catch (Langham & Mathias, 1977), while in the Philippines it was estimated to be 25% (Gomez, 1988). Other reef organisms including seaweeds, molluscs, crustaceans and echinoderms, are also harvested for food (McManus, 1988). In addition, reef organisms are collected for the marine curio and aquarium trade, with the bulk of this harvest exported to countries outside Southeast Asia. Reefs have also traditionally been mined for coral or limestone blocks for use as building material in some countries.

The coral reef is a carbon sink (deposited as calcium carbonate), similar in many ways to the tropical rainforests. Productivity rates for reefs are high due to an efficient and complex recycling system, and the ability of many reef organisms to fix nitrogen. The coral reef provides a visual display of colour and form unmatched anywhere on earth, and is a natural avenue for income from tourism that has been exploited by many nations in this region.

Mangroves cover more than 50,000 km^2 of coastal areas in the region, accounting for more than 30% of the world's mangrove forests (Chou, 1994). About 20 species of mangrove trees are commercially important, being harvested for use as fuel, as building materials and for the production of chipboard. Tannins are also extracted from the bark, and edible fruits and leaves are collected from others (Chou, 1994). The mangroves support a highly productive fisheries. In Malaysia for example, the value of mangrove dependent fisheries in 1990 was reported to be US$28.6 million. Prawn production from mangrove forests are also important in some of the countries in the region, with up to 145,000 tons harvested in 1990 (Chong *et al.*, 1994). The mangrove forests act as nursery and feeding grounds for many species of fish and prawns (Chong *et al.*, 1990). Indonesia produced an estimated US$26 million of mangrove forest products in 1978, and US$194 million in mangrove-linked fisheries (Salm & Halim, 1984).

In addition to fisheries, coral reefs and mangroves, the South China Sea region also contains many other valuable habitats, namely, estuarine river systems, seagrass beds and other nursery and spawning grounds, all of which are tremendously rich resources.

SOURCES OF MARINE POLLUTION

Marine pollution can be described as anthropogenic inputs into the marine environment resulting in harm to living resources and marine life, danger to human health, hindrances to marine activities, and a reduction in the quality and usefulness of sea water (GESAMP, 1969). The most widely distributed pollutants of the oceans may be classified into radionuclides, organochlorine toxicants, metals, petroleum and petroleum products and detergents (Patin, 1982). These pollutants may originate from land (land-based) or the sea (sea-based).

Rapid industrialization and burgeoning populations in the countries of this region have resulted in increased levels of sewage and pollutant discharge into the surrounding seas. Land-based activities, such as agriculture, mine tailing disposal, logging and reclamation, contribute to the elevated levels of organic waste, heavy metal concentrations and sediment loads of the waters. The increased organic waste poses an immediate threat to public health, stimulating the growth of pathogenic bacteria (Thayib & Thayib, 1987) and causing blooms of toxic dinoflagellates (red tides). Manila Bay, for example, was found to be "unsafe" for recreational activities, and red tide occurrence in mid-1983 affected one of the country's major fisheries areas, resulting in the deaths of 21 people, and a loss of US$ 5 million (Guerrero *et al.*, 1987). In 1988, red tides resulted in the loss of 4 lives (Anon., 1992). In Indonesia, the river of Citarum showed a doubling of its faecal coliform concentrations between 1987 and 1990 (UNEP, 1993).

Heavy metal contamination from improper waste disposal is also a major problem. Studies on the Bay of Jakarta indicated that its waters and sediment contained concentrations of mercury, lead and cadmium that were four times higher than normal levels (Thayib & Thayib, 1987). In Malaysia, cadmium and mercury concentrations up to 28 times have been observed at disposal sites of mine tailings (Anon., 1992).

The impact of pesticide residues in the estuaries and other coastal environments is a major cause for concern to the fisheries industry. Studies conducted by the Indonesian Department of Agriculture show that the pesticide residue thiodan has toxic effects even after seven days, and that 3 ppm is lethal to juveniles of the freshwater fishes *Punctius javanicus*, *Cyprinus carpio* and *Tilapia mossambica* (Thayib & Thayib, 1987).

Accelerated erosion from improper land management, reclamation of coastal areas for industrial development and mining in coastal waters have resulted in heavy sediment loads, destroying coral reefs and other benthic communities, and resulting in a decline in fish yields. An estimated 13.5 x 10^3 Mt of sediment reaches the ocean annually, and it has been reported that approximately 215 million tons of dredged material were dumped annually between 1980 and 1985 (GESAMP, 1990). The Huanghe (Yellow River) of China has seen a 4-fold increase in its suspended solids content since 1987 (UNEP, 1993), while sedimentation rates in Singapore have been observed to reach 45 mg/cm^2/day (Lane, 1991; Low & Chou, 1994). Changes in the physical and chemical make-up of the environment have also been observed in areas where dredge-mining occur (Chansang, 1988).

Oil pollution from shipping and offshore oil rigs is a major concern for all countries in the region. The proximity of the countries to one another means that any spillage in one country could affect the coastal waters of others. Tankers carried an estimated 117 million barrels of crude oil through the Straits of Malacca (Chua, 1994), and several accidents have been reported (Anon., 1992). In addition, sludge and waste discharged directly into the sea from petroleum industries has resulted in high concentrations of hydrocarbons in waters around busy ports (e.g. up to 30 ppm in some Indonesian waters; Thayib & Thayib, 1987).

Various forms of marine pollution are thus not only a threat to human health, they may also cause detrimental and irreversible impacts on sensitive habitats and ecosystems, and eventually affect the livelihoods of populations.

INTERNATIONAL INITIATIVES IN MARINE POLLUTION CONTROL

A number of international treaties and conventions have taken place that deal directly with the management and prevention of marine pollution. Some of the conventions and treaties of direct relevance to marine pollution, are the Stockholm Declaration, 1972, the Third United Nations Convention on the Law of the Sea (UNCLOS), 1982, the "Montreal Guidelines", 1985, and more recently, the Convention on Biological Diversity (or Agenda 21, Chapter 17), 1992. An overview of these initiatives has been presented (Koh & Lim, unpublished).

The Stockholm Declaration resulting from a conference held in Stockholm between 5-16 June 1972 contains principles laid down by the United Nations Conference on Human Environment. Two principles (6 and 7) in particular, relate to the prevention of pollution of the seas by substances that are liable to be deleterious to humans, living resources and marine life.

The Third United Nations Convention on the Law of the Sea (UNCLOS), 1982, dealt with the protection and preservation of the marine environment. The Convention contains articles that range from specifying that States are obligated to protect and preserve the marine environment, to calling for regional and global cooperation in preventing marine pollution, to specifications requiring States to adopt national legislation to deal with land-based pollution, sea-bed activities and activities by sea vessels, e.g. programmes to prevent accidents at sea. In the South China Sea region, UNCLOS has already been ratified by the countries Indonesia, Philippines and Thailand.

The 1985 Montreal Guidelines for the Protection of the Marine Environment against Pollution from Land-Based Sources, endorsed by the United Nations Environment Programme (UNEP), were drafted to specifically aid Governments to deal with land-based sources of marine pollution. The guidelines, adopted by the United Nations Conference on Environment and Development (UNCED) are not only intended to help Governments draft appropriate national legislation, they also encourage bilateral, regional and multilateral collaborations in preventing marine pollution. In these guidelines, a holistic approach to environmental pollution control is taken, and programmes on environmental and data management, assessment, monitoring and control are encouraged.

The Convention on Biological Diversity (or Chapter 17 of Agenda 21) was adopted by UNCED in Rio de Janeiro in 1992. It contains seven programme areas of which one specifically addresses marine environmental protection. Whereas UNCLOS dealt with the prevention, reduction and control of marine pollution, the marine environmental protection programme in Chapter 17 of Agenda 21 acts to implement the UNCLOS provisions. The approaches used in this programme are to initiate preventive, precautionary and anticipatory measures, and emphasis is placed on using economic incentives, and pegging costs to environmental degradation. Again, a holistic approach to the management of marine pollution is taken, endorsing methods which are integrated and sustainable, strongly encouraging the participation of local and national agencies to build up activities that involve collaboration regionally and internationally.

In addition to these main international initiatives, other conventions that have taken place also complement the objective of preventing and managing marine pollution. Among them are the 1969 International Convention on Civil Liability for Oil Pollution Damage (CLC), the 1972 London Dumping Convention (LDC), the 1973 International Convention for the Prevention of Pollution and the Protocol of 1978 (MARPOL 1973/78), and the 1990 International Convention for Oil Pollution Preparedness, Response and Cooperation (OPRC).

REGIONAL PROGRAMMES

Apart from the international initiatives that aim to address the problem of marine pollution, there have also been regional programmes that deal with similar issues. The following are examples of such programmes within the South China Sea region:

In Southeast Asia, the Association of Southeast Asian Nations (ASEAN) comprising the countries Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand, has emerged as an important economic and political entity. The countries of ASEAN have successfully collaborated to implement many regional programmes, some of which directly address issues of marine pollution. For example, the ASEAN Committee on Science and Technology (COST) together with its dialogue partners from Australia, Canada, USA, the European Economic Commission and Japan have developed relevant programmes to better manage marine pollution in the ASEAN region, including improving pollution monitoring techniques and resource assessment. To further secure environmental health, an ASEAN Expert Group on Environment (AEGE) was established under COST in 1978, with specific objectives to deal with environmental issues in ASEAN. Some of the projects of the AEGE directly deal with marine pollution matters, in particular oil pollution.

Other collaborative projects between ASEAN and countries like Australia, Canada and the USA have been reported in Chua (1994). These projects include the ASEAN-Australia Marine Science Project that deals with regional ocean dynamics and living resources assessment, the ASEAN-Canada Marine Pollution Project with the objective of determining environmental criteria for the protection of marine resources, and the ASEAN-US Coastal Resources Management Project that was aimed at developing a multidisciplinary and environmentally sustainable coastal area management plan for ASEAN.

In addition, many projects in the region have been initiated by the various agencies of the United Nations, for example, UNEP and the United Nations Development Programme (UNDP). The Coordinating Body of the Seas of East Asia (COBSEA) has developed many programmes dealing the marine pollution. Some of them address oil pollution problems, while others deal with various other forms of pollution. COBSEA was set up by UNEP under its Regional Seas Programme, and has as its agenda for action, an East Asian Seas Action Plan. A new programme initiated by the Global Environmental Facility (GEF) with the collaboration of UNDP and the International Maritime Organization (IMO), began in 1994. This programme, the Prevention and Management of Marine Pollution in the East Asian Seas specifically looks at effective prevention, control and mitigation of marine pollution, and risk management in coastal and international waters of East Asia.

Shipping is one of the most important activities in the South China Sea Region, and understandably, initiatives from the region, and also the private sector, have developed to ensure that pollution from this activity, mainly oil pollution, is prevented and controlled. In ASEAN, a regional oil spill contingency plan was initiated by AEGE in 1970, and has developed to include the participation of IMO and UNEP. The ASEAN Council on Petroleum (ASCOPE) was formed to address environmental issues related to oil and natural gas exploration, while the ASEAN Senior Officials on the Environment (ASOEN) formed in 1990 is expected to ensure that the regional oil spill contingency plan is implemented successfully. In addition, another Oil Spill Preparedness and Response Plan (OSPAR) has been initiated, with Japan providing financial support to ASEAN for equipment to combat oil spills, and also the operation of an information network to document oil spills.

Private sector involvement in addressing oil pollution in the region has also been substantial, with the formation of action groups such as the Petroleum Industries Malaysia Mutual Aid Group (PIMMAG) in Malaysia and the Oil Industry Environmental Safety Group (OIESG) in Thailand. The Tiered Area Response Capability (TARC) and more recently, the East Asia Response Ltd. (EARL), formed by British Petroleum, Caltex, Exxon, Mobil and Shell, stocks equipment capable of handling oil spills of between 10,000 and 30,000 tons (Chua, 1994). Also, the Petroleum Association of Japan and the Japanese Ministry of International Trade and Industry have set up a supply base for oil spill response equipment in Singapore (Koh & Lim, unpublished).

In addition, various regional programmes ensure that international protocols and conventions that have already taken place are effectively implemented. For example, the Asia-Pacific Memorandum of Understanding on Port State Control in the Asia-Pacific Region signed by 18 port states in 1993, undertook to establish and maintain a system to ensure that all foreign ships visiting ports complied with the regulations set by the international conventions of MARPOL 73/78, the International Convention on Standards for Training, Certification and Watchkeeping for Seafarers (1978), the Convention on the International Regulations for Preventing Collisions at Sea (1972) and the IMO Convention No 147 Concerning Minimum Standards in Merchant Ships (1976) (Koh & Lim, unpublished).

Bilateral and sub-regional agreements also exist between countries of the South China Sea region to manage and control activities that carry the risk of marine pollution. For example, to reduce the number of accidents along the heavily used Straits of Malacca and Straits of Singapore, Indonesia, Malaysia and Singapore adopted and implemented the Traffic Separation Scheme (TSS), developed by the Tripartite Technical Experts Group (TTEG), which deals exclusively with technical matters pertaining to the prevention of pollution in the two straits. The TSS has been in operation since 1981, and a Vessel Traffic Information Scheme was set up in Singapore to ensure compliance with the TSS. Programmes such as the TSS are directly in line with the UNCLOS agenda of prevention of marine pollution by vessels at sea.

NATIONAL PRIORITIES

On a national level, individual countries in the region have specific laws to control pollution, as well as various monitoring programmes for the environment. However, countries differ in their approach to pollution control. In the control of solid wastes from land-based sources, for example, the countries of ASEAN have different national priorities (Chua *et al.*, 1992; Table 1). The following are some examples of pollution control programmes in individual countries:

Table 1. Summary of legislation concerning waste management in the ASEAN countries.

NATION	LEGISLATION
Brunei Darussalam	Solid Waste Management Plan (1987) National Water Quality Standards Study (1987)
Indonesia	Public Water Law (1936) Nuisance Ordinance (1926) (Amended 1940) PD 7 (1973) Ministry of Agriculture Directives (1973-1975) Environmental Management Act (1982) Act 4, 1982, Basic Provisions for Environmental Management PROKASIH (1989) Act 24, 1992, Spatial Planning Regulations Government Regulation 20, Hazardous Waste Management (1993) Government Regulation 51, Analysis of Impacts upon the Environment (1993) Ministerial Decree, 1992, River Cleaning Programme Act 5, 1994, Ratification of Biological Diversity Convention Act 6, 1994, Ratification of Climate Change Convention
Malaysia	Land Conservation Act (1960) Waters Enactment Act (Amended 1970) Mining Enactments 146/147 Street Drainage and Building Act (1974) Local Government Act (1976) Rearing of Pigs Enactments (1975, 1980) Environmental Quality Act (1974) (Amended 1985)
Philippines	Republic Act 3931 (Amended by Presidential Degree (PD) 984 (1964) PD 600 (1967) PD 463 (1974) PD 1151 (1977) PD 1152 (1977) PD 1586 (June 1978/June 1982) PD 1121 (1977) Several other PDs
Singapore	Prevention of Pollution of the Sea Act (1971) Water Pollution Control and Drainage Act (1975) Trade Effluents Regulations (1976) (Amended 1977) Singapore Port Regulations (1977) Environmental Public Health Act (1978)
Thailand	Fishery Act (1947) Toxic Substance Act (1967) Environment Quality Act (1975) Sec. 17 National Environment Promotion Bill of 1976 (Amended 1978) Public Health Act 1041) and Factories Act (1969) (Amended 1975 and 1979)

In Brunei, red tides, directly related to the quality of water, have been a concern of the Government since its reported occurrence in 1976. Matdanan & Selvanathan (1984) documented red tide occurrences and their monitoring in detail. Regular checks on water samples are conducted, with toxic assays conducted on the mussel *Perna viridis*, by the Fisheries Department. A National Water Quality Standards Study was launched to address this problem, in 1987.

In the Philippines, many Presidential Decrees and Acts have been issued to tackle the problem of pollution. They include the Republic Act 3931, PD 600 (1967), PD 463 (1974), PD 1121 (1977) and PD 1151 and 1152 (1977). The National Pollution Control Commission (NPCC) spearheaded three programs to monitor water quality, discharge zones and to study physical oceanography in the southern outfall area of Manila Bay, and provided a good opportunity for inter-agency linkages. The NPCC is also monitoring 5 rivers in the Metro Manila area, and 6 rivers outside Metro Manila, to determine long term and seasonal changes in the physical and chemical characteristics of the river water. In addition, baseline studies of over 200 other major rivers and water bodies have been conducted.

There is also a significant contribution from various universities in the Philippines in the area of pollution research, with up to 30% of total pollution research conducted by the universities. Major fishing grounds are monitored by the College of Fisheries, University of the Philippines in the Visayas, while the Marine Science Institute of the University of the Philippines has collaborated with the Bureau of Fisheries and Aquatic Resources, the Natural Resources Management Centre and Silliman University to monitor coral reefs and its organisms.

In Singapore, a central agency coordinates and implements controls on pollution. The Pollution Control Department (PCD) of the Ministry of the Environment is responsible for environmental planning and building development control, air and water pollution control, hazardous substances and toxic wastes management. Industries may be required to conduct environmental impact assessments, including measures to reduce and control discharges of waste water and cooling water, and the disposal of wastes. Industrial effluent must meet the standards set by the PCD, which is backed by several Acts and Regulations, for example, the Trade Effluent Regulations, 1976 and the Poisons Act (Hazardous Substances Rules, 1986). The collection and disposal of toxic industrial waste is also controlled through licensing. Recently, a comprehensive "environment" law covering all aspects of the environment was drafted, and is expected to be presented to Parliament within the next two years (Anon., 1994).

Tolentino (1988) provides a good review on the legislation in the ASEAN countries dealing with marine pollution.

PROBLEMS AND CONSTRAINTS

A major constraint in the implementation of pollution prevention and management measures is the high costs involved, and the time required for the programme to be effective. For example, the programme to clean up the Singapore River totalled S$ 300 million over 10 years. Rehabilitation programmes for larger water bodies, such as Pasig River in Manila and Chao Praya River in Bangkok would certainly require more funds and time.

Coupled with the high costs of the management of pollution, the lack of financial support and technical expertise for implementing pollution programmes also exacerbates the problem in this region. Although countries may be signatories of a particular treaty or convention, and legislation may already exist in the constitution, many nations are unable to ratify the conventions, and implement the regulations effectively. To date only Brunei Darussalam, Singapore, Indonesia and Vietnam have ratified the MARPOL Convention. The lack of technical capability and financial resources have hindered its implementation in other countries (Chua, 1994). Also, although UNCLOS will enter into force on 16 November 1994, only Indonesia, the Philippines and Thailand have ratified this convention.

To compound the problem of lacking financial support, policy makers generally view pollution prevention programmes as an irrecoverable investment, and these projects are therefore not considered a high priority for funding. The monitoring programme by the NPCC in the Philippines for example, could be extended to other areas if adequate funding, facilities, equipment and technical manpower, were made available.

Present day pollution management initiatives call for integrated planning, and protocols that allow for sustainable development. However, countries in this region often lack the experience of implementing practical approaches to integrated and sustainable management measures for the marine environment. Because of the lack of expertise in this region, temperate-zone models and regulations are often ineffectively modified for the tropics. In addition to building up expertise in integrated and sustainable management of pollution, there is a need to convince policy makers that environmental protection and economic development are compatible.

The problem of a lack of experience is also evident in the much researched field of oil pollution. The Exxon-Valdiz incident is one such example. The response to the spill, while admirably swift, was ineffective in preventing the spill from spreading. The disaster has so far cost Exxon US$2.9 billion on the environmental cleanup alone, and billions more in lawsuits (Yoder, 1994). The capabilities of the various oil spill response groups set up in the region have not been tested (Chua, 1994).

In most countries, development plans are based on single-purpose, exclusive assessments of land and water-use. Various agencies take specific measures to manage specific habitats and areas, and often no Ministry or Department coordinates the implementation and enforcement of anti-pollution laws. In Brunei for example, 9 departments from 4 Ministries (Matdanan *et al.*, 1987) are each responsible for implementation of legislation and in the development and study of coastal areas. On the regional level, data management and methodologies used by various countries differ, making comparisons and inter-calibrations difficult. Clearly, more coordination within each country and collaboration within the region are essential if marine pollution management is to be successfully implemented.

PROPOSALS FOR FUTURE PROGRAMMES

One of the first measures essential for a marine pollution control programme to be effective is a regular monitoring programme for the environment. In the past, pollution monitoring protocols only involved the chemical analyses of pollutants in the environment. Presently, the monitoring of changes in genetic, biochemical, physiological and ecological parameters caused by contaminants in the biota has seen widespread applications. The advantage of this method over straight contaminant measurement is that it demonstrates changes taking place in the environment, with changes in parameters measured taken as a basis for further investigation (UNEP, 1993). However, since results are sometimes difficult to interpret, biological monitoring should be used in conjunction with existing chemical contaminant level studies.

Integrated monitoring is defined as the repeated measurement of a range of related environmental variables or indicators in the living and non-living components of the environment, and the investigation of the transfer of substances or energy from one ecosystem to another. The success of this holistic approach requires the use of a set of standard methodologies and failure to do so has hindered international cooperation in the past (UNEP, 1993). Among the networks that exemplify international integrated monitoring are the Global Ocean Observing System (GOOS) and the UNEP Global Environment Monitoring System (GEMS), which monitors priority pollutants at remote sites, in marine and fresh water, the atmosphere and in the biota. With proper training and financial support, countries in this region may utilise these existing integrated monitoring systems effectively.

Due to the transboundary nature of marine pollution, a practical approach would be to deal with pollution at the source. At the local level, strict enforcement is necessary at all sources to combat marine pollution. UNCLOS and UNCED (Agenda 21) not only provide legislative support for implementing and enforcing regulations within the boundaries of each country, they also require member states to cooperate on a global or regional basis in formulating international rules, standards and practices to handle pollution problems (Koh & Lim, unpublished). In Singapore the "polluter pays" principle can be illustrated in its pollution laws. In cases of unlawful discharges from ships for example, the master, the owner and the agent of the ship are individually liable to a fine not exceeding S$10,000 or imprisonment (not exceeding 2 years) or both.

In addition, more regional initiatives should be made to promote UN conventions like UNCLOS and Agenda 21, so that decision makers may be convinced to ratify and implement the regulations in their countries.

This region urgently requires practical marine pollution models to be developed. Effective models can then be used for integrated coastal zone management strategies, which should also involve local governments and industries (Chua, 1994). The development of such models require the collaboration of experts from the various countries. Chua (1994) recommended the development of regional networks for the purpose of exchange of expertise, or the expansion of existing networks for the region. For example, the Association of Southeast Asian Marine Scientists (ASEAMS) links scientists from various fields of marine science in the Southeast Asian region. Clearly, there is also a need for a regional network of experts on marine pollution monitoring and management of databases. Regional networks may also be linked to global networks so that scientists may seek inputs from international experts in the area of pollution management, and vice versa.

Increased bilateral and regional collaboration to deal with specific pollution prevention measures should be actively encouraged. The success of the TTEG in implementing the TSS is one example of how countries sharing the same water-bodies could develop strategies to minimise accidents at sea.

Since financial support is essential for any programme to be sustained, sources of funding should be actively sought, in particular to fund regional initiatives on pollution prevention and control. Koh & Lim (unpublished) have suggested that some form of tax or fee be levied for the users of coastal waters, e.g. the Strait of Malacca. A large source of funds may be obtained from such a scheme as more than 117 million barrels of crude oil pass through the Strait bound for countries like USA, Japan and Australia . Support from these countries both financially and technically could ensure that safety measures are implemented. In addition, private companies can also play an important part in the prevention of pollution from industry, for example, oil spills.

In conclusion, the South China Sea contains valuable resources that the populations in the region depend upon for their livelihood and economic development. Rapidly expanding populations and development has increased the threat of marine pollution in the region. Although many international initiatives to prevent and control marine pollution exist, countries in this region still require financial and technical support to fully implement these initiatives. There is also much potential in the development of regional cooperation in this area. Apart from seeking sustainable sources of financial support for increased regional programmes, integrated monitoring programmes, regional and global networking and technical support are just some other ways that regional cooperation may be fostered in the prevention and response to marine pollution in the South China Sea.

REFERENCES

Anon., 1992. State of the Environment in the Asia and the Pacific, 352pp.

Anon., 1994. Umbrella environment law drafted. The Straits Times, September 9, 1994, Singapore.

Chansang, H., 1988. Coastal tin mining and marine pollution in Thailand. Ambio 17(3): 223-228.

Chou, L.M., 1994. Marine environmental issues of Southeast Asia: state and development. Hydrobiologia 285: 139-150.

Chua, T.E., 1994. Marine pollution: Developments since UNCLOS III, and prospects for regional cooperation in Southeast Asia. Conference on Sustainable Development of Coastal and Ocean Areas in Southeast Asia: Post-Rio Perspectives, 26-28 May 1994, Singapore.

Chua, T.E., L.R. Garces & C.J. Edmonds, 1992. Waste Management in the coastal areas of the ASEAN Region: a need for action. In: Chua T.E. & L.R. Garces (eds.), Waste management in the Coastal Areas of the ASEAN Region: Roles of Governments, Banking Institutions, Donor Agencies, Private Sector and Communities. ICLARM Conf. Proc 33: 197-205.

Chong, V.C., A. Sasekumar, M.U.C. Leh & R. D'Cruz, 1990. The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mudflats and inshore waters. Estuar. Coastal Shelf Sci. 31: 703-722.

Chong, V.C., A. Sasekumar, W.S. Atmadja & J.K.Y. Low, 1994. Status of mangrove prawn fisheries in the ASEAN countries. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds.), Proc. ASEAN-Australia Symp. on Living Coastal Resources, Vol. 1, Status Reviews, Australian Institute of Marine Science, pp. 385-391.

GESAMP, UN/UNEP/FAO/UNESCO/WHO/IMO/IAEA, 1969. Group of Experts on the Scientific Aspects of Marine Pollution. Rep. 1st meeting.

GESAMP, 1990. The state of the marine environment. UNEP Regional Seas Report and Studies No. 115.

Gomez, E.D., 1988. Overview of environmental problems in the East Asian Seas region. Ambio 17(3): 166-169.

Guerrero, R.D., E.C. Llaguno & J.A. Ordonez, 1987. Status report on pollution and other ecological factors in relation to living marine resources in the Philippines. Proc. ASEAN-Canada Regional Workshop on Pollution and Other Ecological Factors in Relation to Living Marine Resources, 23-26 June 1987, Phuket, Thailand, Pp. 172-187.

Hammond, A.L., D. Estes & R.T. Livernash, 1994. World Resources 1994-95. The World Resources Institute, the United Nations Environment Programme and The United Nations Development Programme. Oxford University Press.

Koh, K.L. & C.A.C. Lim, unpublished. Coastal and offshore industries: Legal frameworks for the protection and preservation of the coastal and marine environment. Paper presented at the Asia Pacific 94 Oceans Seminar & Exhibition, 22 & 23 Aug 1994, Singapore.

Lane, D.J.W., 1991. Growth of scleractinian corals on sediment-stressed reefs at Singapore. In: A.C. Alcala (ed.), Proc. Regional Symp. on Living Resources in Coastal Areas, University of the Philippines, pp. 97-106.

Langham, N.P.E. & J.A. Mathias, 1977. The problems of conservation of coral reefs in North-west Sabah. Mar. Res. Indonesia 17: 53-58.

Low, J.K.Y & L.M. Chou, 1994. Sedimentation rates in Singapore. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds.), Proc. ASEAN-Australia Symp. on Living Coastal Resources, Vol. 2, Research Papers, Australian Institute of Marine Science, pp.

Matdanan H.J., M.W.R.N. De Silva & S. Selvanathan, 1987. Status of studies on pollution and other ecological factors in relation to living marine resources in Brunei Darussalam. Proc. ASEAN-Canada Regional Workshop on Pollution and Other Ecological Factors in Relation to Living Marine Resources, 23-26 June 1987, Phuket, Thailand, pp. 9-21.

Matdanan H.J. & S. Selvanathan, 1984. Occurrences of red tide in Brunei Darussalam and methods of monitoring and surveillance. In: A.W. White, M. Anraku & K.K. Hooi (eds.), Toxic Red Tides and Shellfish Toxicity in Southeast Asia. Southeast Asian Fisheries Development Centre, Singapore and International Development Research Centre, Ottawa, pp. 17-24.

McManus, J.W., 1988. Coral reefs of the ASEAN region: status and management. Ambio 17: 189-193.

Munro, J.L. & D. M.B. Williams, 1985. Assessment and management of coral reef fisheries: biological , environmental and socio-economic aspects. Proc. 5th Int. Coral Reef Symp. 4: 543-581.

Patin, S.A., 1982. Pollution and the Biological Resources of the Oceans. Butterworth Scientific, London.

Salm, R.V. & I.M. Halim, 1984. Marine Conservation Data Atlas. Indonesia. IUCN/WWF Project 3108.

Smith, S.V. 1978. Coral reef area and the contributions of reefs to processes and resources of the world's oceans. Nature 273:225-226.

Thayib, S.S. & M.H. Thayib, 1987. Marine pollution in northern coastal waters of Java: a status report.

Proc. ASEAN-Canada Regional Workshop on Pollution and Other Ecological Factors in Relation to Living Marine Resources, 23-26 June 1987, Phuket, Thailand, pp. 30-54.

Tolentino, A. Jr., 1988. Legislative response to marine threats in the ASEAN subregion. Ambio 17(3): 238-242.

UNEP, 1993. Environmental Data Report 1993-94. Blackwell Publishers, Oxford. 408 pp.

Yoder, E.M., Jr., 1994. Exxon's billion-dollar "lesson" may exact some high costs indeed. Extract of article from the Straits Times, 23 Sep 1994, Singapore.

ECONOMY AND ENVIRONMENTAL STRESS ON THE COASTAL ZONE OF VIETNAM

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ABSTRACT

This report describes the significance of coastal areas in Vietnam and conflicts arising from their development. Principal causes of environmental stress in the coastal zone are the increasing population and economic pressures from a variety of coastal activities. The situation of decreasing renewable resources and increasing environmental degradation requires urgent attention calling for integrated management of the sea and coastal space with considerations over present socio-economic structures.

INTRODUCTION

Coastal areas are economically and ecologically important throughout the world and especially in countries of the ASEAN region such as Vietnam. Based on surveys and investigations conducted, the benefits of the coastal zone, state of the coastal environment and human activities on the marine area environment throughout Vietnam was assessed. This included data on demography, resources and economic use. Our research shows that it is important to develop integrated management plans of coastal space which recognises socio-economic conditions.

MATERIAL AND METHODS

Analyses were made based on the collections of past research work by the Institute of Oceanography since 1923 when it was founded to the present. Additional data were obtained from sources such as the Vietnam National Statistic Yearbooks of 1986 to 1993.

RESULTS AND DISCUSSION

Demographic data

The attraction of the coastal zone for human habitation is widespread. The population trends of 26 coastal provinces including 118 districts and towns were investigated. The coastal regions account for 23% of total population (about 16.5 million in 1993, 17% of which live in towns and cities), and the density is about 276 persons/km^2. The population density in the coastal provinces (about 106-2,010 persons/km^2) is higher than that of non-coastal provinces, and 1.3 times higher than the average population density of Vietnam. The annual rate of natural population increase is about 2.5% per year. In the coastal region of Mekong delta plain, the annual population increase rate is highest at about 4%. Perhaps the important factor influencing the change of population density is migration. There has been a dramatic reversal in movements of people in the coastal zones after the liberation in 1975. The coastal regions of Mekong delta plain have been flooded recently by a wave of a million emigrants from other areas.

Most of coastal cities and towns are showing increase in population. The population of the small city of Vung Tau (near Ho Chi Minh City) was 6,000 in early 19th Century. In 1954 it grew to 24,000 and in 1993, it reached 151,012, a 6-fold increase within 40 years. The same picture occurs in other cities, such as Da Nang and Nha Trang. Subsequent settlement in the coastal zone will obviously put stress on the available resources. The demographic change will increase demands upon resources, food, transportation as well as waste discharge in the coastal zone. Our research on the environmental status of coastal waters of Nha Trang showed that a person discharges about 0.5kg garbage per day. All of Nha Trang city discharges about 96 tons of garbage per day (Nguyen, 1991). Gibbs (1979) (in Nguyen, 1991) suggested that each person discharges an average of about 0.54kg phosphor per year which means that the whole population of Nha Trang city puts into the coastal environment about 140,000kg phosphor per year. This creates a big stress on coastal waters, specially through the eutrophication phenomenon.

Coastal economy and environmental stress

In the coastal zone there is a workforce of about 7 million involved in the following: agriculture, forestry and mariculture (71.2%), fisheries (10.4%), facilities (6.6%), industry and handicraft (5.6%) and salt production (1.3%). Unemployed workforce was estimated at 4.9% (according to statistical data of 1991-1993). The coastal zone has a very important role in the economy of Vietnam. Investigations of economic change in the coastal zone and its socio-economic impacts should be considered as important. The coastal economy is presumed to have 5 important parts: agriculture, industry, energy, tourism and transport.

Industry

Petroleum is a key economic product on the continental shelf of Vietnam. The production of crude oil is rising 30% per year: 0.3 million tons in 1987, 2.8 million tons in 1990, and 7 million tons in 1994. The main exploited fields are Bach Ho, Dai Hung and Rong located offshore in the southeastern part of Vietnam. Estimated oil reserves on Vietnam's continental shelf is about 10 billion tons of which 4-5 billion tons can be extracted together with about 250-300 billion tons of accompanied gas. Raw petroleum, drilling solutions, and chemicals can be discharged from oil and gas exploitation. About 20,000 tons of petroleum have been discharged into the sea per year (data from Vietnam Environmental Management Center). If the leakage rate of 0.7% of total exploited amount is taken, we can expect that oil pollution will be very serious in the future.

Coastal industry comprise also of processing frozen seafood, garments for export, leather shoes. Other industries include ship building, manufacture of construction material, ice making, mosaic bricks manufacture.
Industrial productions are not developed yet, but their untreated waste can seriously pollute the coastal zone.

Fisheries and aquaculture

Fisheries and aquaculture are important benefits of the sea. Fisheries production potential is estimated at 1-1.5 million tons (Figure 1, Table 1). In 1994, fisheries production was 820,000 tons. This includes many kinds of valuable marine products: shrimps, cuttlefish, mackerels, sardines, snails. Along the coastal zone there are many fishing villages. Human impact on fish resources is an urgent issue requiring protection of the resources in the future. From the biological point of view, fish stocks in tropical seas are relatively stable due to the wide composition of commercial species (although concentration is not as high), early maturation, prolonged spawning season, wide spectre of food chain, etc. Results of research on fish catches indicate some increase of trash fish but decrease of some valuable species such as grunt, snapper and croaker, compared with 10 years earlier (Nguyen & Nguyen, 1994). It is therefore necessary to enforce measures for the protection of these resources, even though marine fisheries is exploited by small engined boats and that most fishing activities take place within one day rather than continuously over a few days.

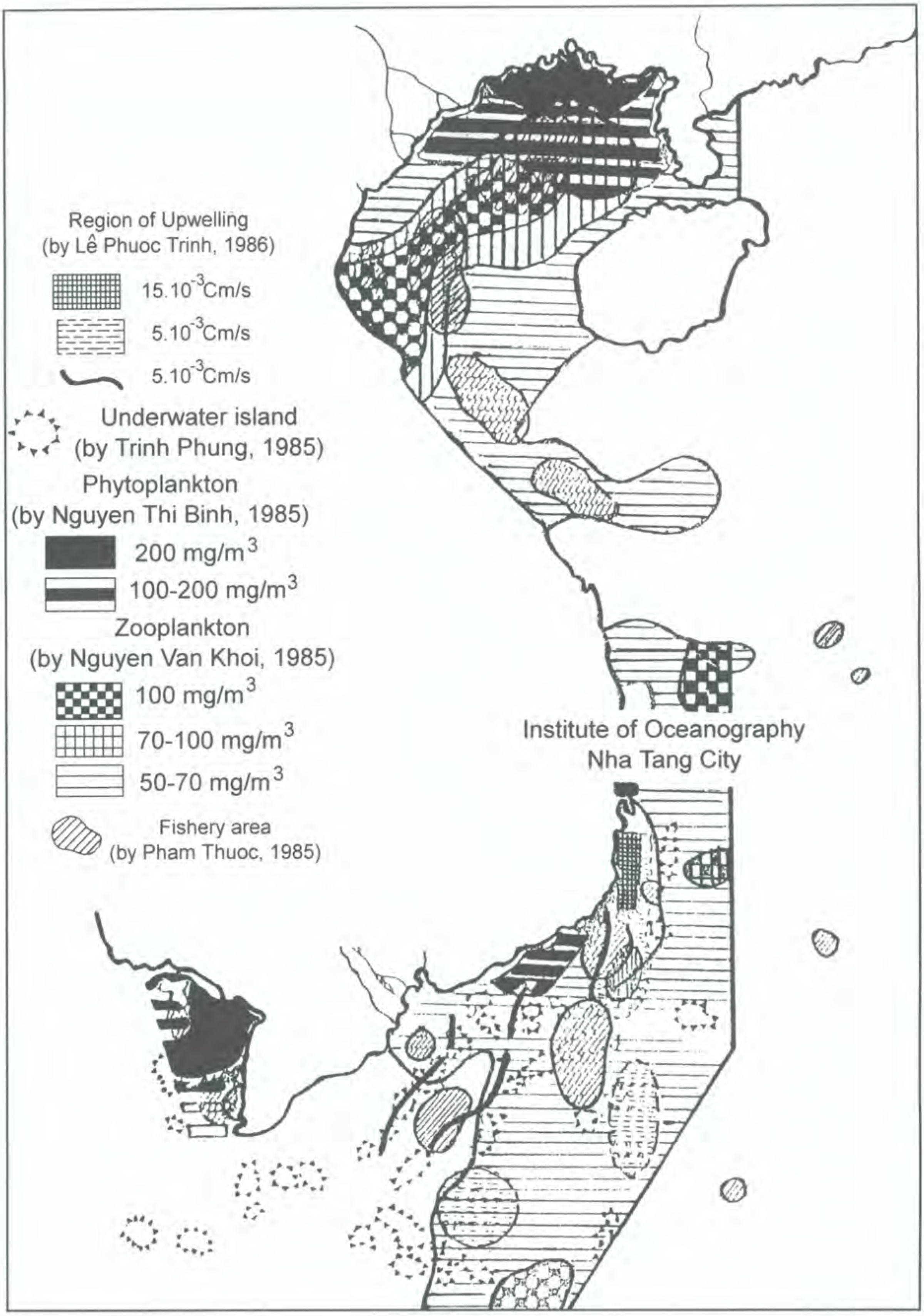

Figure 1. **Main areas of biological production with special oceanographic conditions.**

Table 1. **General estimation of fishery resources in the coastal waters of Vietnam (million tons) (After Nguyen, 1989)**

AUTHOR	ABSOLUTE RESOURCE	POSSIBLE CATCH
Nguyen Tien Canh*	2.49	-
Phan Thuoc**	3.53	1.6
Le Trong Phan***	2.95	-
Nguyen Tac An****	3.40	1.1
Nguyen Tac An*****	3.08	1.0

Average fishery catch for 20 years : 0.7 (0.3-0.8)

* 1984, by biomass feed phytoplankton and zooplankton

** 1984, by fishery catch

*** 1985, by fishery catch

**** 1984, by primary production

***** 1988, by energy balance

An urgent problem presently existing is the widespread use of explosives for fishing which breaks down the coastal ecosystem and kills many fish species unnecessarily. In addition, rules should be worked out for limiting bottom trawling, mesh size, fishing season, and fishing grounds in shallow coastal waters with depths of less than 40 meters.

Environmental conditions of Vietnam's coastal zone are suitable for developing aquaculture. Among 300,000 hectares of land covered by tidal waters, 220,000 hectares are being used to cultivate shrimps and crabs by intensive and semi-intensive methods. Yields range from 200 to 1,200kg/ha. There are two levels of mariculture: farming and ranching. Both farming and ranching of marine organisms, like their equivalents on land, have self-generated and imposed impediments to success. Firstly, these activities compete for coastal sea space with other demands such as transportation, recreation and waste disposal sites. Secondly, continued expansion and existing practises can jeopardize the quality of the environment causing decrease of resources. The following are some of the problems generated by mariculture in Vietnam: (1) competition with natural populations; (2) genetic contamination; (3) decrease of natural habitats; (4) impacts of waste disposal; (5) alteration of the quality of the water column and (6) creation of anoxic environments.

Transportation

Located along international sea routes, Vietnam's coastal zone has a well developed system of 52 seaports among which Da Nang, Qui Nhon, Nha Trang, Vung Tau and Saigon are well-known. Marine transportation in the coastal zone reflects the change in economic conditions of the country. It is now relatively heavy with a density of 30-50 ships/km^2 in the region limited by 50m isobath.

Alteration to life processes in an area surrounding the port can be expected - fishing and nursery grounds of fish can be changed or eliminated. Dredging itself interferes with sediment transport processes. Finally, the increase in ship loading and unloading can put additional stresses upon the port vicinity through the entry of alien materials and non-indigenous organisms to the waters.

Perhaps the most ecologically damaging impact of ship movements is the transport of organisms in ballast water. The biota from the area in which the water is taken can often survive the journey to the discharge site, especially where temperature and salinity differences are small. Mallegraff *et al.* (1991) (in Nguyen & Nguyen, 1994) showed the impact involving the transportation of harmful organisms (toxic dinoflagellates *Alexanfrium cultinella* and *A. tamarense* for example) from one port to another in the ballast water of ships.

Tourism and recreation

Vietnam's coastal zone is an ideal place for tourism and vacation for national and international visitors. Along the coast, 125 beaches have been designated for tourist activities, but only 20 among them, mainly Da Nang, Nha Trang, Vung Tau, are used. Tourism remains small with 1 million national tourists and 0.5 million international tourists per year, because conditions and services for tourism are poor. In the other countries, marine recreational activities take the following :

- beach activities with water contact encompass swimming, wading, surfing, wind-surfing, snorkelling, skin-diving and scuba-diving. Non water contact open-beach activities include hang-gliding, horse back riding, outdoor sports, dune buggy driving, walking, jogging, sun bathing, fishing and shell-fishing and camping.
- boating activities involve sailing scuba-diving and pleasure boating, including water skiing.
- sports fishing.

These kinds of marine recreation may take place in Vietnam in future. Recreational activities today involve mainly water contact swimming. The needs of coastal zone space to satisfy tourist demands include sites for hotels, recreational activities on beaches, transportation facilities (berths for ships, marinas, guided tours, adequate highways) and restaurants. For Vietnam, tourism is a substantial part of the economy, but there is interference in the continuous development of tourists ventures.

Marine transportation is a substantial part of tourism but can have a serious negative impact on the environment through deliberate or accidental discharges from vessels. Beaches soiled by oil or litter do not attract visitors. Pathogens are major problems. Micro-organisms stemming from domestic waste disposal into marine waters will jeopardize the quality of seafood and recreational activities on beaches in Vietnam. The eutrophication in coastal areas can aesthetically insult beaches and adjacent waters through the accumulation of rotting marine plants. This happens in some places of central and southern Vietnam, especially in coastal areas, where there is developed agriculture and marine aquaculture.

Improving the benefits of coastal resources and quality of the environment necessitates development of protected areas like marine parks. This has proved especially promising in Cu Lao Cham Island (Quang Nam-Da Nang), Mun Island (Khanh Hoa), Cau Island (Binh Thuan), Con Dao and Phu Quoc Island (Kien Giang).
The protection of marine resources can come about through regulation at various national and international levels.

CONCLUSIONS

The coastal zone has great importance to the economy of Vietnam. The South China Sea is a large marine ecosystem and any change in one place can influence other places. So the investigation of economic change and economic-social-ecological impacts upon the coastal areas should be of importance today and in future not only for Vietnam but also for other countries. Statistical data indicate that the marine economy contributes 26% of the national Gross Domestic Product (GDP) (average GDP is 310 USD/person/year). The economic potential of the coastal zone however is much greater and can be realised if effective management is taken to contain the impacts already evident.

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REFERENCES

Nguyen, T.A., 1989. The biological productivity of marine waters in coastal zone of Vietnam and their ecological conditions. Unpublished Dr. of Sc. dissertation. 400pp.

Nguyen, T.A., 1991. The report on environmental conditions of coastal region at Nha Trang City, 150pp.

Nguyen, T.A. & V.L. Nguyen, 1994. The study on fishery resources and environmental conditions for planning and developing the coastal economy of Tra Vinh, delta Mekong. Nha Trang, 176pp.

Vietnam National Statistics Yearbook, 1986-1991, 1994.

THE ASEAN-AUSTRALIA LIVING COASTAL RESOURCES PROJECT: A COOPERATIVE CONTRIBUTION TO ASIAN MARINE SCIENCE

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ABSTRACT

The ASEAN-Australia Living Coastal Resources (LCR) project started in the early 1980s when senior ASEAN scientists signalled the need for a closer examination of their coastal resources. The LCR project was funded from 1985 to 1995 by the Australian government, with expertise coming from the Australian Institute of Marine Science. The research and monitoring activities were conducted by ASEAN marine scientists and their students out of universities and research institutes. The LCR project focused on assessing and researching coastal resources using techniques ranging from direct transect measures of resource status to the use of remote sensing to examine large areas. The reasons for success were that this was a predominantly scientific project devised and managed by ASEAN scientists with solid funding and expertise from Australia. The project has: held three international symposia with over 250 publications in the proceedings; published the world's most substantial manual for the assessment of coastal resources; published over 1000 other papers and reports; established the world's largest regional database on the status of coral reefs, mangroves, seagrasses and sediment areas; contributed significantly to understanding by government of resource status and the need for active management; assisted in training many young scientists and providing them with experience; and contributed to developing a large and closely interacting network of marine scientists. All these resources are now available for use by Asian marine scientists for the sustainable management of their living coastal resources.

HISTORY OF THE LIVING COASTAL RESOURCES PROJECT

The Early Stages

In the early 1980s, senior scientists and resource managers from the ASEAN countries recognised that their living coastal resources (coral reefs, mangrove forests, seagrass beds and soft bottom resources and fisheries) were showing signs of severe stress (Boto, 1991; Sudara, 1991). There was need for a collaborative effort to understand the extent of the problem and search for solutions. These people approached the Australian Government through the ASEAN Working Group on Marine Sciences, a sub-committee of the ASEAN Committee on Science and Technology (COST; Soegiarto, 1984).

The Australian International Development Assistance Bureau (AIDAB, now the Australian Agency for International Development - AusAID) recognised these concerns and asked the Australian Institute of Marine Science (AIMS), through Dr Don Kinsey, to develop a collaborative project (Boto, 1991). The project themes were accepted and funding guaranteed for the Phase I period of 1984 -89.

The goals of LCR Phase I were:

- To generate quantitative, management-relevant baseline information on the community structure and distribution of recognised resources within the coral reef, mangrove and nearshore soft bottom ecosystems in the ASEAN region;
- To generate equivalent information for identified examples of polluted coastal environments;

- To develop scientific and technical expertise within the ASEAN region and ensure long-term capability in the acquisition of management-relevant data on coastal ecosystems;

- To facilitate the planning of specific environmental experimentation to test the application of the baseline information to management objectives;

- To develop a network of information exchange such that the overall benefit reflects a regional approach;

- To apply the baseline information obtained to the development of coastal zone management policies, both in the interest of the individual nations and in regional interests of ASEAN.

The Second Phase

The considerable successes achieved during Phase I attracted favourable reports from both ASEAN countries and Australia and these were the basis for planning of a second phase (Wilkinson, 1992). The consultation process in ASEAN was through a committee coordinated by Dr Kevin Boto of AIMS in 1989. AIDAB provided steady funding for LCR Phase II with A$0.726 to $1.004 million annually for 1989-94. During this period, the LCR project was combined with the Regional Ocean Dynamics project to form the ASEAN-Australia Marine Science Project to assist in administration and promote cooperation between the two marine projects.

Phase II (1989-94) continued the objectives of Phase I (1984-89), but built on them by adding:

- To determine, on a regional scale, the medium to long-term stability of the major living coastal resources and biotic and abiotic factors affecting degradation, recovery or success of natural or artificial rehabilitation;

- To determine the degree and mode of connection between the major coastal ecosystems viz., mangroves, soft bottom communities and coral reefs, with particular regard to commercial fisheries and long-term impact prediction;

- To use the information derived from above for the development of living coastal resource management models/policy and for enhanced alternative-use-strategy assessments;

- To encourage and assist in the dissemination of the scientific information and management policy formulation to decision-makers and the general public at all social and economic levels, in order to increase social awareness of the present and potential resource value of living coastal resources;

- To enhance human resource development through specialised and general training programs.

Project Management and Activities

Throughout Phases I and II, decisions about the broader scientific themes of the project and allocation of monies were made by the Project Management Committee (LCR/PMC; Wilkinson, 1992). This contained 2 members from each of the 5 participating countries: Indonesia, Malaysia, Philippines, Singapore and Thailand; and was chaired by Professor Suraphol Sudara of Thailand. The Chief Technical Advisor from AIMS and the Project Manager from Australian Marine Science and Technologies Limited sat as observers on this committee.

Decisions about specific projects and the allocation of monies in-country were made by Project Technical Committees in each country, who met annually to prepare reports on activities and make recommendations for future project themes.

The bulk of activities were concerned with monitoring the status of the living coastal resources of coral reefs, mangroves, seagrasses and sediment areas and conducting research on how these systems functioned. In many instances, the field work was supported by providing rectified images obtained from satellites, which were processed on computers running the Australian MicroBRIAN image processing software in each country. The data was assembled into a large combined database, housed in the Department of Marine Science, Chulalongkorn University, in Bangkok.

In addition to research and monitoring, the LCR project held approximately 3 workshops each year on themes decided by the LCR/PMC. These ranged from re-evaluation of monitoring and research methods to training workshops on connectivity studies between ecosystems, training in advanced remote image analysis and computer database management. There were usually 2 representatives from each country and resource people were either drawn from the region, or Australia.

SCIENTIFIC ACHIEVEMENTS OF LCR

Coral Reefs

Scientists in the project examined approximately 50 sites in the 5 countries during the LCR project by placing almost a thousand transects on coral reefs. They have found that less than 20% of the reefs surveyed were in excellent condition with many showing distinct signs of stress (Chou, *et al.*, 1994a). Scientists reported that there were 783 species within the fish populations, although markedly reduced by strong fishing pressures (Aliño, 1994).

The reefs form several distinct assemblages based on the nature of communities. Thailand reefs were essentially similar in coral structure on east and west sides of the peninsular, but differed in species content; Malaysian and Singaporean reefs were similar and frequently resembled those in the Philippines; whereas the reefs in Java, Indonesia were different from the others. Groupings of fish populations showed that the Thailand, Malaysia and Singapore reefs were relatively similar; whereas the Indonesian and Philippine reefs showed another distinct pattern. Major differences reflected the physical setting of the reefs i.e. whether they were exposed to the full force of oceanic waves, or were protected by other land masses, or within bays.

Scientists also identified the major factors that were impacting coral reefs in the region, thereby providing advice to reef managers on impacts that should be reduced, to conserve coral reefs (Gomez *et al.*, 1994; Ridzwan, 1994; Sudara & Yeemin, 1994; Wilkinson *et al.*, 1994).

Mangrove Forests

The LCR project has demonstrated the economic value of mangrove forests as nursery areas for commercial species (Singh *et al.*, 1994), particularly for fishes (Sasekumar *et al.*, 1994), and prawns (Chong *et al.*, 1994). This is especially relevant as approximately 50% of ASEAN mangrove forest resources have already been cleared for prawn and fish ponds, woodchip and timber harvesting, and domestic and industrial development (Japar, 1994a). Catches of important species have peaked and are now declining through over-development of the fisheries via excessive capitalization in large trawlers (Chong *et al.*, 1994).

The region has particularly high biodiversity with approximately 110 species of mangroves and another 57 species of plants that are frequently found in mangrove forests (Japar, 1994a), along with 545 species of fish (Japar *et al.*, 1994). These forest losses will have major implications for the preservation of many species that are currently threatened with extinction (Low *et al.*, 1994).

Studies on mangrove productivity and reproduction have shown that they are also sustainable resources of both timber and woodchips, provided harvesting regimes are maintained within the natural ability of the forests to regenerate (Gong *et al.*, 1994; Sasekumar & Lim, 1994). Forests can be cleared on 20 to 35 year rotation cycles and still recover, provided sufficient old growth forest is retained to provide seedlings and prevent shoreline erosion.

While significant resources still remain in Indonesia (Atmadja & Soeroyo, 1994) and Malaysia (Gong *et al.*, 1994), there have been disastrous reductions (approximately 80%) in the Philippines (Calumpong, 1994), and Thailand (Kongsangchai, 1994), and 99% losses in Singapore (Ng & Low. 1994). The LCR studies are now sending clear signals to management of the economic benefits for sustainable exploitation and conservation of mangrove forests in the ASEAN region.

Seagrass Beds

These are vastly under-acknowledged resources within the ASEAN region, but they are particularly important nursery and feeding areas for much of the commercial prawn and fish catch from the ASEAN region (Poovachanon *et al.*, 1994a). The major reason for this poor recognition is that most beds occur below low tide, often in dirty water, such that they are rarely seen. There is, however, no coincidence that most of the major fishing grounds in the region are adjacent to seagrass beds.

Research undertaken by LCR scientists during the past 10 years has produced more understanding of the extent and role of seagrass beds than the previous 100 years (Fortes *et al.*, 1994). This research has shown that there have been considerable losses in seagrass beds due to damage from trawlers, pollution and sediment deposition.

Seagrass beds contain at least 318 fish species, of which many are either harvested from the beds for consumption or caught after they have passed their juvenile stages in the beds (Poovachanon *et al.*, 1994a).

Probably the largest and least known seagrass resources occur in Indonesia (Kiswara, 1994), and there are extensive resources in the Philippines (Fortes 1994) and Thailand (Poovachanon *et al.*, 1994b) where damage has been most noticeable. Singapore has few, but well studied, seagrass beds (Loo *et al.*, 1994). Seagrass studies have just re-commenced in Malaysia after a lag of 30 years (Japar, 1994b), showing large, previously unreported seagrass beds adjacent to major fishing grounds.

Soft Bottom Resources

The shallow continental shelf waters of the western ASEAN region support one of the world's most important trawl fisheries. Large amounts of river nutrients flowing off the land provide ideal circumstances for a food chain to support large commercial stocks of fishes and prawns. The LCR project made a major effort to assess these soft bottom resources, focusing particularly on the small animals on and in the soft sediment bottoms (Chou *et al.*, 1994b). The fauna is so rich in these areas that it was frequently not possible to identify animals to species level, or even to genus in many cases. Thus, most analyses were conducted at the family level.

Scientists assessed both the animal communities and biomass of the animal benthos at 35 sites off coral reefs, mangrove forests and seagrass beds as well as some offshore sites, remote from these coastal resources (Chou *et al.*, 1994b). Those sites adjacent to coral reefs had the richest assemblages of animals (295 Families). Sites near mangroves had 171 Families with seagrass sites having 103 Families and estuarine sites having a total of 198 Families (Chou *et al.*, 1994b).

Almost all sites showed distinct signs of stress particularly from over-trawling and pollution. Indeed some estuarine sites in Indonesia were so polluted that they were completely devoid of any animals in the sediments that were totally anoxic (Kastoro, 1994). Detailed studies of sediment communities throughout the Philippines showed that crustaceans and polychaetes were the most prominent animals found at most sites with sediment grain size being the major factor influencing the community composition and biomass, followed by depth and environmental stress (Narcorda *et al.*, 1994).

Studies in Singapore have been valuable in assessing the effects of environmental clean up operations in the Singapore River and adjacent harbour. The government found that the waterways were unacceptably polluted and decreed that all organic wastes be treated. This clean up was followed by scientists at the National University of Singapore, who showed that as the water quality increased, so did the size and diversity of animal sediment populations. Sites around the southern coral reefs and in the mangrove waterways of the Sungei Buloh nature reserve contained a rich fauna. These will be monitored for the effects of future development, including the dumping of domestic garbage on a converted coral reef site of Pulau Semakau (Chou & Loo, 1994).

Database

A unifying feature of the LCR project was the regional database established in the Department of Marine Science, Chulalongkorn University, Bangkok. The database was established early in Phase I of the project as the need and benefits of combining data at one location became apparent (Boto *et al.*, 1989; Reichelt, 1991).

The LCR project has assembled the world's largest regional database on coastal zone resources. This database contains almost a million data entries; some being raw data points, whereas others are data summarised from experiments or transect surveys. A major feature has been the design of structures necessary to allow easy entry of a wide range of biological and physical data and to ensure easy retrieval of those data for both science and management (Cheshire, 1994a).

A major problem associated with a regional database involving many researchers is the consistency of data entry. Earlier problems with inconsistencies (e.g. using several different codes to describe the same species) have been resolved through the use of full taxonomic names and with the implementation of checking programmes to verify the structure of the data (Cheshire, 1994b).

There are now published descriptions for categories of data e.g. coral reefs (Loo & Chou, 1994); mangroves (Japar, 1994c); soft bottoms (Soedibjo, 1994). It is intended that this database will be transferred to major international databases, once current analyses have been completed.

Remote Sensing

As a complementary mechanism to field studies of coastal resources, remote sensing was applied to view the systems at a much larger scale. The Australian MicroBRIAN system was introduced into each country along with the necessary computers, printers and satellite images. The technology and extensive training, both in the region and in Australia, have catalysed a massive increase in published material. For instance, there were no papers from the region prior to LCR, but since then there have been approximately 40-60 published in international journals, proceedings and reports (Thamrongnawasawat, 1994).

The technology has been particularly valuable in assessing the extent and productivity of mangrove forests (Ong *et al.*, 1992) and the impacts of sediment release on coral reefs (Mohd. Ibrahim & Japar, 1992).

OTHER ACHIEVEMENTS OF LCR

Conferences and Publications

There were three major conferences with attendances of approximately 100 at each. The first LCR international symposium was held in early 1989 in Manila, as part of the Second ASEAN Science and Technology Week. The 66 papers and 13 abstracts presented were published in:

- Alcala, A.C. (editor) 1991. Proceedings of the Regional Symposium on Living Resources in Coastal Areas. Marine Science Institute, University of the Philippines, Quezon City, 597pp.

The second symposium in Singapore was part of the Third ASEAN Science and Technology Week, 1992. The LCR project played a feature role producing the largest book of Proceedings with 57 papers and 16 abstracts, following meetings over 3 full days:

- Chou, L.M. and Wilkinson, C.R. (editors) 1992. Third ASEAN Science and Technology Week Conference Proceedings, Vol. 6, Marine Science: Living Coastal Resources, Dept. of Zoology, National University of Singapore and National Science and Technology Board, Singapore. 471pp.

The final Forum and Symposium of the LCR project, Phase II was held in May 1994 in Bangkok. This was an excellent testimony to the success of the LCR project with two volumes of Proceedings and a management oriented booklet. Volume 1 contains 41 reviews of the research and experience of ASEAN scientists:

- Wilkinson, C.R., Sudara, S. and Chou, L.M. (editors) 1994. Proceedings Third ASEAN-Australia Symposium on Living Coastal Resources, Vol: 1, Status Reviews, Chulalongkorn University, Bangkok Thailand, May 1994. Australian Institute of Marine Science, 454pp.

Research results of ASEAN scientists (Volume 2) contains a breadth of topics with 85 papers and 12 abstracts from the 126 presentations at the Symposium:

- Sudara, S., Wilkinson, C.R. and Chou, L.M. (editors) 1994. Proceedings Third ASEAN-Australia Symposium on Living Coastal Resources, Vol: 2, Research Papers, Chulalongkorn University, Bangkok Thailand, May 1994. Chulalongkorn University, 640pp.

The management oriented booklet contained 24 essays:

- Wilkinson, C.R. (editor) 1994. Living Coastal Resources of Southeast Asia: Status and Management. Report of the Consultative Forum, Third ASEAN-Australia Symposium on Living Coastal Resources, Chulalongkorn University, Bangkok Thailand, May 1994, Australian Institute of Marine Science, 144pp.

Personnel from the LCR project published 11 papers and 16 abstracts in the Proceedings of the 7th International Coral Reef Symposium (1993) held in Guam in June 1992 and have featured strongly in many other symposiums and international committees.

'ASEAN Marine Science' was the regular LCR newsletter, and the 20 issues were distributed widely. The project published a detailed prawn identification guide: 'A Guide to Penaeoid Shrimps Found in Thai Waters' by S. Chaitiamvong and M. Supongpan (Australian Institute of Marine Science, Townsville. 77pp.). These are but few of the several thousand papers, theses and reports to governments and international agencies produced during the LCR project.

Methods Development

The methods developed during LCR have achieved widespread international recognition as the most suitable for assessing coastal zone resources for all impacts, including climate change.

Senior ASEAN scientists developed the initial set of methods in collaboration with the Australian Institute of Marine Science in 1985 (Sudara 1991), and since then these have been published as two complete manuals, with revision developed during field work and discussions during workshops in the region.

- Dartnall, A.J. and Jones, M. 1986. A Manual of Survey Methods for Living Resources in Coastal Areas. Australian Institute of Marine Science, Townsville. 167pp.

- English, S., Wilkinson, C. and Baker, V. 1994. Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science, Townsville. 368pp.

The coral reef methods were adopted by the UNEP-IOC-IUCN Global Task Team on Coral Reefs to monitor for global change:

- UNEP/AIMS 1993. Monitoring Coral Reefs for Global Change. Reference Methods for Marine Pollution Studies No. 61, United Nations Environment Programme, Nairobi, 72pp.

Training of Young Scientists

A particularly valuable feature of the LCR project was the provision of funds to support project work by many young scientists whilst undertaking post-graduate degrees. These project activities were directed by senior scientists on themes associated with the broad objectives of country activities within LCR (Table 1).

Table 1. Numbers of graduate students trained either wholly or partially within the LCR project from 1984 to the present.

COUNTRY	Doctorates	Masters	Honours/Projects
Malaysia	4	11	19
Philippines	4	9	7
Singapore	1		9
Thailand	4	8	12

The experience gained during research, conference attendance and paper writing has assisted many of the above scientists to develop their careers, and some have gone on to be scientific leaders in the ASEAN region.

Intangible Products

An important result of the LCR project is a strong network of experienced ASEAN resource scientists and managers, who have considerable understanding of coastal resources throughout southeast Asia. This network, of about 110 senior scientists and younger graduate students, has met regularly over the past 10 years. They include many recognised leaders in marine resource assessment and management, and those who will become the leaders. The LCR project played a large part in strengthening this network through workshops, research and management meetings, and conferences.

This network is itself a potent resource for providing advice on the status of ASEAN resources and what should be done to conserve and manage these resources. Unfortunately, many international funding and conservation agencies seek advice from outside the region when formulating projects for the management of ASEAN coastal resources.

One result to this network is the formulation of the Manila-based 'Coastal Management Center' as a focal point for agencies to access the best advice from senior resource scientists and managers with extensive experience in southeast Asia and other developing countries.

LCR SUCCESS FACTORS

A Collaborative Project

The LCR project was seen a true collaboration between ASEAN and Australian scientists and managers, with extensive experience being gained on both sides. The scientific themes and the nature of methods employed originated predominantly from within ASEAN, or through combined discussions between ASEAN and Australian scientists. Thus, the science was appropriate for the region.

Collaboration meant that experience was shared during workshops and conferences. In addition to AIMS scientists, other organisations were regularly involved e.g. CSIRO and Universities. The increased level of training and experience in ASEAN, along with strong developing environmental awareness, indicates that the current rate of degradation of coastal resources will be slowed and eventually reversed, with the emphasis on sustainable development. This will prove to be a model for the rest of the world to follow.

Many of the major products highlighted above (a strong network; many trained young scientists; world standard methods manuals; and a bounty of research papers and reviews) have arisen because of the close collaboration. The Survey Manual for Tropical Marine Resources is a good example of the collaboration. Many of the methods were developed during the initial Phase I workshops in 1986, and then tested and refined during workshops in ASEAN with input from AIMS scientists.

The chance provided to young scientists by the LCR project to collaborate with scientists from Australia has contributed largely towards them being amongst the world's best at assessing problems in tropical marine ecosystems and suggesting management mechanisms to reverse degradation.

Project Themes and Priority Setting

The research and monitoring themes were those requested by ASEAN scientists and the priorities were set by the Project Management Committee in collaboration with Australian consultants. Thus the activities were appropriate for the region and for the different levels of education and experience of participants.

The methods selected ranged from the basic to the sophisticated, with participating countries able to select their own level. For example, the line intercept transect method was used to assess coral reef communities, with scientists being able to select whether they would collect data using basic lifeform categories or go into more detail and undertake species identification. Mangrove research varied from transect monitoring of tree species to detailed estimation of tree productivity using computer-driven respirometers. When training was requested, courses were made available using a mix of ASEAN and Australian resource people.

The scales of research and monitoring were also appropriate to the facilities and time constraints of senior participating scientists. In Singapore, they were able to examine most of the islands offshore, whereas in Indonesia, efforts were focused on the reefs off Java.

Mix of Activities and Training

In-country Project Technical Committees were able to determine whether the allocated money was directed towards monitoring and research or used to provide post-graduate training for young scientists. Additional money was allocated to a common fund to finance training and meeting activities across the region. Three regional workshops were undertaken each year with those countries having the expertise acting as hosts. The themes were selected by the Project Management Committee.

Technology Transfer

The LCR project has accumulated the world's largest database on coastal resources over an extensive region (Reichelt, 1991; Cheshire, 1994a). Scientists working with this database, containing almost a million records, have been able to assess regional trends in coral reefs, mangrove resources, seagrasses and soft bottoms. This database is a valuable resource to compare the status of coastal resources and potential impacts of global climate change with other areas.

Another important product is a group of young scientists who are trained in handling and analysing large sets of data to find essential information. The LCR project also provided the tools in computers and software for this work.

The latest remote sensing technology, the Australian MicroBRIAN system, has been also introduced to analyse both satellite and aerial images. This is now being used in all 5 ASEAN countries to assess the status of coastal resources over very broad scales, with direct comparisons of assessments made by scientists on the ground.

Project Management and Decision Making

All major decisions on scientific priorities, workshop and training themes were made by the Project Management Committee, with representatives from each of the 5 participating countries (Wilkinson, 1992). This ensured that the scientific activities were designed around real needs, as designated by scientists with considerable experience in the region. This Committee was advised by the Chief Technical Advisor (CTA) and Project Advisor.

The decisions on the allocation of monies were made by the LCR/PMC, which resulted in general agreement on where the money was best spent. Project Technical Committees in each country decided the distribution to individual projects following guidelines established by the PMC.

This management structure ensured that the money was predominantly spent in the region (more than 80%) on regional activities. Throughout the 10 years, scientific and technical advice was provided by the Australian Institute of Marine Science, through the appointment and partial funding of a Chief Technical Advisor with 3 persons sharing this task during the project.

AIMS was considered the ideal choice to provide this advice as it is a world leader in tropical marine research, with particular expertise in coral reefs and mangroves. Many of the training exercises were supervised by senior AIMS scientists and there was always in-depth experience to draw upon when questions were posed by ASEAN scientists.

Thus there was continuity in the provision of advice and ASEAN scientists had considerable confidence that inquiries would achieve answers. In Asia, it is important to establish personal relationships prior to commencing business. All three CTAs experienced a period of acclimation of approximately 18 months to the Asian way of doing business, before reciprocal confidence was established.

Likewise, the project financial management was handled by 2 agencies throughout the 10 years of the project. The first 5 years were administered by AIMS and the second period by the Australian Marine Science and Technologies Limited. Thus fewer problems were encountered in the dispersal of funds or the provision of equipment, than would have been anticipated with regular changes of the agency personnel.

Continuity

Probably the major reason for LCR recognition and success was due to the continuity of funding and activities over 10 years. The Australian Government, through AIDAB, ensured adequate funding to attempt ambitious goals over two 5 year periods. This allowed ASEAN scientists to plan long-term monitoring programmes and provide support for graduate students. Each period was a full 5 years and the 'in principle' decision to fund each Phase was made approximately 12 months in advance of project commencement.

A result of this funding is that scientists collected large amounts of valuable data in the region and now are using the non-funding time to analyse these and write further papers.

Many Asian scientists reported frustration with short term projects (3 years duration or less). Just as experience and valid data are being collected, the funding period stops and priorities are shifted to the next 'fashionable' topic selected by the donor. There are also many shorter projects (a few weeks to months), which usually consist of a conference or training course, without any linkage to follow-up funding or employment for those receiving training. Thus much of the training has been dissipated rapidly after the courses.

For example, a leading Asian scientist stated that there was an inverse relationship between the number of short-term training courses on mangrove studies and the number of scientists employed to implement the training.

Finance and Distribution of Money

A major success factor was that the bulk of the money throughout Phases I and II was spent by ASEAN scientists within the region (ASEAN country allocations 61.3%; Common Fund for joint ASEAN activities e.g. training workshops, symposiums, PMC meetings 20.6%; publications 10.3%; project management in Australia 7.8%). The decisions for distributing the money were made by the LCR/PMC, and in-country Project Technical Committees. Money was distributed throughout the region by the AIDAB coordinating office in Kuala Lumpur to central agencies within each country for the current 3 months (T=1), plus 3 months in advance (T=2). The next round of funding (T=3) was distributed upon acquittal of T=1 monies through the country finance coordinators. This method was implemented to ensure that the science could proceed, whilst the accountants were verifying previous expenditure. This system generally worked well, however some problems were reported because of delays in some government finance departments. Many of the problems resulted from poor understanding of scientific activities by accountants in these departments, particularly when it related to field work that was undertaken without receipts to substantiate expenditure.

RECOMMENDATIONS FOR THE FUTURE

While the economies of the southeast Asian region may be developing rapidly, large sectors of environmental research and management are already well developed. This finding of the ASEAN-Australia LCR project and the ASEAN-US Coastal Resources Management Project constitutes the basis for the following recommendations for future project activities in the ASEAN region.

Wealth of Knowledge and Experience in ASEAN

- International agencies should recognise and use the wealth of knowledge and experience on coastal and marine environments in this region to formulate projects designed to conserve biodiversity, detect the effects of climate change etc.

- The formulation and management of projects should always involve substantial, if not majority, involvement by local experts. Outside consultants generally obtain their information from ASEAN experts, without having sufficient time to understand fully the problems and the socioeconomic context.

- Agencies are recommended to use local bodies with extensive experience in the region during the formulation and management of regional project activities e.g. the Coastal Management Center, in Manila and UNEP (Regional Office for Asia and the Pacific - ROAP and Regional Coordinating Unit for East Asian Seas Action Plan - RCU/EASAP) in Bangkok. These bodies have both the information and networks to formulate appropriate activities, but lack the funds to undertake projects directly.

- Research activities conducted by scientists visiting the region should always be undertaken in collaboration with Asian colleagues for two reasons: the benefit obtained by collaborating with local experts; it is impolite to use Asian institutes and universities as exotic field stations without sharing knowledge and exchanging expertise and information.

Aid or Donor Investment?

- The use of aid as a mechanism to enhance industries and service providers of the donor country rather than those of the recipient country is viewed with considerable scepticism within Asia; whereas those projects that emphasise the reverse receive a greater commitment by Asian scientists and institutes.

Short-term vs Long-term

- There is a need for more financial support for young researchers to undertake long-term research projects and theses; short-term projects, particularly those involving 2 to 3 week training, often appear to be over-supplied in the region.

- The themes for such courses should be selected following consultation with ASEAN scientists, rather than being imposed on the region from outside.

- Graduate research undertaken by Asian scientists in donor countries, where possible, should accentuate projects emphasising ASEAN problems and questions.

- Better in-country coordination is required to ensure that participant selection for short and long-term courses is appropriate, so as to avoid the same people attending courses on very different subjects, while those who would benefit most are ignored.

- Ideally, money for project activities should be provided well in advance to facilitate planning for research and monitoring; and monies should be distributed directly to the implementing institute or university, rather than through central finance departments.

- It is recommended that agencies engage a scientific consultant to coordinate activities between the donor and recipient countries, preferably based in the region or with frequent access.

Collaboration Between Science and Management

- Projects on the living coastal resources should preferentially involve resource managers and scientists working together to ensure that information is distributed in an understandable format to both disciplines and that networks are established for the future conservation of these resources.

- There is an urgent need to continue the monitoring of the coastal resources undertaken within the ASEAN-Australia LCR project in order to detect long-term changes in these resources and provide accurate information to management on recent trends.

- Project participants should assist in transferring new information to all relevant sectors of the community - schools, the public, decision-makers, the media, and through management and scientific literature; and where possible engage in active education of these people on the need for coastal resource conservation.

- New information resulting from research and monitoring of coastal resources should be rapidly transferred to management and decision-makers to ensure that decisions are based on the latest information.

- Frequently there is limited circulation of project publications, therefore participants should urge agencies to ensure that publications are distributed widely to target recipients.

- Finally, there is need for a strong spirit of collaboration between all sectors and disciplines to ensure that the living coastal resources of ASEAN can be conserved for the sustainable use by current and future generations.

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REFERENCES

Aliño, P.M., 1994. Patterns in the distribution of reef-associated fish in the ASEAN region. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 11-22.

Atmadja, W.S. & Soerojo, 1994. Mangrove Status of Indonesia. In: Wilkinson, C.R., S. Sudara, & L.M. Chou, L.M. (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 201-207.

Boto, K.G., 1991. Australian marine science initiatives in south-east Asia. In: Alcala A.C. (ed), Proc. Regional Symp. on Living Resources in Coastal Areas, Manila, 1989. Marine Science Institute, University of the Philippines, pp. 5-8.

Boto, K., S. English, A. Sasekumar, R. de Leon, S. Chitsamphandvej, S. Sudara & S. Tangjaitrong, 1989. Regional data Integration and Management. Proc. of the Regional Data Integration Workshop of the ASEAN-Australia Cooperative Program in Marine Science. Marine Science Institute, University of the Philippines. 150 pp.

Calumpong, H.P., 1994. Status of mangrove resources in the Philippines. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 215-228.

Cheshire. A.C., 1994a. Structure and function of taxonomic databases: importance in the analysis of natural resource assessment data. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 399-406.

Cheshire. A.C., 1994b. The LCR database as a tool to support scientific investigation: problem definition and data preparation. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 385-391.

Chong V.C., A. Sasekumar, W.S. Atmadja & J.K.Y. Low, 1994. Status of mangrove prawn fisheries in the ASEAN Countries. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 147-155.

Chou, L.M. & M.G.K. Loo, 1994. A review of marine soft-bottom benthic community studies from Singapore. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 365-371.

Chou, L.M., C.R. Wilkinson, W.R.Y. Licuanan, P. Aliño, A.C. Cheshire, M.G.K. Loo, S. Tangjaitrong, S. Sudara, A.R. Ridzwan & Soekarno, 1994a. Status of coral reefs in the ASEAN region. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 1-10.

Chou, L.M., N. Paphavasit, W.W. Kastoro, H.M.E. Narcorda, B.H.R. Othman, M.G.K. Loo & B.S. Soedibjo, 1994b. Soft-bottom macrobenthic communities of the ASEAN region and the influence of associated marine ecosystems. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 325-331.

Fortes. M.D., 1994. Philippine seagrasses: status and perspectives. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 291-310.

Fortes, M., W. Kiswara, S. Nateekanjanalarp, S. Poovachiranon & M.G.K. Loo, 1994. Status of seagrass beds in ASEAN. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 243-249.

Gomez, E., P. Aliño, A. Licuanan & H. Yap, 1994. Status report on coral reefs of the Philippines 1994. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 57-76.

Gong, W.K., J.E. Ong, A. Sasekumar & V.C. Chong, 1994. Status of mangrove forests and fisheries in Malaysia. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 209-213.

Japar, S.B., 1994a. Mangrove Plant Resources in the ASEAN Region. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 123-138.

Japar, S.B., 1994b. Status of seagrass resources in Malaysia. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 283-289.

Japar, B.S., 1994c. Database files and structures for mangrove studies. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 375-384.

Japar, S.B., A. Sasekumar, V.C. Chong & J.K.Y. Low, 1994. Mangrove fish resources in ASEAN region. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 179-200.

Kastoro, W.W., 1994. Status of soft-bottom benthic communities of Indonesian waters. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 333-346.

Kiswara, W., 1994. A review: seagrass ecosystem studies in Indonesian waters. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 259-281.

Kongsangchai, J., 1994. Situation of mangrove forests in Thailand. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 233-239.

Loo, M.G.K. & L.M. Chou, 1994. Database system for coral reef studies of the ASEAN-Australia Living Coastal Resources project. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia

Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 417-427.

Loo, M.G.K., K.P.P. Tun, J.K.Y. Low & L.M. Chou, 1994. A review of seagrass communities in Singapore. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 311-316.

Low, J.K.Y., A. Arshad & K.H. Lim, 1994. ASEAN mangroves as a habitat for endangered species and biodiversity conservation. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 157-169.

Mohd. Ibrahim Hj. M. & S.B. Japar, 1992. Application of remote sensing in the study of development impact on a marine park in Malaysia. In: Cracknell, A.P. & R.A. Vaughn (eds), Proc. 18th Annual Conference of the Remote Sensing Society. University of Dundee, September 1992.

Narcorda, H.M.E., H.T. Yap, R.M. Alvarez, J. Onate-Pacalioga & J. Estacion, 1994. Variations in the structure of sediment communities in selected Philippine sites. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 347-364.

Ng, P.K.L. & J.K.Y. Low, 1994. Status of mangroves in Singapore: conservation beyond the year 2000. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 229-232.

Ong, J.E., W.K. Gong, Y.P. Wong & H.K. Wong, 1992. Identification of mangrove vegetation zones using MicroBRIAN and LANDSAT imagery. In: Chou, L.M. & C.R. Wilkinson (eds), Proc. 3rd ASEAN Science and Technology Week Conference, Vol. 6, Marine Science: Living Coastal Resources. National University of Singapore and National Science and Technology Board, Singapore, pp. 383-386.

Poovachiranon, S., M.D. Fortes, S. Sudara, W. Kiswara & S. Satumanaptan, 1994a. Status of ASEAN seagrass fisheries. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources,Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 251-257.

Poovachiranon, S., S. Nateekanjanalarp & S. Sudara, 1994b. Seagrass beds in Thailand. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 317-321.

Reichelt, R.E., 1991. Resource assessment in the ASEAN coastal zone: crossing frontiers of data collection, data management and data analysis. In: Alcala A.C. (ed), Proc. Regional Symp. on Living Resources in Coastal Areas, Manila, 1989. Marine Science Institute, University of the Philippines. pp. 9-12.

Ridzwan A.R., 1994. The status of coral reef in Malaysia. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 49-56.

Sasekumar, A., V.C. Chong & K.H. Lim, 1994. Status of mangrove finfish resources in ASEAN. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 139-145.

Sasekumar, A. &. K.H. Lim, 1994. Compatible activities and mangrove forests. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 101-104.

Singh, H.R., V.C. Chong, A. Sasekumar & K.H. Lim, 1994. Values of mangroves as nursery and feeding grounds. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 105-122.

Soedibjo, B.S., 1994. Review of LCR soft bottom database. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 407-415.

Soegiarto, A., 1984. Opening address. In: Report of the Technical Meeting of the ASEAN-Australia Cooperative Programs in Marine Sciences: Living Resources in Coastal Areas with Emphasis on Mangrove and Coral Reef Ecosystems, Bangkok, Thailand, 25-27 June 1994. Office of the National Environment Board of Thailand, Bangkok, Annex C.

Sudara, S., 1991. ASEAN-Australia Coastal Living Resources Project achievements and prospects. In: Alcala A.C. (ed). Proc. Regional Symp. on Living Resources in Coastal Areas, Manila, 1989. Marine Science Institute, University of the Philippines, pp. 13-15.

Sudara, S. & T. Yeemin, 1994. Coral reefs in Thai waters: newest tourist attraction. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 89-97.

Thamrongnawasawat, T., 1994. Summary of remote sensing of the coastal zone: ASEAN region. In: Wilkinson, C.R., S. Sudara & L.M. Chou (eds), Proc. 3rd ASEAN-Australia Symp. on Living Coastal Resources, Vol: 1, Status Reviews, Australian Institute of Marine Science, pp. 429-440.

Wilkinson, C. R., 1992. The Living Coastal Resources project past present and future. In: Chou, L.M. & C.R. Wilkinson (eds), Proc. 3rd ASEAN Science and Technology Week Conference, Vol. 6, Marine Science: Living Coastal Resources. National University of Singapore and National Science and Technology Board, Singapore, pp. 5-11.

Wilkinson, C.R., L.M. Chou, E.D. Gomez, A.R. Ridzwan, R. Soekarno & S. Sudara, 1994. Status of coral reefs in Southeast Asia: threats and responses. In: Ginsburg, R. (ed.), Colloquium on Global Aspects of Coral Reefs, University of Miami, 331-317.

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