Intergovernmental Oceanographic Commission

Workshop Report No. 47

IOC Symposium on Marine Science in the Western Pacific: the Indo-Pacific Convergence

organized with the support of the Australian Department of Science

Townsville, 1-6 December 1986

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IOC Workshop Reports

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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
4	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO Via delle Terme di Caracalla 00100 Rome, Italy	English (out of stock) Spanish (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stc French Spanish (out of st Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stc
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stc Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English

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INTRODUCTION

The Chairman of the IOC Regional Committee for the Western pacific (WESTPAC), Dr. John Bunt, as Chairman of the Symposium, welcomed the participants to Townsville and to the Sheraton Breakwater Hotel where the Symposium was held. He explained that the Symposium had been sponsored by the IOC and organized, on its behalf, by the Australian Department of Science. Nevertheless, the Symposium could not have been convened at this particular time and place without the generous assistance, in money and/or kind, of a large number of institutions and commercial companies. These were, in the city of Townsville:

Australian Institute of Marine Science
Great Barrier Reef Marine Park Authority
James Cook University of North Queensland
Sir George Fisher Centre for Tropical Marine Science
Townsville City Council
Department of Local Government and Administrative Services

and from elsewhere:

United States National Science Foundation, Washington, D.C.
French Ministry of National Education, Paris
United States Agency for International Development (AID)
Unesco (ROSTSEA), Jakarta
QANTAS, Canberra
ANSETT, Canberra
Butterworths, London

Moreover, a considerable number of institutions presented colorful and attractive displays of their research effort, which complemented the themes taken up by the Symposium.

Dr. Bunt also acknowledged the invaluable contribution of the Keynote Speakers, the Topic Convenors and the Discussion Leaders in guiding the Symposium.

In many diverse ways, the aforementioned institutions, companies and individuals greatly assisted the organizing Committee in arranging the scientific and social programmes for the Symposium, the social activities often allowing unique opportunities for ripening the fruit of the more formal debate and discussion of the scientific activities.

The Symposium was opened by Dr. W.J. McG. Tegart, Secretary of the Department of Science, of the Australian Government. (His address is given below).

The main Keynote Speaker was Professor Roger Revelle, of the Scripps Institution of Oceanography, whose introductory address is summarized below.

The Symposium covered four main themes which were so programmed as to give as much chance as possible for interdisciplinary participation; each theme was introduced by a Keynote Speaker:

(i) Evolution of the Arc Complex: Geology and Speciation - Dr. John Katili, Director General, Geology and Mineral Resources, Jakarta, Indonesia.

(ii) Ocean Variability and the Links with Climate - Dr. J. Stuart-Godfrey, Division of Oceanography, CSIRO, Hobart, Australia.

(iii) Interannual Variability in Marine Communities - Dr. Alan R. Longhurst, Bedford Institute of Oceanography, Dartmouth, N.S., Canada.

(iv) Human Influences on the Marine Environment - Dr. Ed Gomez, Marine Science Institute, University of the Philippines, Manila, Philippines.

The Topic Convenors and Discussion Leaders are listed at the beginning of each thematic section which contains the abstracts of the papers or poster sessions presented within the theme.

The discussion of the papers was far too rich to be recorded in minutes, so each of the four Keynote Speakers summarized the main outcomes of the debates in each theme; their summaries appear at the end prior to the section on the Closure of the Symposium.

OPENING ADDRESSES

The Secretary of the Department of Science, Dr. W.J. Mc G. Tegart, made the Opening Address of the Symposium:

Mr Chairman, Ladies and Gentlemen,

A little over 3 years ago, I had the pleasure of leading the Australian delegation to the third plenary session of the WESTPAC Program Group coincidentally also held here in Townsville. At that session, Australia took over the Chairmanship. Under the enthusiastic leadership of Dr Bunt, the WESTPAC Group has developed the infrastructure and credibility to be in a position to convene a Symposium such as this and to attract such broad support. I believe that some 23 countries are represented by more than 200 participants and I welcome you all to Townsville and, in the case of our overseas visitors, to Australia.

The number of participants, the quality of the papers to be presented, and the calibre of the Symposium keynote speakers and discussion leaders augur well for a stimulating week. Combined, they also demonstrate two things very clearly.

Firstly, that there is enormous international interest in the marine resources and processes of this Indo-Pacific region and their effective utilization and management based on sound scientific knowledge and, secondly, that WESTPAC might appropriately act as a focal point and catalyst for such discussions.

The Australian Government has demonstrated its committment to WESTPAC by providing support to Dr Bunt, during his period as Chairman, through my Department. This support has been extended to assist in the convening of this Symposium and complements direct financial assistance provided by a number of other member states and international bodies. The on-going effectiveness of the WESTPAC Group will be both determined and measured by the input of its member states.

From the Australian Government's viewpoint, WESTPAC is at the crossroads of its development. A strong base, broadly representative of the region, has been established and a solid information exchange mechanism built. This Symposium now provides the springboard for the Group to demonstrate its ability to fulfil a coordination role in the region, and to attract the necessary support required to generate relevant regional research programs which require collaborative effort. I trust that my Department's support over the past 3 years will be vindicated.

Undoubtedly, the marine environment of the Indo-Pacific has played and will increasingly play a major role in the socio-economic development of south-east Asia, the south-western Pacific and Australasia. Utilization of the fisheries and sea-bed resources of the ocean, increasing maritime traffic and the growing awareness of the impact of the ocean on our climate guarantees that the marine environment will continue to be a focal point for both scientific study and political debate.

The Australian Government fully recognises the importance of the marine environment to its economic development and, despite financial restrictions in the public sector, has maintained the continuing development of a strong marine research base in this country.

Data on R&D expenditure indicate a steady climb in direct Commonwealth operational funding for marine research from some $A13 million in 1978/79 to about $A50 million in 1985/86. These figures do not take account of State Government, university, and privately sponsored research which add considerably to the total expenditure.

During this period, there has also been substantial capital expenditure on the relocation of CSIRO Divisions of Fisheries Research and of Oceanography to new buildings in Hobart, and the construction of a new oceanographic vessel to be operated as a National Facility by CSIRO. Further, the Bureau of Mineral Resources, Geology and Geophysics has chartered a specialised vessel for an extensive seismic program in the seas around Australia.

It is most appropriate, from an Australian perspective, that this Symposium be held here in Townsville. Townsville is the centre of this country's tropical marine science effort and could lay claim to being a regional centre of excellence. As many of you will be aware, the Australian Institute of Marine Science, whose facilities and hospitality you will experience first hand later this week, the James Cook University of North Queensland and the Sir George Fisher Centre for Tropical Marine Studies which is associated with the University are all located in Townsville. Similarly, the Great Barrier Reef Marine Park Authority and the Queensland National Parks and Wildlife Service which provide the expertise required for the management of that magnificent resource, the Great Barrier Reef, are based here. Consensus may not always be reached over dinner tables in Townsville but the quality of debate is always high!

A great many other agencies play an important role in the research, development and management of Australia's marine resources. I am pleased to see that a number of these bodies has taken the opportunity to illustrate their activities by way of the extensive poster displays which have been mounted in this and the other conference rooms. The displays provide both a colourful and informative backdrop to the week's presentations and discussions.

Your discussion program is as varied and interesting as the displays, and provides a wonderful opportunity for close interaction between scientists, administrators and the generalist who has an interest in the ocean its resources and processes. The social program is equally as varied, and will encourage interaction and discussion in a less formal atmosphere.

Of particular appeal to a non-marine person, such as myself, is the opportunity to move between and across sessions and subjects. To listen to presentations in, for example, one of the oceanographic sessions and then to relate some of the hypotheses there to discussions of mangrove and seagrass systems should ensure that a high level of interest will be maintained.

I trust that all of you will take the opportunity to sit in on discussions outside of your immediate field of expertise, for one of the primary objectives of this symposium is to encourage a multidisciplinary approach to the marine research and management questions confronting the region. Similarly, the Symposium seeks to promote a closer liaison between the men or women at the bench, or perhaps, at the beach, and their counterparts among the decision-makers.

Pressures on the marine environment, particularly human-induced pressures must be investigated, evaluated and monitored in order that national utilisation and management regimes can be implemented before one's paramount concern becomes remedy rather than maintenance. These pressures on a fragile environment come in a number of forms. Tourism, fishing effort, waste dumping and the like all create a potential environment in which the hackneyed old phrase "the straw that broke the camel's back" can have real relevance.

The prawn fisherman, the tourist operator, the oil rig builder, and the Reef Authority are dependent to a very large extent upon the evaluated results of research undertaken by scientists such as yourselves over both the short and long term. The scientist must therefore be responsive to the needs of that client community and should be encouraged to actively pursue and answer those questions requiring resolution before effective management can be undertaken.

I believe that public acceptance of expenditure on marine S&T will be much easier to obtain if that research has demonstrable application in management of the environment and of its exploitable resources.

The traffic is not however entirely one way. No research agency or individual scientist can be expected to ignore the "pure" aspects of their work for the "applied", merely to satisfy or remedy an immediate situation. Crisis management is both inefficient and invariably ineffective. Equally, development decisions taken without full consideration of sufficient data are doomed to failure. In short, the end users of research must enunciate their long-term objectives, and must design and implement relevant research programs in close consultation with the groups who will be expected to provide the base data for decision making. A cooperative approach to problem solving will hopefully lead to cost-effective research and management strategies.

These observations, whilst obviously stated in a simplistic manner, are designed to encourage collaboration and cooperation and are equally as valid in a regional context as in discussion of researcher/utiliser relationship. The marine environment knows no boundaries and scientific collaboration provides a useful mechanism to overcome perceived political difficulties as well as ensuring that unnecessary duplication of effort is avoided or, at least, reduced. It is a rare situation indeed, particularly when discussing marine questions, where a problem is totally a local one, or does not have relevance in another geographic situation. Tides, tunas and typhoons are not restricted to any particular locale and, to understand fully the processes which govern their behaviour, it is essential that information and hypotheses be available and freely discussed by all who study the phenomena.

I would therefore encourage all of you to actively explore opportunities for the establishment of collaborative research programs in the region which may complement or extend your own domestic programs and which could appropriately be encouraged through the IOC and WESTPAC.

Mr Chairman, you and your Committee are to be congratulated on the design of an interesting and, more importantly, relevant Symposium. You have assembled an impressive array of experts whose contributions will undoubtedly stimulate discussion and raise more questions. This process will contribute to further R&D in the region's marine science sector.

In conclusion I wish you every success in this venture and for the continued development of the Program Group and I am looking forward to participating in your discussions over the next two days.

The Chairman of the Intergovernmental Oceanographic Commission, Professor Inocencio Ronquillo, of the Philippines, then addressed the participants:

Ladies and Gentlemen,

It is for me a great pleasure to be here at this Symposium, for at least three reasons:

First, as Chairman of the Intergovernmental Oceanographic Commission, I can tell you that the Commission attaches great importance to promoting co-operation and intellectual exchange amongst marine scientists even if, as an intergovernmental body, it is mandated to work through the concerted efforts of its Member States.

Although these concerted efforts are usually made through co-operation between Governments, they require co-operation amongst scientists and scientific institutions, at the national, at the regional and at the global level, since oceanography is, perhaps above all other subjects, multidisciplinary.

Today, at the opening of this Symposium, we see the two components - governments and scientists - working together to promote marine science in the western Pacific, for the principal supporter of this Symposium is the Australian Department of Science, and I wish to convey to you, Dr. Tegart, as the Secretary of the Department, the warm thanks of the Commission - its Member States, its Officers and its Secretary, Dr. Mario Ruivo, represented here by the Senior Assistant Secretary, Mr. Ray Griffiths - for the generosity of your country's government, through your Department and through other institutions (which I shall mention in a moment); I should also like to thank your government, through you, sir, for its support of the work of the IOC Regional Committee for the Western Pacific, as manifested in the hosting of this Symposium, and in many other ways.

However, the principal supporter also has supporters, to the great advantage of the Commission and the Symposium. And therefore, I wish also to thank the Australian Institute of Marine Science, for its noble aims in helping to convene this Symposium. When I mention AIMS I must at once thank John Bunt, its former Director and the Chief Organizer of the Symposium. Dr. Bunt is also the Chairman of the IOC Regional Committee for the Western Pacific.

Then, I wish to thank the James Cook University for its significant contribution and its hospitality in housing many of the participants.

The Great Barrier Reef Marine Park Authority has also made notable contributions, for which we are grateful.

Several IOC Member States have contributed to ensuring the basis for success. The Governments of France and the USA have made financial contributions to facilitate the attendance of scientists from developing countries, and a number of other governments and governmental institutions of IOC Member States have assisted scientists from their won countries and sometimes from other, developing, countries to attend. Unesco, through its Regional Office of Science and Technology for South-East Asia, has also assisted some scientists to attend.

This is what we may understand by the "concerted effort" the IOC Statutes require the Member States to make in order to "learn more about the ocean and its resources".

The second reason for my pleasure in being here, is that so many of the meetings I must attend as Chairman of the IOC and in other official capabilities are of the intergovernmental or policy-making kind, and, important though they may be, they are not purely scientific, so I hope to enjoy learning more about our ocean and its resources through the concerted action of the many renowned scientists present here.

I wish therefore to thank those of you who have kindly agreed to play special roles as Keynote Speakers and Topic Convenors, and those of you who will read papers, or who will give poster displays or who have simply submitted papers, or who have just come to exchange intelligence.

The Indo-Pacific Convergence is a key oceanographic phenomenon our knowledge of which determines largely our capacity to predict the effects of the processes that characterize the phenomenon. But it is not simply a convergence of sea water; it is a convergence of tectonic plates and the associated geological processes; it is a convergence of atmospheric features as the southern and perhaps other oscillations of the air-pressure field fix their positions relative to these two great oceans - the Pacific and the Indian; it is a biological convergence associated, in evolutionary terms, with major tectonic plates, but living organisms die hard and the sea is perhaps as often a barrier as a carrier; and it is a cultural convergence, historically dictated by the ocean currents.

It is therefore appropriate, ladies and gentlemen, that we converge here to learn from each other about the guiding forces in our scientific lives. This convergence has been greatly helped by the unstinting efforts of Mr. Bob Harris, of the Department of Science, who is also the Australian Liaison Officer for WESTPAC, and I wish to thank him and the other Departmental staff too.

My third reason is that I have again the pleasure of coming to Townsville and seeing one of the great natural wonders of the world - the Great Barrier Reef. Not for the first time, the IOC is receiving the hospitality of the Mayor and Council and Citizens of Townsville, since the Third Session of the IOC Regional Committee was held here in 1983. I understand that we shall have an opportunity to thank the Mayor for his Town's hospitality later this week.

And lastly, it is my pleasure to be here because symposia such as this one have proven to be an important mechanism for determining the possible new thrusts of the IOC regional subsidiary bodies' actions, for focussing the present thrusts, and for enhancing co-operation between scientists and countries in the search for knowlege by which we may hope to spur our socio-economic development, peace and prosperity in all its forms.

On behalf of the Intergovernmental Oceanographic Commission, I wish you every success in your intellectual exchange and invite you to make practical recommendations to the Commission on the development of international co-operative marine science and its related technology in this exciting ocean region. Thank you very much for your kind attention.

Professor Roger Revelle then delivered the main Keynote Speech to the Symposium. (Since no formal text was submitted, the Speech is summarized here from notes.)

The ocean is already a source of extractable living and non-living resources and provides a medium for shipping, communication and national defence. However, needs for food, minerals and energy cannot now be fully met by the land. There will therefore be growing demands on the ocean as terrestrial sources are depleted. The ocean also moderates the climate, receives the domestic, agricultural and industrial wastes, and provides a source of recreation. Too little is known, however, about the processes that would allow accurate prediction of the consequences of alternative uses or management measures. Without adequate knowledge, resources may be wasted, used inefficiently or inadvertently destroyed; investment in the acquisition of essential knowledge can therefore return large dividends.

The present Symposium covers four main fields of marine scientific endeavour, with especial emphasis on the Indo-Pacific region.

In the field of **geology and geophysics**, it is only recently that the distribution of metalliferous sediments close to the mid-ocean ridges has confirmed that ocean-floor spreading is accompanied by the creation of hydrothermal vents where the hot discharging waters may contain high concentrations of copper, potassium, calcium, barium, manganese, iron and zinc. Cooler vents are characterized by extensive communities of organisms including clams, mussels, crabs and forests of giant tube worms.

Passive continental margins are often among the most poorly understood areas of the oceanic crust, mainly because many of them were formed by breakup a long time ago, so that the structures that were initially created and much of their subsequent history often lie buried under a thick layer of sediments. The study of passive margins is very important for undertstanding the mechanisms operating when continents separated to form new oceans, and for the exploration of hydrocarbons.

Active margins are important sites of present-day tectonic and volcanic activity and there is general agreement about the basic processes at work in them. They are zones of convergence where the oceanic plate is subducted under the continental plate. The deep-sea trench, the volcanic arc, etc. are all manifestations of the subduction process, and the Indo-pacific region is particularly interesting in this respect. Nevertheless, fundamental questions remain about the structure and the nature of tectonic and volcanic processes at active margins. Perhaps, as the oceanic plate is subducted, the sediments are scraped off and imbricated on the overriding plate in the space between the volcanic arc and the trench. Sediments would thus be accreted at the active margin. However, the results of deep-sea drilling in many active margins show that, in fact, the zone of sedimentary accretion may be very small or even entirely absent. The dominant process at several active margins appears to be crustal erosion rather than crustal accretion.

A correct choice of chemical species as markers of past and present biotic processes is fundamental to an understanding of the flux of matter to the bottom sediments. Many products of primary synthesis (for example, steroids, hydrocarbons and carotenoids) retain their identity in

particulate matter for a long time in the deep ocean and may be found in fossil remains of the deep sediments. The direction of modification of these chemical fossils provides clues to the early palaeochemical environment. The sediment-water interface can also introduce a chain of chemical and biotic reactions which modify particulate matter drastically before the material enters the bulk geochemical cycles.

The stratigraphic record of marine sedimentation on the continentsand along their margins reflects the response of relatively shallow depositional marine environments to global (eustatic) sea-level changes. The magnitude of sea-level changes ranges from a few tens to a few hundred metres, but probably not more. Rates and patterns of sea-floor spreading have been invoked to explain long-term sea-level changes due to volume changes of the ocean basins, whereas the short-term, and sometimes very rapid, sea-level changes have been attributed to climatic factors which can result in volume changes of the world ocean (i.e., isolation and desiccation of marine basins) as well as to changes in the amount of water accumulated in the world ocean (i.e., through the accumulation of large ice sheets on the continents during glacial ages). It seems clear from the sediment distributions in shallow marine depositional environments and from the seismic stratigraphies of continental margins that the inferred sea-level changes were global phenomena, but the causes for the changes are not well established.

The high-energy environment is that in which waves and curents can influence geomorphology. Most high-energy environments occur nearshore and on the inner parts of continental shelves. Examples are beaches, tidal inlets and tidal channels, submarine deltas, barrier islands, submarine bottom forms and river mouths. Generally, these combine into assemblies such as estuaries, barrier island chains and pararallel submarine shallows. Frequently, sand dunes form an essential part of the sedimentary structure, so that wind transport is an additional moving agency. The central problem of the high-energy environment resides in the interplay between morphology and hydraulic forces. On the shelf, irregular bottom topography causes tidal residuals, but tidal residuals also cause irregular topography. The interaction is difficult to characterize in any quantitative sense. The same holds, in shallower water, for incoming waves and sand banks. Another problem is the evolution of high-energy environments most of which are, geologically speaking, very young. This is one reason why they often show rapid morphological changes, but such changes also seem to be a fundamental characteristic. The determination of the geographical boundaries of specific high-energy environments and the gains and losses through such boundaries is problematical; some environments are clearly open-ended as, for example, beaches, which are fed by coastal erosion on one side and lose sand by offshore transport on the other. In other environments, such as tidal lagoons, with their inlets and barrier islands, sediments move in a more or less closed system.

There is also a continuing interest in sandy bedforms and the sedimentary sequences in them. Theories of sediment transport and stability have recently been devised for sand waves and tidal sandbanks and ribbons. Because of their aggregated structure in transport and their cohesive nature when deposited, muds are less well understood.

In the field of **ocean variability and the links with climate**, the coupling between the oceans and the atmosphere is particularly strong in the tropical regions. There is good evidence that large climatic fluctuations

are governed by large-scale tropical ocean-atmosphere interactions, and that the dynamics of the equatorial ocean play an important role. At the same time, the detailed dynamics of western boundary currents and their interaction with the rest of the ocean circulation are not well understood. Western boundary currents transport a significant amount of heat polewards, and a strong heat flux from the ocean surface to the atmosphere occurs in the current thermal-front regions. The role of the so-called Southern Oscillation is certainly an important one in the atmosphere-ocean relationship in this region, and is under active study. In the Indo-Pacific region, the exchange of water, and therefore of heat and salt, betweent the Pacific and Indian Oceans, is of paramount importance to a full understanding of ocean variability.

In the field of **interannual variability in marine communities**, classical food-chain work has concentrated on the consumption of relatively large phytoplankton cells such as diatoms and dinoflagellates by "net zooplankton"; e.g., copepods. Now, evidence from a number of directions shows that very small primary producers (nanoplankton and picoplankton) are responsible for a significant portion of the organic flux, and that they are grazed by small copepods, ciliates and mucus-net feeders such as salps. Vertical profiles of biochemical properties in the water column (RNA, DNA and ETS) are beginning to provide estimates of biomass, respiration and growth rates within the water column.

Biologists are now studying the ecological consequences of such meso-scale features as upwelling, rings and fronts, but, to understand biological processes, it is often essential also to know the wind, turbulence and currents that form the dynamic matrix in which the processes take place. The physical processes associated with the upper 300 metres of the ocean dominate many problems of biological oceanography. Turbulence, eddy diffusion, thermal stratification, internal waves, etc. regulate the supply of nutrients to the photic zone, and the nutrient supply ultimately limits the productivity of the area.

Because of the need to experiment with ecosystems, a considerable effort has been made during the last decade to develop enclosed marine ecosystems (variously called microcosms or mesocosms) for experimental purposes. While there is in every case a limit to the size of the organisms that maintain themselves in such systems, it is clear that very often the smaller organisms and communities do well, and that the major features of biogeochemical cycling, in some coastal regions at least, can be well simulated. On larger time/space scales, many important problems arise that are both scientifically stimulating and immediately relevant to the rational exploitation and management of oceanic ecosystems. Some of these problems are under investigation, such as seasonal phenomena, the biological effects of variations in the onset of stratification, and the description of the large-scale biogeographical patterns of species and community types. The response times of biological communities to physical changes vary widely but may sometimes be tens of years, which is important on the time-scale of human life and observation.

CLIMAP (Climate Long Range Investigation, Mapping and Prediction) illustrated the usefulness of recent studies of palaeontology in establishing long time-series against which the fluctuations in present-day communities can be compared. Many of the interpretations of micropalaeontology are based on the results of investigations of the present ecology of groups such as Foraminifera, Radiolaria, Coccolithophorida and Ostracoda.

In the field of human influence on the marine environment, the last fifty years have seen a significant increase in man's input of products and wastes into the marine environment. Research and monitoring of the consequent impacts have also increased, but basic research in this field is still not in a position to provide an adequate scientific basis for pollution management decisions.

Release of potentially harmful substances continue to occur via such sources as oil-well blow-outs, tanker accidents at sea, chemical dump-sites, and discharges of heavily polluted rivers, etc. And new compounds and their by-products may appear as future pollutants.

DDT, its derivatives, and PCBs are halogenated hydrocarbons for which sensitive analytical procedures exist. Their presence in the environment may help in the determination of large-scale processes such as atmospheric distillation and condensation (from warm to cold regions). Analysis of individual PCBs could also help in "fingerprinting" water bodies. Several organochlorine pesticides (e.g., DDT) may be replaced by toxaphenes which are likely to have as great an impact on the marine environment as DDT but the analysis of which is much more difficult. Information on the production, use and release of toxaphenes to the environment will be needed for the evaluation of the hazard they generate and of their suitability as tracers.

The release of freons (chlorofluorocarbons) to the atmosphere has contaminated ocean surface water, so that the analysis of such water can be used to identify areas of vertical water exchange and to study the flow at depth from such areas.

The levels of some metals have turned out to be lower than reported previously. Biological systems may therefore be more sensitive to these heavy metals to the ocean than had been thought. Copper, zinc and lead are of special interest since they are produced and used in huge quantities, and man has appreciably increased the mass of mercury circulating in nature. Methods have been developed for determining methyl mercury species in sea water and air. Other elements such as tin, arsenic, antimony and sulphur are also methylated, so that methylation probably plays an important role in the flow of a number of elements, and may reveal the degree of air-sea exchange of different chemical species, reduction-oxidation processes, etc.

TOPIC I: EVOLUTION OF THE ARC COMPLEX: GEOLOGY AND SPECIATION

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KEYNOTE SPEECH BY DR. JOHN KATILI: EVOLUTION OF THE ARC COMPLEX: GEOLOGY AND SPECIATION

The evolution of the Sunda, Banda and Solomon Arcs over the last 150 million years has been strongly affected by the convergence of the Indian-Australian, Pacific and Eurasian Plates.

It is envisaged that, before the arrival of India, double arc-trench systems with opposing subduction zones existed in the western part of southeast Asia. These volcanic arcs were formed around an older nucleus of micro-continents welded together by collision to form the ProtoSundaland, consisting of parts of Thailand, Malaysia and perhaps West Borneo.

The collision of India with Eurasia, which occurred around 50 million years ago, resulted in a clockwise rotation of the Sundaland accompanied by the generation of major wrench faults in the continental part of east and southeast Asia and Sumatra, followed by the forming of pull-apart basins in Sumatra.

While subduction continued around Sundaland, the opening of marginal seas and back-arc basins in the South China Sea (17-30Ma) and the Andaman Sea (10-20Ma), respectively, still demonstrated the after-effect of the collisional process between India and Eurasia.

The break-up of Gondawana resulting in the development of a major spreading axis in the Indian Ocean was subsequently followed by a major reorganization in the subduction pattern of the Indonesian region. About 20 million years ago, an 8000km-long, east-west trending arc-trench system developed, stretching from the western tip of Sumatra to Buru and even further eastwards to the Melanesian arc by way of Java, the lesser Sunda Islands, Timor, Tanimbar, Kai and Ceram.

Prior to the arrival of the Australian continent at the southeast Asian continental margin, a north-south oriented Sulawesi-Mindanao volcanic arc existed about 800km east of Borneo. Further to the southeast the older east-west trending Sepik and the younger inner Melanesian Island arcs separated the Australian-New Guinea Plate from the Eurasian Plate.

As Australia drifted northwards, New Guinea first collided with the Sepik Island arc about 30 million years ago. Probably about the same time, back-arc spreading had formed a continuous Solomon-New Britain arc to the northeast of the island of New Guinea. Ten million years later, New Guinea and Sepik, now welded into a bigger micro-continent, collided with the inner Melanesian Island arc. This opened the Australian Plate to the influence of the NNW-moving Pacific Plate. Arc reversal occurred in the North Solomon arc. Anti-clockwise rotation of New Guinea about 10 million years ago and continuous northward movement of Australia trapped the Banda

Sea and caused "tectonic shaving" of the Bird's Head of New Guinea along the Sorong transform fault system. Subsequently, Buton and Sula and other micro-continents collided with Sulawesi and Halmahera transforming the double island arcs into a K-shape form. A small west-dipping subduction zone developed in northern Sulawesi accompanied by active volcanoes in Minahasa and the Sangihe Islands. Other small subduction zones with reverse polarities subsequently developed in northwestern Sulawesi and Halmahera, which can be held responsible for the generation of the active Una-Una volcano in the Gulf of Gorontalo, central Celebes, and the volcanoes in the western Halmahera arc. Active collision accompanied by emplacement of ophiolites is presently taking place between the west-facing Halmahera arc and the east-facing Minahasa-Sangihe arc.

Thus, the convergent movement of the Australian-New Guinea and the Pacific Plates could be held responsible for the various tectono-volcanic features in eastern Indonesia such as the loop-shaped Banda arc, the K-shape form of Sulawesi and Halmahera, the back-arc thrusts of Halmahera and Sulawesi, large transcurrent faults in Sulawesi and Irian Jaya and extinct volcanoes in certain sections of an active plutono-volcanic arc.

Assuming that the high convergence rates in this region continue for another 50 million years or so, Australia will move further northward to close with southeast Asia. This complex region of arc-continent and arc-arc collisions, of accretion of allochthonous terranes, of large horizontal and vertical movements, of rifting and small sea-floor spreading in back-arc and marginal basins will ultimately be squashed between Australia and Asia. In the future, the region from the Sumatran to the Solomons arc will resemble a broad and complex mountain system such as we now see in the Alps, the Hercynian and Caledonian mass and the North American cordillera.

DEPTH AND MECHANISMS OF FAULTING IN THE NEW GUINEA FOLD AND THRUST BELT: CONSTRAINTS FROM EARTHQUAKE AND GRAVITY DATA

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Teleseismic long-period and short-period waveforms and P-wave first-motions were used to determine reliable focal mechanisms and source depths for the largest earthquakes in the New Guinea fold and thrust belt since 1964. The two largest events ($Ms \geq 7.0$) were found to have occurred at depths between 5 and 20 km and smaller events were located as deep as 45 km. The depths of these earthquakes and the steep dips of nodal planes imply that active deformation in the fold and thrust belt is not thin-skinned (i.e., limited by a shallow detachment surface) but must involve the crystalline basement. The three largest events, which occurred under the crest of the Central Highlands in eastern Irian Jaya near the Papua New Guinea border, were characterised by strike-mechanisms with the preferred fault plane oriented E-W so that displacement was left-lateral. The predominance of left-lateral strike-slip motion can explain the discrepancy between observed E-W striking thrust faults and folds and the ENE-WSW direction of Pacific-Australian plate convergence. Therefore, the mechanisms and depths of the earthquakes suggest that seismic deformation in the New Guinea fold and thrust belt is dominated by high-angle thrust faults that penetrate crystalline basement and that a major zone of left-lateral shear exists throughout the fold belt.

We are in the process of using gravity data to investigate the possibility that the Central Highlands are supported by the flexural strength of the descending Australian continental platform. If so, gravity and topography data will be used to constrain the extent of underthrusting since the mountains started forming in the late Miocene.

OPENING OF THE GULF OF THAILAND: RIFTING OF CONTINENTAL SOUTHEAST ASIA, AND LATE CENOZOIC TECTONICS

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The Gulf of Thailand on the west of the South China Sea is floored by very thick (up to 1km) mainly fresh-water sediments that include beds at least as old as Oligocene, and possibly considerably older. High heat flow in the sediments suggests a basement of young mantle-derived rocks under the thickest part of the sediments. Seismic prospecting data indicate many north-south-trending normal faults that have moved progressively during deposition of sediments. Rifting was east-west, at right angles to the trend of the normal faults, and the northwest trend of the Gulf of Thailand is not related to the rifting trend, but is inherited from a line of weakness along the Mesozoic northwest-trending sinistral Three Pagodas Fault Zone.

Approximately northeast-trending dextral faults in peninsular Thailand lie roughly at 45 degrees to the east-west sense of extension of the Gulf and accommodate increasing separation, towards the south, of peninsular Thailand from Indochina (the Eastern Gulf Coast). From palaeomagnetic evidence, the Malay Peninsula has rotated anticlockwise away from Indochina with a pole of rotation near or in western Borneo, and its northern end may be overthrusting southern peninsular Thailand.

The trends of the known and inferred Cenozoic faults on land are of the same age as the trends of the horsts and grabens in the northern Gulf of Thailand. Evidently, the east-west extensional tectonic regime that caused the opening of the Gulf extended north through the entire length of western, central, and northern Thailand, and even further north into Burma and Laos.

Intracratonic spreading in the Gulf of Thailand and extensional tectonics on land are probably related to the current subduction of the Indian Plate under southeast Asia along the Java Trench and the Andaman-Nicobar Island Chain. Spreading in the South China Sea and rifting of the Tonle Sap-Mekong Depression and offshore basin are probably also related to this breakup of continental southeast Asia. A few basins north of the Sunda Shelf containing hydrocarbon deposits are probably related tectonics. The time when the tensional faulting commenced in Thailand to the north of the Gulf, in the Gulf, in north Sunda Shelf and in south Vietnam is uncertain, but probably many basins, if not all, come into existence not later than Oligocene times, and have been continuously infilled with clastics since then. Marine deposition is widespread from the Pliocene onward.

The climax of Cenozoic tensional faulting is probably indicated by the small but widespread fields of late Tertiary and early Quaternary decline basalts in Thailand and south Indochina. The climax probably coincided with the main phase of uplift of the present mountains of Thailand and adjacent areas. The mountains have maturely dissected tops and youthful geomorphology on their margins, and contain infrequent but significant Quaternary deposits uplifted to great elevations, indicating probably rapid uplift during the Quaternary.

A plate tectonics model on the geologic evolution of Thailand and continental southeast Asia from early Palaeozoic to late Mesozoic are also briefly summarized.

SEA LEVEL CHANGES, ENVIRONMENTS AND TECTONICS IN THE LAST MILLION YEARS (SEIMY)

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The Intergovernmental Oceanographic Commission (IOC) and the United Nations Ocean Economics and Technology Branch (UN-OETB) jointly established a Programme on Ocean Science in Relation to Non-Living Resources (OSNLR) in 1985. The OSNLR Programme is at an early stage but progress has been made in establishing likely priorities. One of these priorities is the coastal zone, which is seen as an area of particular "need for knowledge" in many parts of the world. It is also an area of great economic significance. With this in mind, a project is proposed on Sea-level Changes, Environments and Tectonics in the last Million Years with the acronym SEIMY. The Guiding Group of Experts also proposed that "Training, particularly as it relates to coastal zones, placers, sand and gravel and carbonates, is given a high priority and should be a focus of effort by TEMA. Some training on phosphate deposits is also recommended". This paper will review OSNLR SEIMY possible research direction in the future and potential areas of training.

SEISMOTECTONICS OF NEW GUINEA: A MODEL FOR ARC REVERSAL FOLLOWING ARC-CONTINENT COLLISION

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The structure and evolution of the northern New Guinea collision zone is deduced from ISC seismicity (1964-1985), new and previously published focal mechanisms and a re-examination of pertinent geological data. A tectonic model for the New Guinea margin is derived which illustrates the sequential stages in the collision and suturing of the Bewani-Toricelli-Adelbert-Finisterre-Huon-New Britain Arc to central New Guinea followed by subduction polarity reversal in the west. East of 149°E, the Solomon Sea plate is being subducted both to the north and south bringing the New Britain and Trobriand fore-arcs towards collision. West of 149°E, the fore-arcs have collided and, together, they override a fold in the doubly-subducted Solomon Sea plate lithosphere which has an axis that is parallel to the strike of the Ramu-Markham suture and that plunges westward at an angle of 5° beneath the coast ranges of northern New Guinea. Active volcanism off the north coast of New Guinea is related to subduction of the Solomon Sea plate beneath the Bismarck Sea plate. Active volcanism of the Papuan Peninsula and Quaternary volcanism of the New Guinea Highlands are related to slow subduction of the Solomon Sea plate beneath the Indo-Australian plate along the Trobriand Trough and the trough's former extension to the west, respectively. From 144-148°E, seismicity and focal mechanisms reveal that convergence between the sutured Bismarck and Indo-Australian plates is accommodated by ramping and wedging within the Finisterre and Adelbert ranges, compression of the New Guinea orogenic belt, together with basement-involved foreland folding and thrusting to the south. Along the New Guinea Trench, west of 144°E, seismicity defines a southward-dipping Wadati-Benioff zone, and focal mechanisms indicate oblique subduction. Only this oldest, westernmost portion of the collision has progressed past suturing to a full reversal in subduction polarity.

QUATERNARY UPLIFT RATES AT A PLATE BOUNDARY: IMPLICATIONS FOR SEISMIC RISK, LAE URBAN AREA, PNG

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Lithofacies data combined with palaeontological and 14C dating yield uplift rates for Lae and the lower Markham Valley, PNG, on the boundary between the Australian and South Bismarck plates. Rates for the north flank of the Markham Valley, as far west as the Leron River, may exceed 4m/1000 yrs, averaged over the past 1 million years. In the Lae urban area a rate of 6m/1000 yrs is indicated for the past 20,000 yrs, with tilting prior to 8000 yrs bp. Experiments are needed to determine whether this uplift is occurring by creep or by episodic large increments, because the mode of uplift has implications for urban seismic risk. The uplift is a result of plate convergence, triple-junction migration and elision of the Solomon Sea plate.

SEA LEVELS IN THE PACIFIC - THE SIGNATURES IN CORAL REEFS OF PASSIVE MARGIN AND HOTSPOT ARCHIPELAGO ENVIRONMENTS

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Through their shallow water and temperature-dependent composition, reefs encapsulate a record of vertical and horizontal tectonics, sea-level change, subsidence history, palaeoclimate and palaeo-oceanography.

Reefs are structures which achieve their maximum growth within 25m of sea level and are bounded top and bottom by sea-level indicative criteria: an individual reef representing a period of reef growth is usually sandwiched between a basal unconformity and an upper surface crowded with sea-level imprints. On this basis and at this level, therefore, reefs are clearly good indicators of the proximity of sea level. However, and in addition, coral reefs contain a strong sea level signature within their framework which is often diagnostic of sea level to within centimetres.

Cainozoic sea-level changes have been rapid compared with the geological norm. Transgressive and regressive changes in the Quaternary of 10-20m 10^{-3} years differ from Tertiary rates only for the shorter lengths of time for which they occurred. In the hotspot-generated volcanic islands of the Tuamotus and the passive-margin generated reefs of northeast Australia, Holocene sea-level history has followed a similar course of very rapid transgression followed by a long period of stillstand. In both areas the reef facies produced, together with their geometrical relationships, are similar, reflect accurately the course of sea level and contain detailed signatures. Reefs can maintain pace with a rapidly rising sea level for a short period of time.

Reefs of passive margins and hot-spot regions preserve a record of vertical and horizontal plate motion. The "Darwin Points" can be identified in both settings. The temperate/tropical boundaries identified define the rates of plate motion.

STRUCTURAL DEFORMATION OF AN ISLAND ARC

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Structural deformation of the central New Hebrides Arc (Vanuatu) resulted from a complex tectonic history of subduction polarity reversal fracture zone-arc collision. Parallel, normal faults along the length of an emerging western belt of islands formed at approximately 25 Ma from thermal

upbowing of the arc during the first (Vitiaz) westward subduction phase. Reversal of subduction from westward to eastward (New Hebrides) at approximately 8-10 Ma led to the emergence of the eastern belt of islands where parallel, normal faults were contemporaneously propagated. Oblique collision of the d'Entrecasteaux fracture zone (DEZ) at approximately 6 Ma initiated wrench-fault tectonics with the formation of wide fault zones transverse to the long axis of the arc. Continuous subduction and collision for approximately how many years since then caused the elevation of horsts that support both western and eastern belt islands and the formation of an intervening intra-arc basin (graben). Wrench faulting enhanced horst and graben structures, formed transpressional-transtensional structural wedges and rotated blocks. Displacement along the transverse fault zones tapped magma chambers along the Benioff zone, thus allowing the construction of picritic volcanoes. A major transcurrent fracture zone, the Aoba fracture zone, exhibits approximately 20km of displacement and offsets the intra-arc basin. Steepening of the Benioff zone at approximately 1 Ma caused the migration of the active volcanic chain westward to its present location along the central axis of the arc. Continued collision of the DEZ is exhibited in recent uplift of Espiritu Santo Island and protrusion of an accretionary wedge westward into the New Hebrides Trench.

DEFORMATION OF THE ACCRETIONARY WEDGE AND THE SEISMIC ACTIVITY ALONG THE NANKAI TROUGH, SOUTHWEST JAPAN

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The sedimentary wedge across the Nankai Trough can be divided into three deformation zones according to their tectonic style and distribution of the compressional wave speed at the basal part of the wedge. These zones are labelled one to three from the trench axis landward. Dewatering and slip regime are obtained from the observed compressional wave speed.

ZONE	STRUCTURE	DEWATERING	SLIP REGIME
1	Basal decollement	Primary dewatering	Stable slip
2	Multiple decollement	Secondary dewatering (Dehydration of clay)	Transitional
3	Seismic thrusting (Tsunami earthquake)	Third-stage dewatering	Stick-slip

The fore-arc region along the Nankai Trough has been divided into 150km long segments by seismic activities (Ando, 1975), and they are hereby defined by shearing stress conditions on the subducting plate boundaries and by shortening of the wedge.

PILOT PALAEOMAGNETIC RESULTS FROM THE BIRD'S HEAD, IRIAN JAYA

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The drift history of the Bird's Head still remains a matter of discussion. Hypotheses to date contain little or no quantitative data of the sort that would provide some measure of the type and scale of relative motion postulated. Palaeomagnetic data on Bird's Head rocks are clearly required to contribute part of this missing element.

We report pilot results from a palaeomagnetic study of a sequence of 9 Bird's Head formations, comprising clastics and carbonates that outcrop along the southwestern margin of the Kemum Block (132.7E, 1.2S). The ages of the formations fall within the range Late Carboniferous to Middle Miocene. Briefly, 7 formations each yield 2 components of magnetization. One component, similar for all, has shallow, upward inclination and is, in general, northerly directed: it is interpreted as a Late Tertiary overprint, possibly of chemical origin. The other component is different for each formation and is interpreted, at this stage, as primary. Results from the remaining 2 formations provide no useful palaeomagnetic information.

Poles derived from the primary magnetizations are in overall gross agreement with the updated apparent polar wander path for eastern Gondwana: they demonstrate the absence of large-scale motion of the Bird's Head relative to Australia since the Late Carboniferous; in particular, large clockwise rotation since the Neogene. Rather, the results point to only small rotations and translations. They suggest some clockwise rotation between the Late Carboniferous and Middle to Late Eocene, followed by some north-northeast displacement completed by about Early to Middle Miocene. A small, post-Early to Middle Miocene component of anti-clockwise rotation could be present, reflecting collision of the Bird's Head with the margin of the Pacific Plate.

LARGE-SCALE ROTATION OF THE HIGHLANDS OF PAPUA NEW GUINA

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In 1984 the BMR in co-operation with the Geological Survey of Papua New Guinea initiated a palaeomagnetic study of the Central Highlands of Papua New Guinea. A pilot collection of over 500 samples was assembled from three regions: (1) the Triassic to Miocene sedimentary and volcanic sequence overlying and northwards adjacent to the Kubor Massif; (2) Lower to Middle Miocene carbonate, calcareous mudstone and greywacke of the Yaveufa Syncline; and (3) Eocene to Miocene carbonate, calcareous mudstone and greywacke from the Papuan Fold Belt in the Mendi-Ialibu region. Pilot demagnetization studies from region (3) show a primary magnetization indicative of minor clockwise rotation. Extensive pilot studies from the other two regions (1,2) show the presence of a pervasive overprint, most probably induced during a Middle to Late Miocene phase of major igneous

activity. These secondary magnetizations (and a single primary magnetization result from region (2) have westerly declinations and indicate a rather coherent pattern of anticlockwise rotation varying in magnitude from about 60 degrees to about 110 degrees. The general consistency of individual rotation observations throughout the Central and Eastern Highlands suggest bodily rotation of a coherent tectonic unit, starting after the Middle Miocene. These rotations are tentatively attributed to telescoping and translation of the northern edge of the Australian craton due to docking and accretion of the East Papua composite terrane and the Finistere terrane in the Middle and Late Miocene.

EVOLUTION OF WESTERN PACIFIC MARGINAL BASINS: AN EPISODIC HISTORY

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The marginal basins of southeast Asia are a jigsaw puzzle of deep and relatively short-lived (less than 30 Ma) basins that are separated by active and inactive arcs, rifted and collided crustal blocks. The major line of the subduction system, the Japan-Ryukyu-Taiwan-Philippine arc-trench system, appears to divide these marginal basins into two types: the continent-affiliated basins (e.g., the Japan Sea, Okinawa Trough and South China Sea) and the oceanic basins. The oceanic basins older than 40 mybp have a similar E-W magnetic lineation pattern and a tendency to become younger towards the north (e.g., the West Philippine Basin, Sulu, Celebes and Banda Basins). They are often interpreted as entrapped oceanic crust.

Based on magnetic anomalies, crustal structure, palaeomagnetic data and DSDP results, the evolutionary history of these marginal basins can be understood in terms of five major episodes of plate reorganization: the Neocomian, Late Cretaceous, Eocene, Oligocene and Miocene. For each episode, the tectonic development seems to be initiated by the collision of massive crustal blocks and followed by a change of plate motion, the development of new subduction systems and the alteration and initiation of spreading centres. The configuration of plate motion, subduction and spreading then appears to remain relatively steady until another cycle of collision. This type of collision-transformation-subduction history can be drawn from the chronological and spatial development of western Pacific marginal basins.

PLATE BOUNDARY PROCESS AND MOUNTAIN BUILDING

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The recent progress on the plate boundary process of divergent, convergent and transform boundaries, is briefly summarized with special reference to mountain building.

The specific effects of the collisions of continents, island arcs, oceanic plateaus or rises, and seamounts, are examined by on-land and undersea examples around circum-Pacific regions. The collision-related orogenic phenomena, i.e., (1) igneous activity, (2) uplifting of regional metamorphic belts, (3) evolution of geologic structure, and

(4) sedimentation, are summarized as follows: (1) Absence of volcanoes along the collision boundary may suggest the lack of subduction-related magmatism due to collision, but the older examples in Asia do not support the idea; instead, dominantly plutonic syn- or post-collision magmatism occurs. (2) The uplifting of low-P/T regional metamorphic belt coincides with the time of collision, but the uplift of high-P/T rocks occurs before the collision in most cases. (3) Two fundamental geologic structures, i.e., imbricated thrust sheets and their rearranged nappes, are observed in the collision zones together with the collision-related transform-fault deformations. (4) The episodic zoned growth of accretionary complex may be related to rapid sediment supply by collision. Most accreted oceanic materials are pelagic sediments, reefal limestone, and fragments of seamounts or rise (plateau), and are rarely mid-ocean ridge basalts (MORB). Their modes of occurrence suggest their mixings as trench olistostrome as observed in modern trenches.

EXPLOSION MELANGE

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The term mélange is currently used to describe several different kinds of mudstone-rich rocks that are broadly characterized by an obscure stratigraphy, stratal disruption, or a chaotic "block-in matrix" fabric. Proposed origins of mélanges include: (1) layer-parallel extension (Hsü, 1968; Cowan, 1982), (2) muddy debris flow (olistostrome) (Maxwell, 1974); (3) tectonic mixing (Suppe, 1973; Cowan, 1974); (4) flow mélange (Cloos, 1982); (5) mud diapirism (Larue & Speed, 1984);and (6) combinations of (1)-(5) (Hsü, 1973; Cowan, 1985). The term "explosion mélange" is presented here to describe some chaotic units, as inferred from ubiquitous occurrences of gas hydrates in arc-trench gaps, the binary phase diagram of CH_4-H_2O together with the effects of the third components of CO_2, NaCl, C_2H_6, C_3H_8 and H_2S, the offscraping structures near the toe of accretionary wedges, and a few on-land examples. The instantaneous 170-fold volume expansion of gas hydrate diapir by the depressurization, triggered by earthquakes, would highly disrupt the unconsolidated subduction complex.

TECTONICS OF THE EASTERN SUNDA AND BANDA ARCS INFERRED FROM THE SOURCE DEPTHS AND FAULT-PLANE SOLUTIONS OF LARGE, SHALLOW EARTHQUAKES

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One of the important problems concerning the tectonics of the eastern Sunda and Banda arcs in Indonesia is the mechanism by which the Australian continent converges with the SE Asian plate. I address this problem by determining accurate focal depths and fault-plane solutions of the region's largest earthquakes by inversion of their teleseismic, long-period P and SH waves.

N-S shortening occurs across the entire Banda Basin, by thrust faulting at its northern and southern margins and by strike-slip faulting within its interior. The strike-slip faulting falls within a series of NE trending ridges and most likely accommodates the NE motion of the SE Banda Basin relative to SE Asia. Also, strike-slip faulting dominates the seismic energy release in the fore-arc from Sumbawa to Timor and indicates that the fore-arc responds to the collision by N-S shortening and E-W elongation. Very few earthquakes indicate under-thrusting and are concentrated near Sumba Island (and of small seismic moment) and south of the Seram Trough. Large thrust earthquakes with roughly N-S trending slip vectors are prominent south of western Seram and along the back-arc slopes of the Sunda island arc from Bali to Wetar.

I conclude that convergence between Australia and SE Asia is not accommodated locally by thrusting at the Timor trough but rather that it is taken up by compressive deformation distributed over a 700km-wide area. The eastern Banda Basin is migrating E away from SE Asia and over the Arafura Shelf, thereby forming the southern Aru Trough. This mechanism can explain the decrease in convergence at the Timor Trough and can account for the bend and apparent NW convergence direction at the eastern end of the arc. The deformation in the Banda Basin is analogous to that in Asia north of the Himalaya.

THE EFFECTS OF COLLISION ON THE EASTERN AND PAPUAN PLATEAUS IN EASTERN NEW GUINEA

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The Eastern and Papuan Plateaus form a southeasterly prolongation of the Australian craton situated between the Coral Sea Basin/Osprey Embayment and the Papuan Peninsula in eastern Papua New Guinea.

The collision of these plateaus with the East Papuan Composite Terrane in the Miocene formed the eastern part of the New Guinea Orogen. The effects on the plateaus of this collision include reactivation and reversal of movement on some plateau-forming normal faults, tilting and subsidence of the northern margin of the plateaus and the formation of foreland style basins. Despite their comparatively small size, the ocean/continent boundary along the south side of the plateaus appears to be unaffected by the collision events along the northern margin. The plateaus appear to have responded to the collision in a similar fashion to the craton further west.

STUDY ON THE HEAVY MINERALS DISTRIBUTION OFF MAPTAPHUT BEACH, RAYONG PROVINCE, EASTERN THAILAND

AMPAI POKAWANVIT
Mineral Resources Department, Bangkok, Thailand

The origin of heavy minerals at Maptaphut Beach is still controversial. To prove the source, 54 surface samples were collected from nearshore and offshore zones off the beach. These samples were then processed through heavy-mineral separation. Optical investigation and grain-counting were also conducted in order to determine the content of each mineral. The result obtained indicates that the heavy minerals in the study area are dominated by tourmaline, zircon and ilmenite, with small amounts of rutile, leucoxene and monazite, and very small quantitites of cassiterite, anatase, xenotime, topaz, garnet, pyrite, magnetite, siderite and alterite. Amounts of tourmaline, rutile, leucoxene, anatase, xenotime and topaz, the lighter minerals, increase landwards from offshore to nearshore, while zircon, ilmenite, monazite and cassiterite, the heavier minerals, display the reverse character. This relationship reflects hydrodynamic sorting; accordingly, offshore exploration should be undertaken to delineate and evaluate the source.

STORM MORPHOLOGIES OF WESTERN KIRIBATI ATOLLS

BRUCE M RICHMOND and PETER S ROY
CCOP/SOPAC, Suva, FIJI

The Gilbert Island atolls of western Kiribati are developed on mid-plate oceanic volcanoes. Numerous low-lying coral islets on their outer rims are best developed along south and east windward margins. The islets, generally less than 5 metres above present mean sea level, exhibit numerous features interpreted as resulting from severe storm activity. These features include:

(1) Islet dissection by channels, typically with armoured margins of cemented coral rubble. Clast-size decreases from ocean to lagoon side where sediment lobes often protrude.

(2) Shore-normal tongues of coral conglomerate developed on seaward reef-flats. With heights greater than 1m above the modern reef flat surface, the edges are commonly an erosional scarp.

(3) Islet surfaces strewn with loose reefal debris up to boulder size.

All of these features can be attributed to storm activity under present mean-sea-level conditions without invoking a Holocene sea level higher than at present.

THE FORMATION AND COMPACTION OF MARGINAL SEAS

WALTER D ROOTS
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The calculated top-cooling rate for oceanic mantle, being three times greater than that for continental mantle, explains sub-continental rising convection plumes, and central continental rifting. As continents drift from over the convection cells that rifted them, they are replaced by oceans, accelerating top-cooling of cells and starting cell decay. The new plumes forming under drifting continents will expand while their parent continents remain intact, by pushing back their common boundary with older adjacent cells. Common cell boundaries move from an initial position beneath continents, towards COBs. On passing beneath COBs, the interface between cells comes beneath (subductable) oceanic lithosphere. Subduction starts as an edge of oceanic lithosphere is pulled into the interface between cells (where flows from adjacent cells converge and turn down). Cell boundaries then cease normal steady movement, due to the resistance of trapped slabs to seaward movement, even though cells are still changing in relative power. Eventual breaking of the slab from the lithosphere (by increasing stress between upper opposed flows) allows convection flows to meet again, to find an equilibrium position well to seaward of the last position, and to start subducting a nappe of oceanic lithosphere leading to back-arc spreading and formation of a marginal sea. More marginal seas then form as occasional fracturing of the slab is followed by further jumps of subduction seaward. Eventually, the new cell rifts its parent continent, and all marginal seas are accreted to the continental fragment that moves to the active subduction zone, forming Andean-type margins.

GEOLOGICAL STRUCTURE AND MAGNETIC PATTERNS IN MARGINAL SEAS

WALTER D ROOTS
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All well mapped arcuate marginal seas have chaotic magnetic anomaly patterns, whereas well mapped linear marginal seas have ordered linear magnetic anomaly patterns. This empirical relationship results from differences in the mode of marginal-sea opening in each case. Linear marginal seas can and do develop long mid-ocean ridge (MOR) spreading segments from the start of true spreading, so that long linear magnetized areas are formed on the sea floor and can be mapped and correlated. In contrast, marginal seas that begin spreading with an arcuate shape will have a large proportion of their margins oriented at an acute angle to the spreading direction, and so can develop only short spreading segments (and magnetic anomalies). Only after considerable opening can long spreading segments form, and most marginal seas have ceased spreading before this occurs. Marginal seas which cease spreading with their outer arc stretched longer than when spreading began (Japan Sea, Mariana) are more complex again, since this geometry involves two-dimensional spreading. Magnetic and seismic data used together can aid interpretation of complex spreading patterns, as in the Labrador Sea where similar spreading geometry has produced a magnetic quiet zone over rough basement, a characteristic of acute-to-margins spreading.

COASTAL SEDIMENTATION AND DELTAIC PROGRADATION ON A TILTING COAST, NORTHEASTERN GUADALCANAL

PETER S ROY and BRUCE M RICHMOND
CCOP/SOPAC, Suva, Fiji

In the coastal plain and nearshore zone of northeastern Guadalcanal, seven relatively large rivers form coalescing deltas whose morphology is strongly modified by waves. Except for the Lungga River which is discharging directly into deep water, the deltas are prograding over a relict shelf platform less than 60m deep. This platform is thought to represent a Pleistocene deltaic plain that has subsided due to tectonic tilting of the island. The prograding delta lobes are rather steep and convex in profile whereas the intervening embayments between lobes are flatter and concave upward. Nearshore sediments are mostly terrigenous muds, sands and gravels which correspond to different deltaic facies whereas further offshore calcareous muds and sands predominate on the current-swept shelf. Lower river-channel morphologies vary from braided coarse-sediment types to incised and meandering fine-grained forms. Response to flooding varies greatly between the different channel morphologies. Mineral assemblages of the beach sediments on each delta correlate well with its river catchment lithology suggesting little lateral mixing.

TECTONIC RECONSTRUCTIONS IN EASTERN INDONESIA

ELI A SILVER and HARDI PRASETYO
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Reconstructions are based on global plate movement histories, local palaeomagnetic information, and regional geology. For reconstructions over the past 40 Ma, we have two somewhat independent approaches. One assumes a fixed hotspot framework, to which all major plates can be referred. The other examines relative plate motion through a global circuit, including the Pacific, Antarctic, Australia-Indian, African, North American, and Eurasian Plates. We have used both methods and find little significant difference in results. A major uncertainty is the history of deformation in Asia, and that introduces some error into all reconstructions. An equatorial seaway connected the Pacific and Indian oceans until almost 10 Ma ago. Crustal fragments from Irian Jaya can be backtracked to potential initial positions along major plate trajectories. Lithologic data from the Banda Sea show initial separation of the Banda ridges from Irian Jaya in middle to late Miocene, and geochemical studies of the Banda ridges and the Banda arc volcanics imply that subduction beneath the Banda arc originated prior to 7 Ma ago.

UPPER MANTLE VELOCITY OF FIJI REGION FROM SURFACE WAVE DISPERSION

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Single-station group velocities over the period range 15-100 s are computed for nine fundamental-mode Rayleigh-wave-propagation paths that cross tectonic provinces of the Fiji region. These computations are based on recordings of the earthquakes around the Fiji islands by the WWSSN stations AFI, HNR and WEL. The inversion of the derived dispersion curves for shear velocity - depth structure shows that uppermost mantle velocity beneath South Fiji Basin, Lau Basin and North Fiji Basin is slightly lower than that derived for the Pacific Ocean region of similar age by Yu and Mitchell (1979). The uppermost mantle LID is almost absent beneath these marginal basins, and the shear velocity is between 4.0 and 4.3 km/s in the depth range from Moho down to 220 km.

Interstation phase velocities between WEL-AFI are computed for one earthquake. When this dispersion curve is interpreted in terms of a flat-earth parallel-layer model it indicates a higher mantle velocity. This could be taken as the indication of the presence of subduction.

PRELIMINARY RESULTS OF A PALAEOMAGNETIC STUDY OF MISOOL, IRIAN JAYA

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Parts of the Indonesian islands around the Banda Sea, and the Banda Ridges within this Sea, have basements of Australian affinity; they were probably displaced by strike-slip faulting from Irian Jaya.

The island of Misool, just west of the "Bird's Head" promontory of Irian Jaya has excellent coastal exposures of a Palaeozoic through Quaternary sequence of carbonate and clastic rocks. We are utilizing the palaeomagnetism of these rocks to investigate the tectonic relationships between Misool, Irian Jaya, and Australia. The palaeomagnetic data will also provide a framework in which to evaluate the displacement of the various allochthonous slivers in the Banda Sea region.

We collected 614 oriented core samples from 107 sites for palaeomagnetic study of 14 formations in the Misool archipelago. Detailed pilot thermal demagnetization experiments on representative samples from each formation demonstrate that secondary overprints can be removed allowing isolation of a stable magnetic direction. Very weak magnetization of most of the Tertiary carbonates makes accurate measurement of these rocks difficult. The Late Cretaceous Fafanlap and Waaf formations, however, retain well defined, pre-folding magnetic directions that suggest substantial counterclockwise rotation of Misool relative to Australia.

POSTERS

SEDIMENTARY PROCESSES RELATED TO FORE-ARC DEVELOPMENT: THE LOMBOK AND SAVU BASINS, EASTERN INDONESIA

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and D KUSNIDA, P KRIDOHARTO and S TJOKROSAPOETRA
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The Lombok and Savu Basins form fore-arc basins of the central and eastern Indonesian fore-arc system, and have been studied until now only to a limited extent.

Seismic and acoustic profiling carried out during the Snellius II expedition in 1984-1985, complemented by extensive piston coring, shows that in the Lombok Basin underthrusting resulted in the formation and uplift of the Lombok Ridge but that uplift is much less than along the Sumba-Savu-Roti-Timor Ridge. The latter has resulted in large-scale gravitational gliding and slumping from S to N into the Savu Basin and causes the widespread occurrence of acoustic voids in the turbidites forming the present sea floor of the Savu Basin. Uplift of the Lombok Ridge has resulted in the widespread occurrence of growth faults along the ridge margins, and of small-scale slumping. Sedimentation rates in the Savu Basin are twice as high as in the Lombok Basin: preliminary rates are 25 cm/1000 year for the Savu Basin and 9-11 cm/1000 years for the Lombok Basin sediments

ARC-RIDGE COLLISIONS AND BACK-ARC RIFTING IN THE SOUTHWEST PACIFIC

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Orstom, B P A5, Noumea Cedex, New Caledonia

The first and fifth legs of the R.V. JEAN CHARCOT SEAPSO cruise were devoted to the study of three arc-ridge collisions along the New Hebrides and Tonga subduction zones, using SeaBEAM bathymetry, magnetics, gravity and single channel seismic reflection profiling. d'Entrecasteaux Ridge, Loyalty Ridge and Louisville ridge illustrate, respectively, the cases of a ridge arriving perpendicularly, in parallel and obliquely to the trench.

During the second leg, we surveyed the New Hebrides back-arc area, especially the troughs extending northward (Vanikoro and Vot Tande Troughs) and southward (Efate and Coriolis Troughs).

The poster shows the main results of these three legs, emphasizing the structural aspects with 3-D colour block diagrams. Detailed SeaBEAM maps are also presented.

SUMMARY REMARKS ON TOPIC 1: EVOLUTION OF THE ARC COMPLEX: GEOLOGY AND SPECIATION

BY DR. JOHN KATILI [1]

In the section on the Evolution of the Arc Complex: Geology and Speciation, two main lines of discussion were envisaged: Plate Tectonics and Palaeogeography; and Sea-level Environments and Tectonics. It turned out that the papers presented fell predominantly in the first body of discussion. There were eleven papers on plate boundaries, including arc evolution and plate movements; four papers on stratigraphy and/or sedimentation; three on basin evolution; two on local geology and seismology; two on sea-level in general and one on rifting.

Cooper/Taylor, in discussing a model of arc reversal following arc-continent collision for the Bewani-New Britain arc and its suturing to central New Guinea, showed that the Solomon Sea plate is being subducted to the north and south, thus moving the New Britian and Trobriand arcs towards collision.

Green and his co-authors described in detail the palaeotectonic history of the central New Hebrides arc.

McCaffrey, reporting on tectonics of two island arcs (East Sunda and Banda) inferred from accurate determination of focal depths and fault-plane solutions of large earthquakes in the region, described the convergence of the Australian and south-east Asian plates, and the fore-arc response to the collision by N-S shortening and E-W elongation. The convergence appears not to be accommodated locally by thrusting at the Timor Trough but rather by compressive deformation over a wide area.

Crook informed us of specific uplift rates for two parts of Papua New Guinea as a result of plate convergence, involving triple-junction migration and the elision of the Solomon Sea Plate.

Maruyama reviewed recent progress in the study and interpretation of plate boundaries (divergent, convergent and transform) with special reference to mountain building, particularly the relation of the timing of uplifting to that of collision, noting that accreted materials are rarely mid-ocean ridge basalts.

Pigram/Symonds described the effects of the collision between the Australian and the Eurasian plates on the Eastern and Papua Plateaus, noting that the collision events along the northern margin of these Plateaus do not appear to affect their southern margin; this suggests that collision, although a major manifestation of tectonic activity, is a comparatively localized phenomenon.

Sudaralingam described upper mantle velocities of earthquake waves crossing tectonic provinces in the Fiji region, suggesting that this is a region of subduction.

Abers/McCaffrey determined reliable focal mechanisms and source depths for large earthquakes in the New Guinea fold and thrust belt. The

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1 A text not having been made available, these remarks are developed here from notes.

considerable depths of the smaller events show that active deformation itself may operate at considerable depths. They showed also that deformation in the fold and thrust belt is dominated by high-angle thrust faults penetrating the crystalline basement.

In contrast, **Klootwijk** and his co-authors provided palaeomagnetic evidence that, after the Middle Miocene, a bodily anticlockwise rotation of a coherent tectonic unit occurred, which they tentatively attributed to telescoping and translation of the northern edge of the Australian craton.

Silver/Prasetyo showed that two approaches to the tectonic reconstruction of eastern Indonesia - one assuming a fixed hot-spot framework, the other, relative plate movements world-wide - lead to comparable results.

Thripp/Silver/Prasetyo reported on a palaeomagnetic study of the island of Misool, Irian Faya, just west of the Bird's head, comparing the results with those for Australia. They found that certain formations retain well defined pre-folding magnetic directions, suggesting substantial counter-clockwise rotation of Misool relative to Australia.

Kagami reported results of a study of the sedimentary wedge across the Nankai Trough; he showed that the wedge is characterized by three deformation zones with different tectonic regimes, which illustrates the complexity of the tectonics of the western Pacific region.

Klootwijk and his co-authors, presenting palaeomagnetic results from the Bird's Head in Papua New Guinea, showed that seven of nine outcrops covering the period Late Carboniferous to Middle Miocene indicated a shallow upward inclination more or less northward which probably represents a late Tertiary overprint. A possibly primary component, different for each of the seven formations, wBas also observed. Somewhat surprisingly, two formations yielded no useful palaeomagnetic information. The inference is that the Bird's Head in Papua New Guinea has remained attached to Australia since the Late Carboniferous, but with some clockwise notation up to the Eocene. This contrasts with the results presented by Thripps, Silver and Prasetyo.

Maruyama described explosion melanges - chaotic geological structures (obscure stratigraphy, stratal disruption, chaotic block-in matrix) - and suggested several possible processes leading to their formation.

Roy/Richmond described coastal sedimentation and deltaic progradation on a lifting coast (north-eastern Guadalcanal). The deltas cover a Pleistocene plain tilted by tectonic activity, with little lateral mixing between channels.

Chao Sung/Widde described the evolution of western Pacific marginal basins; they are relatively short-lived and of two types: continental and oceanic, the latter possibly being trapped oceanic crust. The basins reflect five major episodes of plate reorganization: collision followed by change of plate motion, with new subduction and spreading zones being established. This again suggests the complexity of the tectonics of this region.

Roots described the formation and compaction of marginal seas in terms of differences in the cooling rates of convection cells beneath

continental crust and beneath oceanic crust. Convergence beneath ocean crust subducts a nappe of oceanic lithosphere leading to back-arc spreading and formation of a marginal sea. This subduction leads to cell decay in the mantle and, later, to reformation of the cell seaward of the previous subduction. **Roots** also described some geological structures and magnetic patterns in marginal seas, showing that the palaeomagnetism of marginal seas is generally related to their mode of formation and of spreading; linear marginal seas therefore have more regular palaeomagnetic features than do arcuate marginal seas (stretched outer edge relative to the rift).

Bunopas described the rifting of Thailand and the related tectonics, stressing its relation to subduction of the Indian Plate under south-east Asia along the Java Trench and the Adaman-Nicobar Island chain.

On a more local scale, **Pokawanvit** described the distribution of heavy minerals off Maptaphut beach in eastern Thailand, and **Richmond/Roy** described the effects of severe storms on the morphology of the Gilbert Island atolls of western Kiribabi. They attributed the observable features to storms at present mean sea level without the need to move invoke a higher Holocene sea level.

Davies described how coral reefs provide a record of vertical and horizontal tectonic movements, of sea-level changes, palaeoclimate and palaeo-oceanography because of the strong correlation between coral growth and the depth at which this growth naturally occurs.

Cook outlined the IOC-UN Programme of Ocean Science in Relation to Living Resources, with specific reference to the Sub-Programme on Sea-level Changes, Environments and Tectonics in the Last Million Years.

Application of the results of marine geological and geophysical studies is important in many ways: in prospecting for hydrocarbons and metallic minerals; in assessing and possibly mitigating the effect of geological hazards such as earthquakes. Study of the stratification of ocean-bottom sediments has made possible a determination of climatic changes in the past and has increased understanding of such changes, which, should help us to predict future climates.

The results of recent investigations suggest that the zone between the trench and the volcanic arc appears in some areas to be more like a passive margin consisting of older rocks that have been eroded and subsided rather than a "stack" of geologically very young sediment slices scraped off the oceanic plate. The back-arc basins are often thickly covered with sediments of terrestrial origin. The sediments are young but the high values of heat flow that have been measured in many such basins may indicate that the organic content in the sediments is mature, making these areas important for the exploration of hydrocarbons.

The papers given at this Symposium have indicated that, although many aspects of plate tectonics are still imperfectly understood, and some results do not seem to fit current hypotheses, a great deal is to be gained from further exploration using state-of-the-art technology.

TOPIC 2: OCEAN VARIABILITY AND THE LINKS WITH CLIMATE

Topic Covenor:

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Keynote Speaker:

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Discussion Leaders: (a) Exchange of Water Between the Oceans

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(b) Upwelling

Dr Matthias Tomczak
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(c) Ocean/Atmosphere Interaction

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(c) Deep Basins and Adjacent Seas

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KEYNOTE SPEECH[1] BY DR. J. STUART GODFREY: OCEAN VARIABILITY AND LINKS WITH CLIMATE.

This talk was to have been given by Professor Klaus Wyrtki, who was unfortunately unable to attend due to illness. It is a great pity that Professor Wyrtki could not come, because it is he more than anyone else who has put oceanography on a sound basis in the WESTPAC region. From his early work while in Indonesia in the 1950s up to the present time, Professor Wyrtki has introduced a steady stream of useful, simple ideas about how the ocean works in this area. In particular, he has played a pioneering role in showing how ocean behaviour in this region is intimately linked to variations in the world's climate, such as the El Niño-Southern Oscillation events that, in some years, cause serious drought in Australia, Indonesia and elsewhere. In this talk I will try to show what these links between the ocean and climate are, and to explain why further study of the region's oceanography is essential if we care to understand (and hopefully predict) climate changes in our region.

Why is the ocean heat budget in the equatorial West Pacific important for understanding climate variations?

Regarding the mean distribution of cloud cover in the Pacific Ocean, throughout the year, two well defined bands of cloud form an unsymmetrical V pattern, with the tip of the V north of PNG. One band, roughly parallel to the equator at 5°-10°N, is the Inter-Tropical Convergence Zone (ITCZ); the other, angling east-southeast from PNG, is the South Pacific Convergence Zone (SPCZ). Heavy rainfall occurs in each of these bands; the latent heat released in them is the main driving force for both the Hadley and Walker circulations, and hence for Pacific tropical winds. The winds in turn drive the ocean currents and contribute to determining the sea-surface temperature (SST) distribution.

The resulting annual mean SST pattern contains two ridges of maximum SST- and the cloud bands lie almost directly over the SST ridges. This is not a coincidence, and seems to indicate a positive feedback loop from rainfall through winds, currents and SST back to rainfall. This impression is confirmed by recent analysis of ENSO events (e.g. Gill and Rasmusson, 1983): in the 1982-83 event, the entire system - cloud bands, rainfall, winds, currents and SST maxima - move eastward as much as 3 000 km and, in the process, rainfall continues to occur most strongly above SST maxima and ridges. As a result, Indonesia and much of Australia become drier, and the central Pacific experiences heavy rain.

If this positive feedback link idea is accepted, then it seems likely that Pacific (and global) climate should be extraordinarily sensitive to small

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1 Dr. Godfrey kindly replaced Prof. Klaus Wyrtki as Keynote Speaker on this topic and based his Keynote Speech on his formal presentation of a paper on Air-Sea Interaction in the Tropical Pacific and Indian Oceans. This paper has been edited, without specific reference to the original Figures and without specific bibliographic references, for the purpose of presenting Dr. Godfrey's Keynote Speech in a suitable form here.

SST changes in this region. For example, an increase of about 0.5°C at (0°S,170°E), combined with a decrease of about 0.5°C near (0°S,140°E), will drive the SST maximum about 2 000 km eastwards. Precisely such an event is seen at the start of an ENSO event.

Further confirmation that global climate is extremely sensitive to SST in this region is provided both by numerical model results, and by correlation studies of SST on Australian crops. Thus, Palmer and Mansfield performed a control run of their atmospheric General Circulation Model (GCM) with a typical SST pattern; then they ran two other runs, with Pacific equatorial SST anomalies of quite different types. In one, the model shows that massive SST anomalies occur near South America (as observed in an ENSO event), but there is no SST anomaly in the western Pacific. In the other, the eastern Pacific anomalies are removed, but small SST anomalies occur in the western Pacific. The area integral of the anomalies in the first case is about 20 times that of the anomalies in the second, yet the GCM response was substantially stronger to the anomalies of the second case than to those of the first.

Turning to the correlation of SST on Australian crops, Nicholls obtained a time series of the values (in 1983 Australian dollars) of five crops- wheat, oats, barley, sugar cane and potatoes - from 1953-1982. After removing the long-term trends due to technology change etc., by a cubic spline fit over the period, the gross value of all five crops shows a strong correlation with the annual mean SST from merchant ship reports from a large region north of Australia.

The rms magnitude of the crop variations is about $ 300 million, but the rms magnitude of the SST variations is only about 0.3°C.

These examples show that global and Australian climate do appear to be sensitive to changes of as little as 0.3°C in SST north of Australia. This is probably particularly true within 1000km or so of the annual mean SST maximum north of Papua New Guinea. Evidently, it becomes important to know what causes these SST changes to occur, and hence whether they are likely to be predictable. This involves understanding the heat budget for the ocean's surface mixed layer, in this region.

Recent progress in understanding heat-flux variations in the equatorial western Pacific has shown that the heat input into the surface mixed layer is the algebraic sum of inputs through the sea surface (Qtot), through the base of the mixed layer by mixing (Qmix), and through horizontal advection (Qadvect):

$$DTt = Qtot + Qmix + Qadvect \qquad (1)$$

where D is mixed-layer depth. (One might think the time-dependent term on the left should be (D T), but the term DTt accounts for variations of mixed-layer depth due to passing planetary waves etc., and should be left out of a thermodynamic equation for surface temperature, T). Meyers *et al.* have recently used (1), estimating only Qtot on the right side, to show that observed changes in DTt correlate rather well with changes in Qtot through 1979-83. The observed sea-surface temperature (SST) between New Caledonia and Japan shows that equatorial SST was rather constant until early 1982, when a strong cooling took place. From then through 1983, the normal winter

coolings in each hemisphere penetrated more deeply than usual towards the equator.

The value of Qtot as a function of time near 2°N, along the Noumea-Japan route was estimated from normal ship's observations of cloud cover, wind speed and direction, air speed and humidity and SST, using a number of empirical formulae for the different terms (latent and sensible heat flux, solar and infra-red radiation) contributing to Qtot: Negative values in the observed rate of change of heat content of the mixed layer indicate cooling events. They tend to correspond to negative values of Qtot, of about the right magnitude.

On further examination, Meyers et al. found that the main contribution to the changes in heat flux came from the latent heat term; in particular, cooling events tended to occur when winds from the winter hemisphere blew across the equator. The observed wind field from the Australian Bureau of Meteorology data, during two cooling events (one each for the winters of each hemisphere), and the corresponding wind fields during two winters in which cooling events did not occur, supporting Meyer's view.

These results give us the first indication of how the small temperature changes that precede an ENSO event probably occur.

However, Meyers et al.'s mean value of Qtot was quite large - about 80 watts/m². Since they did not try to estimate Qadvect or Qmix, this result implies either that Qmix + Qadvect also have a mean of about 80 watts/m² and relatively small interannual variations, or that there are systematic errors in estimating Qtot.

The "systematic error" hypothesis is supported by examining annual mean values of Qtot estimates by various authors (Hastenrath and Lamb; Weare et al., Esbenson and Kushnir; Hsiung). All these authors estimate Qtot as the sum of a number of contributions:

$$Qtot = Qr - Qb - Qe - Qs \qquad (2)$$

where Qr is incoming total radiation, Qb is back radiation, and Qe and Qs are the latent and sensible heat losses. Different authors differ by as much as 60 watts/m² in their estimates of the annual mean of some of these terms, at least in the eastern Indonesian region, with which Hastenrath and Lamb's Indian Ocean studies can be compared.

However, it is recent oceanographic data that highlight the problem with the estimates of Qtot. These data suggest that Qadvect and Qmix are both no larger than perhaps 5 watts/m². Since we need to estimate this sum to roughly 10 watts/m² if we are to understand how SST changes of 5°C occur over 3-month periods, such an error in the annual mean is unacceptable.

Let us now consider the different terms in equations (1) and (2) in a little more detail.

Regarding heat fluxes across the air-sea interface, from maps of total annual mean heat flux, from various authors, and from similar maps of individual components of this flux, approximate values (within one contour interval) have been estimated near (0°S, 120°E). The results (all values are

in watts/m²) are tabulated below. The years listed beneath each author give the period in which the data were taken, where available. Comments on possible reasons for the discrepancies follow.

Author(s)	Contour Intervals	Qr	Qb	Qe	Qs	Qtot
Hastenrath and Lamb (1911-70)	20	180	40-50[1]	60	<5	60
Weare et al. (1975-76)	20,5[2]	220	40	120	5	60
Esbenson and Kushnir[3]	20,5[2]	160	40	80	<5	40
Reed (1970-79)	25,10[2]	225	30	75	<5	75-100
Hsiung (1946-79)		-	-	-	-	60
Range		60	20	60	0	40

Regarding solar radiation, these data show that individual estimates of solar radiation differ from one another by as much as 60watts/m², near 0°S, 120°E. The differences depend primarily on different formulations of the dependence of downward solar radiation on cloud cover - as reported by the (subjective) shipboard observer. The region of interest contains heavy cloud; the empirical formula used by Reed and Weare et al. is due to Reed, and was tested in the eastern Pacific, a region of stratus or trade cumulus cloud. The formula may break down in the high cumulus towers of the western Pacific. Hastenrath and Lamb's formula is due to Bernhardt and Philipps; it is considerably more sophisticated than Reed's, and their value (180 watts/m²), if correct, goes some way to reducing the high net heat flux found by Reed. Esbenson and Kushnir used an algorithm due to Berliand; it contains a quadratic term in cloud amount that was absent in the Reed formula. Esbenson and Kushnir's estimate is also substantially lower than Reed's.

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1 Estimated by averaging from four seasonal maps, rather than an annual map.

2 For minor components (Qb, Qs) the authors use the smaller of the contour intervals shown.

3 Some relevant contours are not labelled in Esbenson and Kushnir's map; the values quoted are subject to confirmation with the authors.

However, none of the formulae make any attempt to allow for regional differences in cloud type - nor in any subjective bias by observers, in estimating cloud amount in cumulus-tower conditions.

Regarding back radiation, considerable differences occur between different authors' formulae; however, since the range of values obtained is small, we shall not examine these in detail here.

All estimates of latent heat loss have been made using a formula of the form:

$$Qe = Ce\ (U, Tw - Ta)\ U\ (qw - qa) \qquad (3)$$

where qw, qa are specific humidities appropriate to water at temperature Tw, air, respectively; U is wind speed, and (Tw-Ta) is the air-sea temperature difference. Different authors use different expressions for the "bulk transfer coefficient", Ce (U, Tw-Ta).

Values of Qr and Qe may differ by as much as 60 watts/m^2. Part of the error may lie in neglect of a "salt correction" - Weare et al. estimated qw with a formula appropriate to fresh water. Not all authors give their formulae in sufficient detail to be able to track down such subtle points.

However, (3) must break down in sufficiently light winds, because free convection can carry moderate (and presently poorly known) evaporative heat fluxes even under zero-wind conditions; i.e., Ce (U, Ta-Tw) is singular at zero wind speed.

Presently used formulations for Ce (U, Ta-Tw) for light wind conditions are due to Bunker, and to Liu et al. Reed, Weare et al. and Hsiung all used Bunker's formulation; Esbenson and Kushnir used Liu et al's formula, while Hastenrath and Lamb used a constant Ce of 0.0014.

However, Bunker's form is based on BOMEX observations that are rather sparse at low wind speeds, and all wind speeds below 5 m/s are given a single value of Ce; i.e., the singularity is ignored. Liu et al's formula seems better, but it was not tested well against observation at low wind speed.

In practice, the singularity is likely to manifest itself when winds are so light that the Monin-Obukhov length - which is essentially the thickness of the layer in which the ordinary bulk formula can be applied - is less than the typical height of the ship's observation platform, typically 10 m; under such conditions, the observation platform is likely to sample spasmodic "thermals" rather than a mechanically turbulent boundary layer. This occurs for wind speeds less than about 3 m/s.

On a mooring at 0°S, 150°E, such wind speeds occurred nearly 50% of the time, in August-September 1985, so we could expect significant errors in estimating latent heat fluxes in this region. Furthermore, Tw-Ta was seldom less than 1.5°C; such large air-sea temperature differences imply large values of Ce. There is a further minor puzzle here: Hastenrath and Lamb, Ware et al., and Reed agree that an average value of (Tw-Ta) from merchant-ship data is only 0.5°C. Hopefully, this puzzling discrepancy will be resolved.

More fundamentally, however, there is a need for direct observations of latent and sensible heat fluxes, and calibration of them against a revised, low-wind version of the bulk formula (3).

So far, we have not discussed the oceanographic reasons for believing that the net heat flux estimates tabulated above are all too high. The first attempt to see how the ocean disposed of such large net heat fluxes in the western equatorial Pacific is due to Niiler and Stevenson, who considered the annual mean heat budget of the waters enclosed by the annual mean 28C isotherm in the Pacific Ocean (also the 26°-C isotherms in the Pacific and Atlantic Oceans). Mass continuity ensures that annual mean flows cannot advect heat through an annual mean isotherm; however, seasonal flows can generate an "eddy flux" of heat across the isotherm - e.g., if seasonal flow anomalies are into the enclosed region in winter when the water is below annual mean temperature, a net cooling will occur.

Niiler and Stevenson concluded that (in the Atlantic) the Ekman contribution to this "seasonal advection" term should only be about 0.04 watts/m², with a contribution of similar magnitude from the geostrophic flow; i.e., they concluded that seasonal advection was negligible. Though their argument was loose, it seems unlikely that their estimate could be in error by the factor of over 100 needed to be significant compared to the fluxes tabulated above.

On the other hand, Niiler and Stevenson estimated eddy diffusion through the broad base of the 28°C pool, using estimates from Crawford and Osborn's turbulence measurements: they found that, away from the equator, heat fluxes 4-12 watts/m² could pass through the 28°-C isotherm from this cause, while within 1 degree latitude of the equator, heat fluxes of 40-150 watts/m² were possible. The area average was about 5-19 watts/m² over the 28°-C pool; this compared quite well with the area average of the net surface heat flux from Weare et al., which was 22 watts/m².

More recently, however, CSIRO scientists have obtained results suggesting that Niiler and Stevenson's estimate of turbulent heat flux through the base of the surface mixed layer are too large. The argument is based on the observation of a number of temperature and salinity profiles in the western equatorial Pacific; typically, salinity starts to increase rapidly below about 40m, while temperature remains roughly constant down to 60 or 80m. Within the depth range 40-80, the stratification is so strong that mixing can only occur by wind-induced turbulence: an eddy diffusivity can be estimated by considering the salt balance of the top 60 m. This diffusivity can then be used to estimate heat fluxes. The salt balance places an upper bound on the diffusivity of 2 x 10-5 m²/s leading to a heat flux of less than 3 watts/m².

The error in Niiler and Stevenson's argument regarding turbulent heat fluxes is primarily due to extrapolating Crawford and Osborn's observations from the central Pacific to the western Pacific, a much quieter and less turbulent region. If we accept their conclusion regarding seasonal advection of heat as being correct within two orders of magnitude, it follows from the recent CSIRO results (and equation (1)) that the heat-flux estimates tabulated above are all incorrect.

Evidently, substantial progress has been made in understanding how the small SST variations that are so important to ENSO take place. However, before

Meyers et al.'s results can be turned into useful quantitative tools for understanding climate change, more must be done on improving the empirical formulae used in their calculation.

CORAL SEA - SHELF WATER EXCHANGE IN THE GREAT BARRIER REEF

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The mechanisms of exchange between the shelf sea and the Coral Sea in the Great Barrier Reef province include very low-frequency (seasonal) fluctuations in the poleward-flowing East Australian Current, upwelling at the shelf break induced by relaxations or reversals of the prevailing southeast tradewinds, tidal mixing involving flows and internal waves, and peculiarities of circulation around reefs on the outer shelf. Progress in identifying, understanding and quantifying these processes has occurred over the past decade but most activity and advancement has taken place during the 1980s. The mechanisms are presented within the context of ocean dynamics and their consequences for the ecosystems of the Great Barrier Reef, including determination of residence and exchange times for lagoon water, nutrient fluxes into the shelf sea from upwelling processes and the trajectories and fate of living or other material released into the shelf sea from the reefal systems.

MONSOON-INDUCED CHANGES IN THE PELAGIC ECOSYSTEM OF THE BANDA SEA (SNELLIUS II EXPEDITION 1984-1985, FIRST RESULTS)

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The few hydrographic data available on the upper waters of the Banda Sea tend to suggest upwelling conditions during the southeast monsoon and a strong stratification with downwelling during the northwest wind seasons (Wyrtki, 1957). As such changes between seasons could be expected to affect nutrient concentrations and hence biological activity in the surface waters of the area (e.g., Birowo and Ilahude, 1975), a comprehensive study was made covering hydrography, chemistry and various biological characteristics during both monsoonal periods. Preliminary results suggest indeed up and down-welling conditions as indicated, in particular in the eastern part of the area, notwithstanding the presence of stratification during both seasons. Nutrient concentrations were found to be significantly higher during the southeast monsoon, again in particular in the eastern part. On most criteria tested (e.g., chlorophyll, primary production, microbiology, algal assemblage, meso- and macro-zooplankton, acoustic surveys) biomass and bio-activity in the area were clearly enhanced during the southeast monsoon.

WIND FIELDS INDUCED BY TROPICAL STORMS IN THE MARINE BOUNDARY LAYER

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The surface winds generated by tropical storms were investigated using the wind data obtained at the 10-m high beach tower in Cheju Island, near the East China Sea, in August 1985. As the isallobaric low proportional to the gradient of the isobars approaches the coast the rapid increase of wind speed is simultaneously exhibited due to mass flux convergence towards falling pressure. The nature of isallobaric distributions may give a good indication of the movement of tropical storms in the East China Sea.

In general, the real wind fields may constitute gradient, isallobaric and frictional retarded wind components. The relationships of ageostrophic, isallobaric and gradient wind components to the observed ones are discussed considering the dynamic concepts and given here with an analytical model for the prediction of marine wind speed and direction.

VARIABILITY IN PHYTOPLANKTON PRIMARY PRODUCTION ASSOCIATED WITH BARRIER REEF SYSTEMS BORDERING THE CORAL SEA

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Measurement of phytoplankton primary production over several years in the central Great Barrier Reef province and adjacent East Australian Current indicates that "normal" levels of primary production and seasonal, within-seasonal and spatial variability in production are of similar magnitude. Pronounced short-term increases in production (up to 10-fold) can be associated with major meteorological events such as monsoonal rains or cyclones, but no clear association between production and intrusive upwelling could be demonstrated. High-productivity events are usually dominated by larger (>10 um) phytoplankton. Conversely, under appropriate low-energy wind and tidal conditions, phytoplankton blooms may develop within enclosed or semi-enclosed reef lagoons and thereafter be flushed into surrounding waters. On a regional scale, early summer primary production rates in the oceanic Coral Sea were low and relatively uniform. Higher production was measured near Papua New Guinea and the Solomon Islands, suggesting local upwelling or "island mass" effects. The observed levels of variability in phytoplankton standing crop and primary production in the GBR shelf system require that sampling designs and frequencies be sufficiently dense to capture productivity events of short duration and limited spatial extent.

AIR-SEA INTERACTION IN THE TROPICAL PACIFIC AND INDIAN OCEANS

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Satellite photographs show, in the mean, two narrow bands of cloud that form an assymmetrical "V" shape in the tropical Pacific: one band lies along 5-10°N, the other angles east-southeast from Papua New Guinea. Rainfall and latent heat release in these bands, and in the Indonesian-Australian monsoon rain bands to their west, drive the major wind systems of the tropical Indian and Pacific Oceans. The winds in turn drive the ocean currents of the region, and play a large role in determining sea surface temperatures (SST); but the rainfall tends to occur over maxima in SST, so the atmosphere and ocean circulations act on one another in a closed, feedback loop. The system is unstable: one dramatic manifestation is the El Niño-Southern Oscillation phenomenon, which every few years brings drought to Indonesia and Australia, and heavy rain to Peru. To predict these droughts, we must understand the coupled tropical ocean-atmosphere system quite deeply on all time scales from the diurnal to the interannual; present understanding of the system is briefly reviewed.

A SVERDRUP MODEL OF THE WORLD OCEAN, AND THE INDONESIAN THROUGHFLOW

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The annual mean depth-integrated steric height P and stream function of the world ocean are calculated from a Sverdrup model of the world ocean, with Hellerman and Rosenstein's (1983) annual mean winds. The parameterization of friction is unspecified, but friction is assumed to be important only along western boundaries. The circulations around Australasia, New Zealand and Malagasy are calculated as 17+4 Sv, 29+7 Sv, and 4+3 Sverdrups, respectively. Inclusion of island effects results in more accurate flow estimates in the Southern Hemisphere than have previously been obtained from Sverdrup models.

The calculated world field of P is compared with observed depth-integrated steric height, relative to various depths of no motion, obtained from the Levitus world data set; agreement with observations is generally good, in both hemispheres, though a large unrealistic zonal jet occurs west of the south tip of South Africa. The observed difference in annual mean P from Western Australia to Indonesia suggests a Pacific-Indian Ocean throughflow of about 12 Sverdrups.

The model calculations are repeated with the Indonesian passages closed. In the model, the Indian Ocean becomes very much "colder"; the predicted drop in P could be created by a uniform drop of temperature of 6°C in the top 500 m over the entire southern Indian Ocean, with smaller changes elsewhere.

A CONVECIVE MODEL OF THE LEEUWIN CURRENT, WESTERN AUSTRALIA

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The Leeuwin Current accelerates down a pressure gradient into the prevailing wind. In the present model, this gradient is maintained by convective cooling of the Leeuwin Current waters towards an equilibrium temperature that varies with latitude. Unlike most (wind-driven) models of eastern boundary current behaviour, the present model displays some interesting non-linear phenomena.

PACIFIC-INDIAN EXCHANGE WITHIN THE INDONESIAN SEAS

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The Indonesian seas represent the only tropical inter-ocean link, connecting the reservoir of warm and fresh surface water of the western Pacific with the eastern Indian Ocean, while transforming it through vertical mixing and air-sea interaction on its way. The heat and fresh-water flux between both oceans through this link is estimated to be considerable and have large-scale, perhaps global-scale, impact on the ocean and climate.

Various estimates of the mean throughflow transport have been made, using different methods. A summary of these estimates, which also briefly indicates how they are derived, is discussed. Clearly, there is agreement among all of them that the mean flow is from the Pacific to the Indian Ocean, but there is a wide range of estimates of its magnitude. Very little evidence is available as a basis for speculations on magnitude and time scales of throughflow variability.

THE NORTH PACIFIC SUBTROPICAL MODE WATER: VARIATIONS OF OUTCROP AREA IN WINTERTIME

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An outcrop area of the North Pacific Subtropical Mode Water (SMW) was investigated, mainly based on the published surface temperature maps. Following a series of studies by Masuzawa, we regarded the 16°-19° C temperature band in winter as the outcrop area of SMW. In the cooling season, the band moves southward and crosses the Kuroshio Axis whose positions lie between 37° and 35° N. Then the band rapidly widens and stagnates there during winter. This fact reflects the formation of SMW, which was supported by a concrete example of the existence of a deep mixed layer at 300-400 m depth. The interannual variability of the outcrop areas was also presented. Years of low temperature corresponding to a large amount of SMW formation were 1974, 1977, 1978 and 1984.

SURFACE SLICKS

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Observations of currents in the uppermost few metres of the ocean are now possible with remote-sensing groundwave HF radar techniques. These observations are restricted to the coast (0-200km) because the groundwave mode of radio-wave propagation is particularly lossy. However, the backscattered echoes are not contaminated by ionospheric dynamics as in the over-the-horizon radars which use the same backscatter process.

Results show that the surface current in the first few metres of water is influenced by tides and the large-scale wind field is as predicted by hydrodynamical numerical modelling. However, in fluctuating winds, the surface current is seen to be closely coupled to local winds. The horizontal scale of variations is that of the wind field when the wind is fluctuating as in squalls or storms. Divergence (+ and -) in the surface velocity field identifies localized upwelling and sinking. It is argued that the observed scales of horizontal fluctuations, and the associated divergence and convergence patterns in the surface flow field lead to the accumulation of buoyant material in oceanic front lines.

AIR-SEA INTERACTION IN THE WESTERN PACIFIC

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Importance of the wester Pacific in air-sea interaction is addressed with showing a strong correlation between the eddy strength in the East China Sea and El Niño events, for which a hypothesis has been proposed. A project of Chinese Academy of Sciences, which will last for 5 years, has started this year in the Philippine Sea to examine the hypothesis and to really understand the meridional process.

Preliminary results from the first cruise completed by the end of October 1986 were showed. Some striking circulation features were revealed. (I) Western boundary current east of Luzon and Taiwan is characteristic of eddies, which is different from traditionally - accepted one - a northward mean flow. (II) Branching of the western boundary current near Bashi Channel - the current gets into the South China Sea from north of Luzon and comes back to the western Pacific from south of Taiwan. (III) High salinity core at about 100M in the south and 150m in the north of the Philippine Sea suggests that the water mass in the Philippine Sea is somewhat characteristic of the subtropical water, which needs further study.

INTERANNUAL VARIABILITY OF THE PACIFIC TO INDIAN OCEAN THROUGHFLOW

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A global, numerical model is used to examine the seasonal and interannual variability of the Pacific to Indian Ocean throughflow. The model equations are the non-linear, shallow-water wave equations for a single-layer reduced-gravity model on a spherical grid. The latitudinal extent of the model is 71°N to 66°S. The grid spacing is 1.25° in the meridional direction and 1.5° in the zonal. To within the resolution of the model, realistic coastline geometry and island chains are utilised throughout the model domain. Although the horizontal and vertical resolution of the model are very coarse, the study is presented in the spirit of providing a 'first order' approximation to the seasonal and inter-annual variability of the Indonesian throughflow between the Pacific and Indian Oceans. The wind forcing utilises the Hellerman-Rosenstein climatology for the first 20 years of the model integration in order to arrive at statistical equilibrium; subsequently, the Fleet Numerical Oceanographic Center marine winds from 1977 to 1984 are applied. Preliminary experiments reveal a mean throughflow of 7.3 x 10^3 m^3/sec with a seasonal variation of +3.5 x 10^3 m^3/sec. The numerical simulations also revealed significant interannual variations of the throughflow preceding and during the 1982-83 ENSO event with magnitudes of up to 4.5 x 10^3 m^3/sec. Experiments in which the throughflow is blocked were also examined in order to assess the effects of this inter-basin transport on the circulation within and near the Indo-Pacific Convergence region.

THE GEOSTROPHIC CURRENT OF THE EAST VIETNAM SEA

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The geostrophic current of the East Vietnam sea (South China Sea) was calculated from the seasonal mean density distribution by the dynamic method relative to the 600-decibar reference surface.

It is clear that, in both main monsoons, the cyclonic current always exists in the western part of the East Vietnam sea. In the north and at the centre of Vietnam the current near the coast is directed to the south. The divergent zone is situated along the coast and it moves near the coast in the southern part in summer. Along the main axis of the sea the current is directed to the northeast, but in summer this direction is more stable than in winter. This tendency of the current exists only in the layer from the surface to depths of 200-300m. Below this depth the current has the inverse tendency.

ESTIMATING THE EXCHANGE OF WATER BETWEEN THE INDIAN AND PACIFIC OCEANS FROM VOLUMETRIC RMS MULTIPARAMETER ANALYSIS

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Isopycnal analysis of mixing between water masses of the Indonesian archipelago and the Indian Ocean has been shown to overestimate the flux of Pacific waters through the archipelago. Locally, the overestimation can be up to fifty percent in volume.

To quantify volumetric exchange rates accurately, the analysis of mixing must be independent of the type of mixing and the layering of the water masses. RMS multiparameter analysis involves a minimum of assumptions and extracts the maximum of information from oceanographic data. Volume estimates for transport through the Indonesian archipelago based on rms multiparameter analysis and currents in the outflow area into the Indian Ocean will be presented.

A SEA-LEVEL MONITORING NETWORK IN THE ASEAN REGION

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A Development Aid Project has been negotiated between Australia and the ASEAN countries for the study of tides and tidal phenomena. The region of operation is of prime importance for many reasons:

(1) In this extensive shallow-water zone comprising a complex collection of gulfs and straits, the variability of the tidal signal is very great and possibly greater than in any other region.

(2) The region is unique in that it provides interconnection between two major oceans. Furthermore its geographical position, straddling the equator, allows for the transport of heat over vast spatial scales.

The ASEAN sea-level monitoring array of some 27 new instrumental installations, supplementing a similar number of existing stations, represents a strategic facility in the continuing study of the inter-ocean throughflow.

THE EQUATORIAL UNDERCURRENT IN THE WESTERN PACIFIC OCEAN

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The Equatorial Undercurrent (EUC) is one of the primary eastward-flowing currents of the tropical oceans. Understanding of the variations in its transport in the western Pacific is important in our understanding of oceanic heat fluxes and the dynamics of El Niño Southern Oscillation (ENSO) event initiation. The EUC is one focus of the Western Equatorial Pacific Ocean Circulation Study (WEPOCS), a joint Australian-American project studying the circulation of waters of the tropical ocean between 140°E and 155°E. Cruises were completed in mid-1985 and early 1986 which collected primarily CTD, nutrient and upper-ocean velocity data. Current-meter moorings obtained six-month records of velocities in Vitiaz Strait, St George's Channel, and the Equatorial Undercurrent at 150°E.

Early results indicate the following:

1) Strong northwestward flow through Vitiaz Strait which does not appear to vary seasonally, thus providing a continuous source of southern waters to feed the EUC.

2) A single eastward flowing core of the Undercurrent around 200 m depth of magnitude 30 cm/sec during the southern winter and spring.

3) Reversal of the near-surface westward flow during the southern summer, resulting in the development of a second and distinct eastward flow in the upper 100 m.

4) An increase in the speed of, and variability in, the EUC core during the southern summer.

5) Large amplitude (20 cm/sec) semi-diurnal baroclinic tidal signals extending from the surface into the core of the Undercurrent.

UPWELLING ALONG THE PAPUA NEW GUINA COAST

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During the Western Equatorial Pacific Ocean Circulation Study (WEPOCS), two joint US-Australian expeditions were made to the region north and east of Papua New Guinea. The first expedition took place during June-August 1985, during which the Southeast Trade Winds influenced the ocean circulation in the Solomon and Bismarck Seas. The second expedition was conducted during January-February 1986, at the height of the Northwest Monsoon. Upwelling along the PNG coast was pronounced during the Northwest Monsoon, and was absent during the Southeast Trades. The New Guinea Coastal Undercurrent (NGCU) was observed during both periods, suggesting that it is a permanent feature of the circulation.

During the Southeast Trade regime, the high-salinity core of the NGCU is found at a depth of about 160 m at 143°E, and low salinity from river runoff extends to a depth of about 50 m. The high-salinity core is found at about the same depth during the Northwest Monsoon; however, high salinity water is upwelled to the surface near the coast, and the fresh river runoff is generally confined to the upper 15 m. The thermal structure also clearly reflects the coastal upwelling during this period.

MATHEMATICAL MODEL OF SIDEWAYS CONVECTION IN THE OCEAN

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Horizontal temperature and salinity gradients can be great at hydrological fronts. A mathematical model describing the stratified sea-water layer motion on the rotating Earth in the presence of predetermined temperature and salinity gradients at the layer boundaries has been suggested on the basis of the hypothesis of sideways convection connecting the temperature inversion in the Timor Sea with the advection of waters with higher salinity due to evaporation on the Australian shelf. Exact stationary solutions of equations of oceanic convection were found for various types of boundary conditions. The analysis of these solutions shows that the spatial oscillations of the vertical characteristics caused by B-effect take place in the ocean and their frequency is defined by the Ekman parameter value.

PACIFIC-INDIAN INTERBASIN EXCHANGE THROUGH THE LOMBOK STRAIT

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A significant flux of mass, salt and heat from the Pacific to the Indian Ocean basin via the Indonesian archipelago has been suggested by various investigators to bear crucially on the balances of heat, fresh water, and mass in the Pacific and the Indian Oceans. Since Wyrtki's (1961) estimate of 1.5 Sverdrups (Sv), more recent workers have by indirect means determined significantly higher values for the possible throughflow: Godfrey and Golding (1981), 10 Sv; Piola and Gordon (1984), 14 Sv; Fine (1985), 5-6 Sv; and Fu (1986), using inverse methods, 6-7 Sv net transport.

The predominant pathways are generally believed to be the deep passages north and south of Timor. In transport capacity, the Lombok Strait, between Bali and Lombok Islands, is second only to the Timor passages. An array of 21 current meters, supplemented with pressure gauges, and quarter-annual CTD surveys were run over a 14-month period (January 1985-March 1986) to study the dynamics of exchange through the Lombok Strait. Our STD data show that the Pacific Subtropical Lower Waters and Northern Intermediate Waters have penetrated through the Java Sea, into the Lombok Strait, and out into the Indian Ocean. Our current-meter data during the northern winter indicate that a persistent southward net flow into the Indian Ocean is interrupted by 4-7 day pulses of northward flow. The strong northerly pulses are driven by typhoons and tropical cyclones transiting the Timor Sea from east to west.

Our second current-meter deployment, during the eastern monsoon (May to July), shows an even stronger mean flow into the Indian Ocean, as expected. Our estimate of 1.5 Sv net transport through the Lombok Strait alone (excluding cyclone phases) from our current-meter data supports the high values of throughflow for the entire archipelago deduced by Piola and Gordon and Godfrey and Golding.

OCEAN CURRENT FIELD IN THE WESTERN PACIFIC

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Since 1984, the Hydrographic Department has been conducting an oceanographic observation cruise extending to the equatorial region every winter. It was intended to monitor long-term variation of the ocean structure in the western Pacific circulation. Current measurements have been made by CTD, shipborne Doppler current meter and drifting buoys. From three cruises, it is becoming clear that the ocean-current field is not simple, as shown in the statistical current map. Current direction and/or speed change year to year and meso-scale eddies seem to exist mainly in the area north of about 15°N. It was observed that, in February, a westward flow of the South Equatorial Current had been replaced by an eastward flow in the surface layer above a depth of about 50m, associated with a relatively strong flow of the Equatorial Counter Current.

The east-west component of current velocity (cm/s) along 143-142°E in February of 1985 and 1986 were compared.

MONSOONALLY WIND-DRIVEN TRANSPORT IN THE INDONESIAN WATERS

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The effect of the regional monsoonal wind on the ocean transport in the Indonesian seas has been examined by means of a barotropic primitive numerical model, applying the monthly mean wind field as the driving force. Realistic bottom topography and linear dissipation were incorporated in the model.

The experiments reveal interesting results which suggest that the regional wind field has a significant effect on the associated transport on a seasonal time scale, but is negligible on an annual basis.

During the Southern Hemisphere winter, the wind field drives a flow into the Indian Ocean with a magnitude of 4 Sv, whereas during the southern summer the flow is in the opposite direction; i.e., into the Pacific Ocean, with a similar magnitude. Connections with the larger-scale circulation will also be discussed.

SOME GENERAL FEATURES OF THE WATERS BELOW 1000 M IN THE PRINCIPAL BASINS OF THE PACIFIC-INDIAN OCEAN CONVERGENCE ZONE

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Typical profiles of temperature, salinity and oxygen within the basins of the zone and the present knowledge of their interconnections are reviewed. Rates of inflow of Pacific waters into the basin system and compensatory outflows into the Indian Ocean are estimated. The large-scale distribution of these outflowing waters at intermediate depths in the eastern equatorial Indian Ocean is shown. Some evidence of time changes at depths below 2000 m in the Java Trench is presented. Other more limited information about the long-term stability of these deep basin waters is discussed.

SEA LEVEL FLUCTUATION AND CHARACTERISTICS IN THE SOUTH CHINA SEA, GULF OF THAILAND AND MALACCA STRAIT

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The principal cause of fluctuations in sea level is the astronomical tide. The type of tide is analysed using the ratio of the amplitudes of the diurnal and semidiurnal constituents. In the South China Sea, the tide is mainly diurnal, while in Malacca Strait, it is semidiurnal. From the mouth to the head of the Gulf of Thailand, the tides vary from mixed (principally diurnal) to diurnal to mixed (principally semidiurnal). The

mean range in the Gulf is about 1 m. Maximum monthly MSL in the Gulf occurs in November and minimum in June or July. In Malacca Strait and the south coast of Thailand, they are highest in June or July and lowest in February and March. Long-term variation of yearly MSL at mid-Gulf and on the Andaman coast is relatively stable, but stations near the head of the Gulf of Thailand show rising sea level or submergence of land.

NUMERICAL SIMULATION OF A BAY CIRCULATION UNDER THE INFLUENCE LAND AND SEA BREEZES

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A two-dimensional, non-linear numerical model is used to investigate the barotropic circulation generated by time-dependent wind forcing such as the land and sea breezes. Four cases were considered: a flat-bottom bay with strong and moderate breezes, and a bay with reef and trough under the influence of strong breezes. The results of numerical simulation showed interesting circulation patterns changing in consonance with the veering winds.

INVESTIGATION OF THE PHYSICAL CONDITION OF WATER MASSES USING NOAA-SATELLITE AVHRR DATA IN THE GULF OF THAILAND

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The physical condition of water masses in the Gulf of Thailand is investigated with seven 512x512 scenes of NOAA-satellite digital Advanced Very High Resolution Radiometer (AVHRR) data. Digital data processing was performed using the software and hardware systems of the International Imaging System (I^2S). The albedo patterns of channel 1 are mapped for the studies of turbidity and riverine sedimentary plumes. Sea-surface temperature (SST) maps are produced from channels 4 and 5 by applying the Strong and McClain (1984) atmospheric correction equation. With turbidity, river-plume and SST maps the water is detected to drift from the Gulf into the South China Sea during the southeast monsoon season. The reverse water circulation is detected when the northeast monsoon becomes dominant. Zones of high albedo and low SST, possibly areas of upwelling, are observed near the west and east coasts of the Gulf in August and November, respectively. No sedimentary plumes are detected from four main rivers entering the Bight of Bangkok. The sedimentary plume of the Mekong River is, in contrast, observed throughout the year.

The Andaman Sea water has, in August, a surface temperature approximately 2.0°C lower than the Gulf water. Thus, during this period, there are very different water masses with varying circulation patterns in this region. The result of this study indicates that the AVHRR data are definitely usable for daily investigation and monitoring of the physical condition of sea features over the Thai region.

ON THE TIDAL COMPONENTS AND THE SEA-LEVEL FLUCTUATIONS CAUSED BY MONSOONS AND TYPHOONS IN VIETNAM

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The spectral and harmonic methods of analysis of sea-level fluctuations were applied to coastal and estuarine conditions in Vietnam which has various types of tides with significant tidal range, and the influence of monsoons and typhoons on them is important. The multifarious structure of periodic fluctuations of tidal type with many high-order harmonic shallow-water components is evident. In the classical harmonic analysis scheme by Darwin, a few components might be omitted. At the same time, the non-tidal sea-level fluctuations caused by the monsoon with one-year period, half-year period, 3,6-month period, 3 to 10 day period and those caused by typhoons with a 26 to 78-hour period, are indicated.

The research results allowed us to acquire a full and more accurate understanding of the peculiarities of tide and sea-level fluctuations in Vietnam.

THE ORIGINS OF CENTRAL WATER IN THE CORAL SEA

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The water mass of the oceanic thermocline, commonly known as Central Water, is believed to be formed at the Subtropical Convergence. In the western South Pacific Ocean, the Subtropical Convergence reaches its most poleward position, coinciding partly with the southern limit of the WESTPAC region.

The role of the Subtropical Convergence as a source of Central Water for the Coral Sea is confirmed by the close similarity of temperature-salinity curves in the thermocline of the Coral Sea, Indian and South Atlantic Oceans. Zero and first derivative analysis of CTD profiles in the Coral Sea indicates, however, that the water is not advected along the shortest path, that is, northward through the Tasman Sea, but westward from the central South Pacific Ocean.

The analysis also shows that salinities in the upper thermocline are higher than those found in the Subtropical Convergence indicating a second source for Central Water. Evidence will be presented that this source is located in Polynesia where high salinity water appears to be formed at the surface and sink to about 200m depth. The path of this water into the Coral Sea will be discussed from observations.

CORAL REEF RESEARCH OF THE INDONESIAN-DUTCH SNELLIUS-II EXPEDITION

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Of course the Snellius-II expedition in eastern Indonesian waters, the center of the world from the point of view of coral reef scientists, included coral reef research. Most issues of the programme were purely scientific but because of the great economic importance of the reefs quite some attention was given to aspects of exploitation, monitoring and management.

The expedition was mainly ship-based, which has the advantage that large groups of scientists of different disciplines can be transported to remote areas with all sophisticated equipment they need and that they can work there efficiently in comfortable circumstances.

Eastern Indonesia is a vast area with an enormous surface of coral reef, a great variety of reef communities and many different ways of exploitation. Relative to the magnitude of the management tasks the available research capability is still underdeveloped. Training and development of feasible research and monitoring methods were important topics of the expedition.

Methods included aerial photography, field censuses under water, standardized reef transect studies, taxonomic inventories of several groups of organisms, sea grass community studies, and studies of socio-economic aspects, particularly fisheries.

In general the nine different areas visited proved to be in a better condition than was expected. Consequently management measures can still be taken in time. The most important one already taken, a ban on fish blasting, proved to be enforced strictly in most areas. The area that was found to be most diverse, the sea around the island of Komodo, has luckily already been declared a marine park. However, because of the size and complexity of the area as a whole and the generally increasing human pressure on the systems, more basic research is urgently needed, from fieldstations but also from ships. In this respect other Westpac countries could be of great help.

TIDAL JETS, NUTRIENT UPWELLING, AND THEIR INFLUENCE ON THE PRODUCTIVITY OF THE ALGA *HALIMEDA* IN THE RIBBON REEFS, GREAT BARRIER REEF

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JOHN O'BRIEN
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A field experiment was carried out to study water circulation and benthic biological productivity near a passage through the Ribbon Reefs in the northern Great Barrier Reef of Australia. The currents through the passage were phase-locked with the tide. During rising tides, strong currents through the passage generated localized upwelling on the upper continental slope, enriching the depleted surface waters in nutrients, particularly nitrate and phosphate. Simultaneously, on the shelf side of the passage, a tidal jet-vortex pair system developed, which separated from the Ribbon Reefs so that the coral reefs themselves received little of the upwelled water. This was propagated as a bottom-trapped layer towards the meadows of the calcareous alga *Halimeda* situated several kilometres inshore of the reefs. *Halimeda* can accumulate nutrients, particularly nitrate, from the relatively low concentrations available from the upwelling events. The quantity of nitrogen upwelled was more than sufficient to supply the total nitrogen requirements of the *Halimeda* vegetation.

A tidal jet also formed, offshore from the reef passage, during falling tides and the coral-covered offshore side of the Ribbon Reefs may be sustained by the subsequent vertical turbulent entrainment into the jet of deep, nutrient-rich water immediately offshore from the reef passages. The processes require a continuous barrier reef with only narrow passages several kilometres apart.

Numerical models successfully reproduce the observations of jet-driven upwelling and of the dynamics of the tidal jet-vortex pair system. The model predictions are very sensitive to the details of the bathymetry of reef passages. Since such data are presently unavailable, it is not yet possible to use these models to calculate the jet-driven nutrient upwelling for the whole Great Barrier Reef.

THE WESTERN PACIFIC OCEAN: A CRADLE OF CLIMATE VARIABILITY

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The western equatorial Pacific and the Southeast-Asian Waters are the region of the world oceans where sea-surface temperature is highest and where rainfall is greatest over the largest contiguous area. Consequently, this region harbours the largest atmospheric heat source and the largest region of convection on the globe. The region of maximum convection is subject to large north-south fluctuations of its location with the annual cycle, and to interannual variations in the east-west direction, which are related to the Southern Oscillation and the El Niño. The ocean underneath the heat source is also subject to a large net heat gain, chiefly because of a lack of evaporative cooling. Horizontal ocean circulation is insufficient to remove this net heat gain effectively, which results in a slow accumulation of stored heat. The El Niño is the process by which this excess stored heat is removed from the tropical ocean.

CLIMATE SYSTEM MONITORING

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The traditional notion of climatology conjours up an image of tables and atlases of long-term averages of meteorological variables and synthesized classifications of the world into fixed climatic zones. While one does not deny the value of such work for a vast range of man's activities, there is a strong realisation now for the need to monitor variations in the climate system in a "real-time" mode.

With the recent establishment of a National Climate Centre, the Bureau of Meteorology has joined a number of other nations in preparing monthly climate bulletins which, through the broad-scale analysis of a variety of climate parameters, attempt to monitor the continuous variability that is a feature of the climate system.

The poster display will present a selection of, and short commentary on, the analyses and climatic indices which are routinely prepared for the southern hemisphere and the Australian region each month by the National Climate Centre.

OCEAN CIRCULATION IN THE TRIANGLE BETWEEN NW AUSTRALIA AND INDONESIA

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Satellite-tracked drifters were released on and near the continental shelf of northwestern Australia in 1982-83 as part of a survey of fisheries resources and the marine environment. The drifters showed that the triangle betwen northwestern Australia and Indonesia was a source region for the Leeuwin Current and the South Equatorial Current of the Indian Ocean. The triangle itself is subject to input from the Archipelago. The nature of the circulation revealed by the drifters is examined and compared with historical and contemporary findings and data.

CLIMATIC CHARACTERISTICS OF THE SOUTH CHINA SEA WATERS

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The patterns of the temperature and salinity spatial distribution at the standard levels for the winter and summer are constructed. Some 6685 hydrological observations are used. Current meter data were utilised to analyze the surface layer pattern.

The inflow of comparatively cold waters is from the north through Taiwan channel while warm water inflow is from the south through Karimata channel.

In summer along the Vietnam coast at 14°N - 16°N are marked decreased temperature and increased salinity at the subsurface levels.

OPERATIONAL OCEANOGRAPHY IN THE BUREAU OF METEOROLOGY

PHILLIP R PARKER
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The Bureau of Meteorology is developing its marine services to include an expanded range of operational oceanographic products. Current services such as numerical sea-state prediction are being upgraded. A surface current prediction system is being developed for areas around the Australian coast. An upper-ocean analysis system (using BATHY-TESAC data) is being planned for the tropical Indian and Pacific Oceans and for the Australian region oceans. This poster describes some of the features of these developing and planned marine services.

FINE STRUCTURE OF WATER MASSES IN THE NORTHWEST PACIFIC

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On the based of a many years' CTD data the peculiarities of space distribution and space-time variability of fine structure characteristics in the main structural zones and the Far-Eastern seas are revealed. It is established that the regions with different conditions of the fine structure generation are distinguished by their forms and values of statistical characteristics. We have found some evidence for the presence of relatively stable and typical small-scale structures in various regions. These structures characterised by different forms, space-time scales and profile disturbance amplitudes.

DOUBLE DIFFUSION PROCESSES AS IMPORTANT FACTOR OF CLIMAT FORMING AND WATER MASSES TRANSFORMATION IN THE NORTH PACIFIC

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Based on mean temperature and salinity data isolated are structural zones and layers. Within their limits there are favourable conditions for the development of double diffusion processes. It is shown that distribution of their parameters is conditioned by location of intermediate water masses boundaries and fronts. Available energy of instability of temperature or salinity stratification is transformed by large scale motions and dissipated in small scale salt finger or "layer convection".

MONSOON INFLUENCES ON ZOOPLANKTON POPULATIONS OF THE INDONESIAN ARCHIPELAGO

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The eastern Banda Sea and western Arafura Sea are strongly influenced by a monsoon type climate. The SE monsoon (June-September) causes enriched upwelling conditions and the NW monsoon (December-March) impoverished stratified conditions. Related to this phenomenon an alternating current pattern occurs in the area, with an influx of Pacific water during the SE monsoon and a prevailing Java Sea/Indian Ocean influx during the NW monsoon. The fauna of the Indonesian waters has endemic species, but is influenced by Pacific and Indian Oceans faunas. These factors together make the Banda Sea area, from a biological point of view, very complex. In the context of the Snellius II Expedition, two cruises, that is, August 1985 (SE monsoon) and February 1986 (NW monsoon), have been carried out to investigate the monsoon effect on the zooplankton populations in this area.

Zooplankton samples collected during these cruises show that biomass, vertical distribution, diel migration, and species composition differ between the seasons and that parallels can be drawn with areas of constant upwelling and areas of stratification in the North Atlantic Ocean. Biomass and respiratory activity were two times lower in February than in August, while the activity, estimated with ETS measurements, per unit of sample remained the same. The zooplankton population reacts to the changing situation by an adaptation in biomass and abundance but not by a change in metabolism. Diel vertical migration is found to be enhanced during the poor stratified period, suggesting that the availability of food plays a role in determining diel migratory activity.

Meristical data of pteropods Clio pyramidata and Diacria quadridentata group showed an influx of the Pacific fauna in this area during the SE monsoon period, which is not the case in the NW monsoon period. The mean size of investigated taxa was smaller during the warmer stratified period, showing an adaptation to the lower water densities.

SUMMARY REMARKS ON TOPIC 2: OCEAN VARIABILITY AND THE LINKS WITH CLIMATE BY DR. GEORGE CRESWELL

I should like to start by thanking IOC, WESTPAC, John Bunt, Bob Harriss and their team. I also thank Keynote Speaker Stuart Godfrey, along with Discussion Leaders Arnold Gordon, Matt Tomczak and David Rochford for their excellent work.

After decades of inadequate oceanographic scrutiny, the WESTPAC region, and the Indo-Pacific Convergence that it contains, have become the focus of attention of oceanographers world-wide. The reasons for this attention are wrapped in the uniqueness and complexity of the region.

Klaus Wyrtki described it as a cradle of climate variability: slight changes to its sea-surface temperature produce awesome far-reaching changes in the atmosphere. The throughflow from one tropical ocean to another is unique and has effects far beyond the WESTPAC region. The processes of enrichment in the WESTPAC region appear to be complex in the extreme, and they choose to wear different disguises in different areas.

The equatorial region, with its currents and undercurrents, and countercurrents, resembles a stack of assorted squashed noodles being drawn variously east and west, at differing speeds.

The presentations covered all the recent major expeditions, contemporary models, interpretations of historical data, and plans for continuing or future work.

The sessions were on: Upwelling Ocean/Atmosphere Interaction, Deep Basins and Adjacent Seas, Exchange of Water between the Oceans.

The group of papers on **Upwelling** included the following:

- **Tanchotikul** discussed seasonal upwelling revealed by satellite in the Gulf of Thailand;

- **Schalk, Baars** and **Zijlstra** described preliminary results on upwelling in the Banda Sea as part of the Snellius II Expedition. These comprehensive observations from a data-poor region were particularly welcome. Upward velocities of 3m/day were measured. Flow into the Banda Sea was from the Pacific in the south-east monsoon and from the Java Sea and Indian Ocean in the north-west monsoon.

- **Lukas** presented data from earlier this year showing upwelling near the Papua New Guinea coast during the north- west monsoons.

- **Wolanski, Drew, Abel** and **O'Brien** discussed the transport of nutrients by a tidal jet vortex pair in the Great Barrier Reef.

- **Furnas** and **Mitchell** described variability of production through the central part of the Great Barrier Reef due to causes such as cyclones and intensive upwellings.

- **Andrews** described the response of the central part of the Great Barrier Reef waters to the meridional wanderings of the weather band. Wind events produced bottom enrichments of large horizontal extent that propagated inshore at almost 20 km/day.

The subsequent discussion revealed that, in many cases, the processes described as upwelling did not bring nutrients quite to the surface. The surface productiviy was high though. What was happening? Perhaps transient wind mixing was involved, but the general inability of oceanography to come up with vertical mixing coefficients was highlighted. **Miles Furnas** advised us that the phytoplankton primary production could take up nutrients in a matter of an hour. What then, it was asked, do the ecosystems do to survive during the non-upwelling season? **Matt Tomczak** pointed out that we oceanographers complain that the meteorologists do not give us data on appropriate time and space scales; at the same time, we do not give the biologists the information that they need.

The coastal-zone color scanner aboard the NIMBUS satellite can solve some of these sampling problems - unfortunately it is on its last legs and no plans exist for a replacement.

One of the papers in the session that bridged several disciplines was that of **Wolanski, Drew, Abel and O'Brien.** It had sampling appropriate to the problem, which was: Why are there calcareous Halimeda meadows several kilometres inshore of the passages of the Ribbon Reefs?

Halimeda is capable of accumulating nutrients. The meadows lie on 15-m thick banks of dead Halimeda. The authors surmised that tidal inflow may have been pumping nutrients from below the shelf edge into the lagoon in the manner of Thompson and Golding. They observed and modelled the flow and found that certain combinations of reef passage width and bottom topography could generate localized upwelling and that this water was carried along the bottom to the meadows by a tidal jet vortex pair.

The nutrient input was found to be sufficient to satisfy the Halimeda meadows - in fact the authors calculated that the 15-m thick banks had been established by 1 million upwellings in the past 10 000 years.

The **Ocean-Atmosphere Interaction** presentations were lead by Stuart Godfrey. He elaborated on his Keynote Speech.

Heron presented the results of using a 10-m λ radar for studies of near-surface currents and their responses to the wind.

Hyo Choi discussed storms in the East China Sea.

Sodusta and **Estoque** presented numerical model results of wind-driven bay circulations.

Kinonmonth and **Coughlan** described Bureau of Meteorology products, particularly those relating to climate monitoring and tropical meteorology.

Parker described the Bureau of Meteorology's entry into Operational Oceanography and this prompted some spirited and, I think, healthy debate with Australian sections of the audience.

In the session on **Deep Basins and Adjacent Seas**, the following presentations were made:

Hanawa discussed subtropical mode-water formation - the cooling and deep mixing to 400-500 m that is capped over in summer. The water is advected to the south-west. The amount formed shows an interannual variability.

Wen described frontal phenomena associated with the Yellow River.

Siripong presented analyses of tides in south-east Asia.

Lennon described the ASEAN sea-level monitoring array and outlined the value that it will have for studies of tides, tidal phenomena, and interannual variations. He presented Australian sea-level data to show that an El Niño year is primarily a recovery year after a sea-level event in the previous year,

Rochford reviewed the water characteristics of the deep basins of the Indonesian Seas. He had to rely on Snellius I, Dana and CSIRO data from the 1960s. Obviously, the region needs more study. He also showed the Banda Intermediate Water spreading from the Archipelago as a plume at about 1 000-m depth over to Madagascar.

The **Hu, Nishida** and **Lindstrom/Lukas** papers were exciting because they dealt with comprehensive research vessel data sets for roughly the same region from the past year. They described complex current situations. It was a bonus for WESTPAC to get these oceanographers together. Incidentally, we learned that there were 7 ships from 5 nations working in the western tropical Pacific early this year.

Godfrey presented a model of the Leeuwin Current that successfully reproduces many of its features.

I presented a poster on satellite-tracked drifters in the Timor Sea.

Tomczak discussed the water masses of the Coral Sea and how they had a component from as far south as the subtropical convergence off Tasmania, but reaching the Coral Sea via the South Pacific. Another, highly saline, component had to come from the salinity maximum in the central Pacific. The nature of the T and S properties also gave indications of the type of mixing processes involved. In the discussion, Tomczak criticized the Australian oceanographic community because, in general, it would not commit itself to repeated deep sections; for example, in the manner of China and Japan. Part of the reason for this, however, is that the country has a single civilian research vessel for oceanography and it has pressures on it to work in many places.

The session on the **Exchange of Water between the Oceans** was lead by Arnold Gordon. Possibly the flagship of our sessions was on the exchange of water between the oceans - or throughflow from the Pacific to the Indian Ocean. This really is a hot subject and this Symposium was its first airing. Collectively, the speakers left no stone unturned - historical data were re-analysed, modern observations were presented, no less than three numerical models were described, and the plans for the Indonesian Seas Experiment (INSTEP), scheduled to start in 1988, were outlined for comment.

What did we find out?

That the observations and models give a scatter of transport values for the Indo-Pacific exchange, the transports ranging up to 20 Mt/s.

That some authors think that the throughflow comes from the North Pacific; some, from the South Pacific. Arnold Gordon claims that the water properties point to the North Pacific.

That the favoured pathway of the movement is the Strait of Makassar.

That the models do a good job of showing a seasonal signal.

The **Godfrey** model showed that, if we look ahead to when the throughflow is squeezed off (10 million years), the Indian Ocean will become 6°C cooler and the East Australia Current will sweep down to and around Tasmania like the Agulhas Current sweeps south of South Africa.

We learned from **Murray** of the problems of instrumenting the Straits that carry the throughflow. The tidal currents in Lombok Strait are well in excess of 6 knots. One satellite picture showed a warm plume heading tens of kilometres southward from this passage. The non-tidal flow through the passage was 2.8 Mt/s and it was found to reverse when Timor Sea cyclones changed the sea-surface slope.

This important phenomenon, the throughflow from the Pacific to the Indian Ocean, with its consequences for climate control, dispersal of marine life, and perhaps modification of sediment beds, seems inadequately described and modelled, and more work is needed.

We were able to reach the following conclusions:

For the processes of upwelling and enrichment, sampling arrays and frequencies must be designed to enable us to see what is happening.

More observations are needed on current responses to seasonal and short-term wind changes.

Continued observational and modelling efforts are needed for the study of the throughflow between the Pacific and Indian Oceans.

Nevertheless, the recent expeditions by many countries have given us a quantum leap in our knowledge of the Indo-Pacific region.

TOPIC 3: INTERANNUAL VARIABILITY IN MARINE COMMUNITIES

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Discussion Leaders: (a) Crustacean Resources

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(b) Coral Reefs and their Communities

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(c) Coastal Vegetation - Mangrove and Seagrass Communities

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KEYNOTE SPEECH [1] BY DR. ALAN LONGHURST: INTERANNUAL VARIABILITY IN MARINE COMMUNITIES

In this Symposium, we are asked to review variability in a region for which we need superlatives just to describe the status quo, so our task will not be easy.

On a planet still affected by the Pleistocene glaciations it is in the western Indo-Pacific that tropical marine ecosystems are most fully developed. Here the warm-water world of the early Tertiary has been most completely preserved, and only here can we experience the rich fauna of the Tethys Sea that girdled the tropics throughout the Mesozoic, and on into the early Tertiary. Beyond the East Pacific Barrier and in the Atlantic, the fauna of the tropical seas is impoverished, and an east-west gradient in biological diversity of almost an order of magnitude exists between the Gulf of Guinea and the western Indo-Pacific. This is best known for coral genera, but occurs also in all other benthic and demersal biota: only the pelagic species, and especially those of the open ocean, do not so strongly follow this pattern.

The Indo-Pacific contains the largest, deepest pool of warm tropical surface water that exists today, with mixed layer temperature exceeding 29°C over a very large part of the Philippine Sea and Micronesia, where thermocline depths reach 150-200m. This region of clear, warm seas supports profuse development of all kinds of coral reef: three major barrier reefs, hundreds of oceanic atolls, and innumerable examples of fringing and platform reefs on the shallow continental shelves. Paradoxically, the rivers between the Ganges and the Huangho carry 40% of all the silt discharged by all the rivers of the world, so the Indo-Pacific is rich also in shallow, turbid, muddy seas.

The Indo-Pacific conjunction is a region of complex geography, a function of movement of the Australian plate and many small continental blocks. Within the Philippine , Indonesian, Melanesian and Micronesian archipelagos, ventilation of several deep basins is constrained by sill depths ranging from several hundred to several thousand metres. The archipelagos themselves stand on, or lie eastwards from, the largest single areas of continental shelf anywhere today: at least eleven Grand Banks of Newfoundland could fit onto the continental shelf between northern Australia and Thailand, and another four or five up through the east China Sea.

The reversal of the monsoons over the Indo-Pacific conjunction is reflected as a seasonal reversal of flow through the maze of channels, some extremely shallow, that lie between the islands. The reversing currents sweep past countless capes,

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[1] For the purposes of this Report, references are not included with the text of this Keynote Speech.

gulfs and shelf-edges so not only are dynamic oceanographic processes highly complex, localised and little known, but there are two independent sets: one during the northerly, one during the southerly, monsoon river discharge and the status of coastal wetlands is highly seasonal, driven by the alternation between wet and dry seasons.

The basic description of this complex part of our planet is so far from complete that variability is well known only for some of the fundamental climate variables, and only for some places. We are certainly very far indeed from assembling the data for a synthesis of the between-year biological variability of this region, and I shall attempt no such thing. Rather, I shall briefly outline some of the environmental changes that can be expected to occur between years, and then suggest how some of the more important biological processes may be expected to respond to such changes.

Physical Forcing

It is now well established that the principal mode of interannual variability of tropical sea-surface temperature, and so of many other environmental variables, is related to change of the Southern Oscillation Index (SOI = Tahiti minus Darwin normalised sea-level pressure) and to the El Nino-Southern Oscillation (ENSO) events that occur after the SOI shifts from a positive to a negative value as a weakening of the Trades occurs. However, even when the Walker Circulation is well developed, and the Trades are blowing strongly, there are differences between years in monsoon rainfall in regions further to the west. These differences may drive the coastal marine environment where the continental shelf is dominated by river discharge, as in the Bay of Bengal, the Gulf of Tonkin or the Gulf of Carpentaria.

The environmental changes that ensue when the sign of the SOI shifts from a positive to a negative value are now well described, especially since the 1982-83 mega-event and especially in the eastern Pacific. The slackening of the trades and the occurrence of sustained westerly winds in the western Pacific foreshadows a series of Kelvin wave pulses that propagate eastwards in very low latitudes. Each causes a lowering of sea-level and a rapid rise of the previously deep thermocline of the western Pacific.

Sea-level may fall by as much as 25-30cm, and mixed-layer depths may be reduced from 200 to less than 100m in just a few weeks. Over a wide region of the western Pacific, negative SST anomalies occur very early during the onset of an ENSO event, and the area of highest sea-surface temperatures (>28.5°C) extends eastwards depending on the duration and strength of the ENSO event. Some northerly extension of the warm-water pool may also occur during some ENSO events, producing positive SST anomalies in the central South China Sea. During a normal ENSO-event, SST anomalies are of shorter duration in the western than the eastern Pacific. Usually, SSTs return to their normal values after about two months, and the 1982-83 event was quite unusual in that these anomalies persisted for about one year.

Year-to-year monsoon variability and even ENSO events occur as noise on decadal trends in SST and rainfall anomalies. For rainfall, long time-series are well known and exhibit clear decadal-scale variability. Similar trends can also be found in the NOAA Marine Data Deck of observations of SST from the 1880's to the present day. These trends are consistent globally, but are expressed in tropical latitudes by changes of much smaller amplitude than in high latitudes; it is no surprise that this should be so, because of the upper limit set on SST by the rapidly increasing rate of evaporation from the sea surface as SST rises. In this context, we should remember that, even during the Mesozoic period when an atmospheric CO_2 greenhouse caused ice-free polar seas, equatorial SST^{2}s were about the same as occur today in the western Indo-Pacific.

There is some independent and indirect evidence for changing SST s in the tropical Pacific on a decadal time-scale from stable oxygen isotope ratios in the dated growth rings of coral skeletons from Fanning Island. Though the data are fragmentary, there is evidence of a warming trend sustained through the 1960 s, and also that SST s during the 1930 s were about 0.5-1.0°C warmer than a decade later. We should note that sign and amplitude of SST trends are similar in the two sets of evidence, and also that the amplitude is of the same order as major variability on much shorter time scales in western Pacific SST s.

Biological Effects

So much for the kind of environmental variability that might be expected to drive ecological changes from year to year in the western Indo-Pacific Now, for what kinds of biological changes should we be examining our data sets?

Estuarisation of the Continental Shelf –

Perhaps a useful starting point would be to consider the immediate consequences of variable river discharge, because this is probably the most obvious between-year change in the marine environment as experienced by people working at sea on tropical coasts. The fauna of continental shelves in tropical monsoon regions contains a large percentage of species specialised for existence in water of variable salinity and high turbidity. This is a consequence of the massive seasonal estuarisation of tropical continental shelves under a monsoon regime, and perhaps also because the physiological cost of osmoregulation for fish is a negative function of temperature, dropping by 90% between 10° and 30°C. Nevertheless, the fauna of neritic and estuarine regions is displaced seasonally as wet season run-off is discharged from tropical rivers and estuarine species, such as the shrimp, Acetes spp, appear along the open coastline. Major seasonal shifts much occur in the distribution of many Indo-Pacific species that are specialised to water of relatively low salinity, such as the copepods Acrocalanus inermis, Paracalanus crassirostris, and Pseudodiaptomus aurivillii or the fish Polynemus nigripinnis, Johnieops volgleri and Harpodon translucens.

The relative species composition of the tropical estuarine and neritic fauna appears to be relatively unstable, as would be expected in such a highly varying biotope. Seasonal analysis of 40 species of nekton in an estuary in Papua-New Guinea suggested that though overall abundance was linked to river discharge, the between-year differences in relative species composition were more important in structuring the ecosystem than the seasonal changes in general abundance. Perhaps this is a general rule in the tropics, for the same thing has been recorded for the benthos of an estuary in the Gulf of Guinea.

A special case of the consequence of variable river discharge concerns the recruitment of penaeid prawns, obligate estuarine or lagoon organisms during part of their juvenile growth. This relationship will be dealt with by other speakers later in this Symposium, so that here it is sufficient simply to note that a statistical relationship has been found between recruitment and river discharge for tropical prawn stocks in several places: the southern USA, Mexico, West Africa, India and the Gulf of Carpentaria. Where it has been investigated, the mechanism which drives this relationship is found to be complex. In the Gulf of Carpentaria, the amount of rainfall determines both the size of emigrants and also the percentage of the estuarine population of juveniles which emigrates each season.

Spawning and Recruitment -

More enigmatic and diverse are the mechanisms, beyond simple stock-recruitment relationships, which determine recruitment in continental shelf fish. The environmental control of recruitment is perhaps the most important problem facing fisheries scientists today, and how it functions in tropical seas is very little known. However, we ought to be able to go beyond the simple statistical relationship known to exist between river discharge and catches on the adjacent continental shelf (for example, in the southern Gulf of Mexico) to which recruitment variability is attributed, but for which a causal mechanism is not established.

Any recruitment mechanism must satisfy each of three simple criteria: larvae must (i) encounter adequate food supplies and (ii) a tolerable level of predation, while (iii) they must complete their larval life in a suitable location to enter the next stage in their life history. These criteria emphasise matching the timing and location of spawning with suitable food and suitably few predators. Since both spatial and temporal cues are variable, as are the conditions governing successful recruitment, a variety of reproductive strategies are utilised in all latitudes.

Reproductive strategies of fish form a series whose extremes have been called the 'big bang' and the 'hedged bet' strategies; in the former, all individuals spawn synchronously while, in the latter, serial spawning extend throughout a season. Generally, in temperate latitudes, pelagic

spawners with small, fast-growing larvae adopt the 'big bang' strategy while benthic spawners, with relatively slow-growing larvae, hedge their bets by producing many individual cohorts, usually spaced about three weeks apart. Synchronous spawners in temperate regions may use cues that enable them to spawn when suitable food occurs in maximum abundance, but predator swamping is an alternative and in some ways more attractive hypothesis to explain this reproductive behaviour. Serial spawning, on the other hand, is usually interpreted as ensuring that at least one cohort shall encounter conditions that ensure good survival.

Can we transfer this analysis of reproductive strategies to the tropics and in particular to the western Indo-Pacific? Many, perhaps most, species of fish of the tropical continental shelves have rather extended spawning seasons. Reviews of the reproductive cycles of fish species of many families from the Philippines revealed that the reproductive season tends to include two spawning peaks about 4.5 months apart - the same interval as the two peaks of monsoon rainfall - and that there is a significant tendency for reproductive quiescence during the seasons of strong monsoon winds. This kind of reproductive cycle occurs also in tropical Atlantic continental shelf fish.

Two explanations have been offered for the observation that spawning of tropical continental shelf species occurs preferentially at times of low wind stress. First, this is when the water column is most strongly stratified and layers of abundant planktonic food organisms will be available for the nourishment of fish larvae which may be unable to obtain a sufficient energy return from searching for prey in a well mixed water column where plankton is unstratified. Second, during periods of quieter winds it is less likely that massive off-shelf advection of fish larvae would occur. At least under some circumstances this is thought to lead to poor recruitment in some species of continental shelf fish.

Some organisms, such as larval rock lobsters and penaeid prawns, have ontogenetic or diel vertical migration patterns that interact with differential current vectors at different depths in the water column to achieve transport that will maintain them in a region where survival is likely to be high. In the open ocean, Taylor columns and lee-ward gyres may act to maintain populations of pelagic larvae near islands and sea mounts so that sufficient numbers are able to recruit to demersal or coastal pelagic populations.

Somewhat paradoxically, it is also in tropical seas and in the western Pacific that the most extreme cases of synchronous spawning have been observed, both in fish and invertebrates. Settlement of metamorphosing larvae of some pomacentrid fish on the Great Barrier Reef occurs as 2-3 short pulses, each lasting about one week on about the same calendric day each year, so not keyed to the lunar or tidal cycle. A polychaete worm on the reefs of eastern Melanesia spawns at the sea surface simultaneously on only two nights each years,

cued by the date of the full moon in October. Spawning of >100 species of corals on the Great Barrier Reef occurs on only a few nights (and before moonrise on each night) between the full and last-quarter moons of October and November, when tidal streams are weak.

Detailed studies of the reproductive ecology of demersal fish along tropical coasts with fringing reefs have revealed, on the other hand, a variety of mechanisms clearly related to predator avoidance both by the spawning fish themselves, and for the young larvae. The corals, hydroids, crustaceans and small fish of the reef fauna are efficient at trapping zooplankton (and hence fish larvae) by a myriad of different techniques, and spawning fish tend to release their eggs in locations that ensure they will be carried offshore and held there long enough for local dissemination to occur at the end of the larval period.

The larvae of many species of fish of the open tropical continental shelves seek shallow, turbid coastal water that will serve (in the same manner as for the penaeid prawns of the continental shelf) for nursery grounds perhaps because this may give some protection from predators, especially in the inner creeks of estuarine systems which often hold the highest relative abundances of metamorphosing larval fish of certain species on sub-tropical coasts. On tropical shelves, under a monsoon regime, turbid water affording some protection from predation occurs close inshore, along the open coastline and there is some evidence that nursery grounds for many demersal fish are not so restricted to enclosed estuarine habitats as in higher latitudes or - presumably - as on arid tropical coasts.

What kind of variability in recruitment is driven by the action of environmental variability on these different reproductive strategies? There is far less information on recruitment-driven changes in stock size in any tropical fisheries than in termperate fisheries where year-class structure of populations is a routine measurement in stock management. Also, it is not clear whether variability in relative abundance is caused by differences in year-class (or cohort) strength or if it is an effect of different settlement or migration patterns. The abundance of pomacentrids at several locations on the Great Barrier Reef, between years and over a four-year period, varies by a factor of x 2-9, but this is probably an effect of settlement patchiness, not overall stock recruitment. In the same region, statistical analysis of relative settlement of labrid larvae on 7 reefs showed that abundance did not covary between reefs or between years, nor yet between closely related species.

Likewise, there is some difficulty in interpreting cases where stocks, such as oil sardine and mackerel in the northern Indian Ocean, exhibit major changes between years in availability at the coast in a manner apparently linked with differences in the strength of the monsoon: to what extent, in poor years, is a stock really smaller or is it simply less

available because its migration routes are different? The case of the oil sardine (Sardinella longiceps) and mackerel (Rastrelliger kanagurta) on the south-west coast of India deserve to be more widely known, since it is possible to construct a time series of almost 60 years for relative abundance of these species to a fishery which has evolved only marginally during the whole period. This shohld be an excellent data base with which to study the effects of environmental changes on stock abundance and location, and to disentangle these effects from those imposed by the fishery.

Rastrelliger availability is much less variable than Sardinella, and the reasons for this are probably complex. It is clear from the descriptions of the fishery that the monsoon conditions influence migration patterns each year, and that conditions during the principal spawning period appear also to influence recruitment to the subsequent fishery, which is dominated by the O-group. Such a relationship appears to be driven through variability of the inshore production of planktonic food, both plant cells and small crustacea, which arises as a result of different monsoon conditions each year and which seems to exercise overall control on population abundance. It is surely not coincidental that the Sardinella stock underwent a sustained increase in abundance in 1955-56 in response to a strengthening of the Indian monsoon after a period of several decades of weak monsoons. Nor that the almost complete failure of the 1941 monsoon was the same year in which the Sardinella population started a massive decline from which it took several years to recover.

Whether recruitment variability in Sardinella is driven by altered parent fecundity of by differential larval survival is far from clear, but both possibilities have their adherents. Oil sardine and Rastrelliger share the same environment, where both occur in massive numbers, yet their nutritional demands are slightly different. Rastrelliger, being the more eclectic feeder does relatively better than the oil sardine in those years when the phytoplankton response to the monsoon is weak; conversely, it is argued, oil sardine exclude Rastrelliger from the coastal zone in those years when there is a strong diatom bloom.

OPEN-OCEAN ECOLOGICAL RESPONSES -

Turning now to the biota of the open ocean of the western Pacific, there is only slim evidence to show how the pelagic ecosystem actually responds to a fully developed ENSO event, but there is sufficient understanding of the dynamics of pelagic ecosystems to enabgle us to speculate, at least qualitatively with some confidence.

All the principal attributes of the upper kilometre of the open ocean are structured in a locial and predicatable manner along the vertical gradients of light and density. This is not the place to discuss the details of the layer biocoenoses of the pelagic ecosystem, and it is sufficient to remind

ourselves how growth of plant cells is controlled by self-shading (thus determining the depth of the euphotic zone) and nutrient flux - by regeneration within the euphotic zone and by turbulent transport at its base within the thermocline. In the open ocean, ambient levels of inorganic nutrients within the euphotic zone are extremely low and internal recycling is very fast. A nutricline leads down to nitrate and phosphate levels of ~20 and ~2ug at/litre, respectively at the base of the thermocline. Plant cells form two associations - a light-limited community deep in the euphotic zone and a nutrient-limited community above. Plant biomass can be modelled as a chlorophyll profile containing a deep maximum which we can trace across whole ocean basins as a single feature. In the open oligotrophic ocean the rate of plant growth, expressed as carbon fixation rate, commonly has two peaks - one on the upper shoulder of the deep chlorophyll maximum and one near the surface.

We have already noted that the principal consequence of an ENSO event in the western Pacific Ocean is a rapid shoaling of the deep thermocline to about 40% of its normal depth and a negative temperature anomaly in the mixed layer. The biological consequences of this stress on the ecosystem can be predicted qualitatively. The thermocline will carry up with it the main features of the biological and chemical profiles that drive plant growth; as the nutricline and the shade-adapted flora rise to depths where ambient illumination is stronger there will be an increase in plant production and a relative deepening again of the nutricline as nitrate is taken up and recycled. Increased plant growth will cause stronger self-shading, shoaling the bottom of the euphotic zone, and there will be increased sedimentation of algal cells and faecal pellets from below the thermocline into the deep sea; the size structure of the zooplankton population will shift towards smaller organisms, as the individual species reproduce and increase the proportion of juvenile forms in response to a higher availability of plant cells and microplankton.

There are just a few observations which suggest that something like this scenario did accompany the 1982-83 ENSO in the western Pacific; mixed-layer chlorophyll values on the Fiji-Hawaii ship-of-opportunity transect were anomalously high, and changes occurred in copepod populations that await detailed description. That an ENSO event can cause changes in the growth of phytoplankton that have measurable consequences for the global CO2 budget is clear from calculations made for the deficit of plant production in the eastern Pacific during the 1982-83 ENSO; calculations appear not to have been made of the extent to which a deficit in production in areas with deepening mixed layers might be balanced by enhanced production in the Indo-West Pacific.

The tuna of the open ocean perform transoceanic migrations each year, and these are probably guided partly by the existence of location-specific features of Indo-Pacific oceanography. Major shifts of ocean features occur in ENSO

years, and massive disruption of normal migration routes of at least some tuna species in the western half of the Pacific were noted in 1982-83; in the estern Pacific - and also presumably in the Indo-Pacific - annual recruitment in subsequent years of yellowfin tuna appears to have been within normal limits of variability.

Responses of coral reef biota - finally , we should discuss some of the consequences to coral reefs and island life of the changes in wind direction, storm tracks, cloudiness and rainfall that accompany a major ENSO event. Atolls are like ships under sail, structurally oriented to the direction of the prevailing winds and the windward reefs differ biologically and morphologically. The windward reef carries buttresses and surge channels which are moulded by the prevailing swell. It lies at a relatively shallow angle, and is topped by a ridge of calareous algae more able than corals to withstand to pounding of heavy surf. The leeward reef usually has no algal ridge, and forms a relatively steep-to wall bearing a luxuriant growth of large tabular and bracket-shaped coral colonies.

Sustained winds from an unusual direction have serious consequences for such a system though, unlike a sailing ship, it is capable of self-repair. Heavy swells pounding the leeward reef frequently cause collapse of blocks of limestone and the destruction of coral colonies down to about 30m depth, with the surf-zone being swept clear. In most severe conditions, as when a tropical cyclone strikes an atoll, new ramparts of coral rubble may be thrown up and it has been suggested that this process is important in the evolution of many atolls. Such ramparts may subsequently be modified by 'normal' wave action to become permanent features of the atoll. During destruction of coral cover, there is a mass migration of reef fish to deeper parts of the atoll or fringing reef, but recolonisation begins again immediately after the event, though impeded by an algal bloom on the exposed limestone which precedes resettlement of coral colonies.

Not only on atolls, but in all reef areas, the coral colonies of the reef flats are susceptible to damage by excessive warmth - as occurred widely in the eastern tropical Pacific during the 1982-83 ENSO - and by heavy rainfall when exposed. The greatest mortality seems to occur among the more rapidly growing genera (eg Pocillopora, Millepora) and may be preceded by the general expulsion of symbiotic algal cells from the tissues of coral polyps, as occurred during anomalous warmth at Okinawa in 1980. There is a suggestion, also, from events in the estern tropical Pacific, that destruction of the fringing Pocillopora thickets may subsequently permit the Crown-of-Thorns starfish (Acanthaster) to attack previously protected but more vulnerable coral species.

Seabirds, and other biota which depend on predictable biological production in eddy streets in the lee of capes or isolated islands, may suffer catastrophic reproductive failure and general mortality if a sustained shift in prevailing winds or current direction causes the biological process to cease or to shift to the other side of the land mass. Such an event is the most probable cause of the complete reproductive failure of all 18 species of seabirds at Christmas Island almost on the equator, and south of Hawaii, in late 1982, when many species failed to rear their young and others were totally absent. Although such biological events were mostly reported for the eastern Pacific, and particularly at the Galapagos Islands, during 1982-83, this was probably because most attention was focussed on this region: events similar to those which affected seabirds, reptiles, mammals and fish at the Galapagos certainly must have occurred also among the archipelagos of the western Pacific though probably in the early, rather than the late, part of the ENSO event.

These, then seem to me to be the principal processes which should be looked for in analysing the biological consequences of environmental variability at all scales in a region as complex in all its aspects as the Indo-Pacific conjunction. The only substitute for accumulation of time-series of environmental data that already exist for the Indo-Pacific region lies in the possibilities afforded by satellite remote sensing of the sea surface, and this technique undoubtedly will be essential to future success. But so great is our relative poverty in biological time-series for almost any biological time-series for almost any biological variable, almost anywhere in the ocean, that none should be neglected. So turn out your dusty drawers and illuminate your grey literature, and perhaps we'll be in a better position to interpret biological changes next time the ocean turns over in bed.

TUNA BAITFISH RESEARCH IN THE SOLOMON ISLANDS AND MALDIVES

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Tuna are fished throughout the tropical and temperate waters of the world using three main methods: purse-seining, long-lining and pole-and-line fishing. Most of the tuna catch of the Solomons and Maldives is made using a traditional pole-and-line method. This technique cannot operate without a regular and adequate supply of suitable baitfish species. These are small fish mainly of the families Engraulidae, Clupeidae, Caesionidae, Apogonidae and Pomacentridae, which are thrown live into the sea to attract tuna schools within range of the boat. The tuna industry is vital in the Solomons and the Maldives where it provides a major source of food, much employment and high export earnings. This paper describes the new CSIRO/ACIAR, Solomon Islands and Maldives collaborative research project on baitfish biology. The primary objective of the research is to collect and analyse biological information on the important baitfish species of the Solomons and Maldives, in order to provide the basic scientific data necessary for traditional owners, and in order to allow continuing maintenance of supplies for the expanding tuna industry.

ANNUAL OCCURRENCE OF POSTLARVAL PENAEID SHRIMP AT PHANG-NGA BAY, SOUTHERN THAILAND

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The occurrence of postlarval penaeid shrimp was studied in estuarine water adjacent to the mangrove areas at Phang-nga Bay during January-December 1984. Five species of commercially important shrimp, viz Penaeus monodon, P. semisulcatus, P. merquiensis, P. indicus, and P. japonicus, were found in these areas. P. merquiensis was the dominant species. The major occurrence of postlarval penaeid shrimp was Metapenaeopsis spp., followed by P. merquiensis. The maximum numbers of penaeid shrimp were found at the station in the inner part and on the west coast of the bay. The peak occurrence of penaeid shrimp was found in July and October during the southwest monsoon season.

The numbers and monthly variations of other groups, such as Acetes spp, Caridea and Mysidacea were also recorded during the period studied.

THE DISTRIBUTION OF PRAWN NURSERY GROUNDS IN NORTHEASTERN QUEENSLAND COASTAL WATERS

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Thirteen species of seagrass and juveniles of six penaeid prawns of commercial importance were found in seagrass beds in coastal waters between Cairns and Cape York. The pioneering seagrass species Halodule uninervis and Halophila ovalis were the most common seagrass species. Often dominant tropical seagrass species, such as Enhalus acoroides and Thalassia hemprichii were uncommon. Seagrass biomass was greatest in 2-6m of water. Halophila decipiens was the only species found in depths >11m of water. The most numerous penaeid prawn species in the commercial trawl catch, Penaeus esculentus and Metapenaeus endeavouri, were also the most common juveniles in seagrass beds. Preservation or management of seagrass habitat in northern Australia will be an important aspect of the long-term management of the prawn fishery.

MODELLING THE INTERANNUAL VARIABILITY IN CRUSTACEAN RECRUITMENT

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The classical Ricker and Beverton-Holt stock-recruitment models are simple deterministic models incorporating stock-dependent and density-dependent forms of compensatory population regulation, respectively. Recent generalizations of these models allow more complex functional forms but do not consider specific environmental effects on recruitment nor do they allow consideration of random variation in mortality rates. Recruitment patterns of many marine organisms are highly variable and deterministic recruitment models typically explain only a small fraction of the variation in recruitment. At least two alternative approaches to dealing with recruitment variability are possible: (1) develop more complex deterministic recruitment models with specific environmental inputs; or (2) develop stochastic recruitment models. In the paper, both approaches are described and illustrated with examples for a number of crustacean populations.

Extensions of the Ricker and Beverton-Holt recruitment models with explicit environmental terms are described and applied to crustacean populations. Problems in parameter estimation resulting from autocorrelation in stock, recruitment, and environmental data are described and modelling approaches based on time-series analysis are considered. Stochastic analogues of the Ricker and Beverton-Holt models are also described. These models do not explicitly incorporate environmental factors but do allow specification of variability in mortality rates. The full probability distribution of recruitment levels for both models is described.

Finally, the implications of complex multistage life-history strategies in crustacean populations are evaluated. There is considerable variation in reproductive characteristics among the crustacea (e.g., forms of parental care, incubation period, duration of larval phase etc.) with important implications for resilence to environmental perturbation and recruitment variability.

INDO-WEST PACIFIC AFFINITIES OF PHILIPPINE SEAGRASSES

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Hierarchical (cluster) analysis partitioned the Indo-West Pacific seagrass ranges into seven discrete provinces. These are: (1) Province A (Philippines, Malaysia-Singapore, Indonesia, New Caledonia, Papua New Guinea, Queensland, Micronesia, Vietnam, Ryukyu Island, Thailand, Borneo, India, Sri Lanka, Burma and Hong Kong); (2) Province B (Kampuchea); (3) Province C (Japan); (4) Province D (Fiji and Tonga); (5) Province E (Korea); (6) Province F (New Zealand); and (7) Province G (Western Australia, New South Wales, South Australia and Tasmania-Victoria).

A high probability exists that Halophila, due to its wide distribution from Tasmania to Japan, represents a major connection between most of these provinces, strongly influencing the clustering of the seagrass floras in the region. The phytogeographic affinities of the Philippine seagrass flora is primarily to the west with the Indian Ocean and southeast Asian coasts.

INTERANNUAL VARIABILITY IN CORAL-REEF FISH COMMUNITIES IN FRENCH POLYNESIA

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Changes in the composition of coral-reef fish communities on the fringing reef, the barrier reef and the outer slope of the northwestern part of Moorea Island (17°30'S and 149°50'W) were examined over 15 months in 1982-83. These data indicate the relative constancy of the communities between successive years (WOLDA's AV<0.18).

This constancy is not, however, apparent over a longer time period. Between 1976 and 1983 the number of fishes increased by 39% on the fringing reef (from 1.5 to 2.2 fish m^{-2}) and by 47% on the barrier reef (from 1.4 to 2.0 fish m^{-2}). During this time the trophic composition of the community

also changed significantly with an increase in the proportion of herbivorous fishes (Acanthuridae Scaridae) and a decrease (except the Labridae) in the proportion of carnivorous fishes (Chaetodontidae, Holocentridae, Mullidae).

This interannual variation is attributed to the degradation of the coral-reef system observed in French Polynesia since the early eighties. In this area of Moorea live coral cover was reduced to half its original amount between 1979 (35%) and 1982 (19%).

LONG-TERM CHANGES IN THE COMPOSITION OF AN EXPLOITED TROPICAL DEMERSAL FISH COMMUNITY

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Between 1963 and 1965 an extensive trawl survey of the southeastern Gulf of Carpentaria was undertaken to assess the feasibility of commercial prawn trawling. It also provided valuable data on an unfished demersal fish community.

Since then, the Gulf has become a major prawn fishery with trawling taking place at night predominantly for tiger prawns (Penaeus esculentus) and during the day for banana prawns (P. merguiensis). Both these fisheries catch a considerable amount of fish as a bycatch all of which are discarded dead.

In April 1985 and April 1986, two trawl surveys were carried out replicating a subset (n=58) of the sites fished in April 1964. The fishing method, sites, fish taxonomy and time of the day were duplicated. The 1964 and 1985-86 datasets were compared for composition and relative abundance of the main fish species. Within the survey area, sites were grouped into three zones by the pre-trawling faunal composition and the fishing effort over the period 1970 to 1985.

Overall, the abundance of most species showed a decrease compared to the pre-trawling values. For example, the monacanthid Paramonacanthus japonicus, the predominant species in 1964, was present in low numbers in 1985 and 1986. The Leoignathidae were still one of the dominant families though changes have occurred in the relative importance of the various species within the family. Changes in the fish composition appear more pronounced in the areas of high fishing intensity. Day/night variations occur with some day-species showing increases in abundance.

The significance of these differences is assessed in view of the large year-to-year variations indicated by the 1985 and 1986 surveys. We would suggest that fishing effort is an important factor in explaining the observed differences in the data sets.

MUD LOBSTERS AND MANGROVE PLANTATIONS IN SOUTHERN THAILAND

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Many problems affect mangrove plantation development, including low pH of acid sulphate soils, damage by sesarmid crabs and overgrowth of seedlings and saplings by undesirable ground flora. These variables are further affected by the presence of the mud lobster (Thalassina anomala), an abundant crustacean, which occurs in the terrestrial fringe of mangrove forests. Mounds are constructed until one half of their height is above the normal tidal level.

This investigation was conducted near the Kra Buri River, Ranong Province, southern Thailand, where Thalassina mounds covered approximately 40% of the mudflat area. Twenty two mangrove tree species were planted in July 1983 at 1.5m by 1.5m spacing. Two years later, Rhizophora apiculata, R. mucronata and Brugiera gymnorhiza were growing successfully in the space between the Thalassina mounds, and Xylocarpus granatum, B. cylindrica, Lumnizera littorea, Excoecaria agallocha and Cerbera odollam were growing on the mounds. R. apiculata, R. mucronata, B. parviflora, B. cylindrica, B. gymnorhiza, B. sexangula and Ceriops decandra, had reduced survival (65, 76, 68, 56, 64, 68, 71, and 68%, respectively) six months after planting, due to the combination of low pH, crab damage and weed growth. It appears that establishing a mangrove plantation in an area characterized by high densities of mud lobsters is more difficult than soft mud areas with lower mound densities.

TEMPORAL CHANGES IN PREDATOR/PREY RATIOS: OMNIVOROUS COPEPODS VS FISH LARVAE

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Seasonal and annual variations in the concentrations of fish eggs, fish larvae and predatory copepods have been monitored at stations off the southeast Australian coast. The copepods (which capture and ingest fish larvae hatched in the laboratory) increased in field numbers 2-3 weeks after summer and autumn peaks in the concentrations of fish eggs.

TRAWL FISH COMMUNITIES OF THE ARAFURA SEA

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This project is focussed on the bycatch fish species composition from the foreign vessel trawl fishery in the Arafura Sea. There are two fishing operations in the fishery - Taiwanese pair-trawlers operational since 1971 and Thailand stern-trawlers. The Thailand venture entered the fishery in late 1985 and is presently utilizing almost unfished stocks to the east of New Year Island.

A preliminary examination of community characteristics (diversity and dominant species) and their relationship to habitat type and fishing intensity was made. Clay habitat was found to have lower diversity than sand or sponge habitats on the "new" fishing grounds. Marked differences in dominant species composition between "heavily-fished" grounds (Taiwanese pair-trawl data) and "new" grounds (Thai stern-trawl data) were observed. However interpretations of these differences cannot be made without further samples and sediment analyses.

THE POTENTIAL USES OF LONG-TERM ENVIRONMENTAL RECORDS IN CORAL SKELETONS

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Massive living corals possess an impressive array of historical environmental proxy data, in some cases going back a thousand years, which can be retrieved using novel field and analytical techniques. These corals are widespread throughout the tropical Indo-Pacific, and therefore could be used to provide huge local inventories of planning data for many developing countries.

Among those most useful in scientific, economic and social terms are proxies of drought, river discharge, rainfall, land-use changes, sea temperatures and pollutants in terrestrial runoff. Long proxy sequences at temporal resolutions as short as one month are possible. Knowledge of the interannual variability in the intensity of these parameters is of great value in dynamics and organism-environment interaction, including the effects of human activity.

OBSERVATIONS ON INTERANNUAL VARIABILITY IN THE OCCURRENCE OF SOME PENAEID PRAWN SEED RESOURCES IN THE HOOGHLY-MATLA ESTUARINE COMPLEX OF SUNDERBANS

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In order to study the interannual variability in the occurrence of penaeid prawn seed, collections were made with Midnapore-type shooting net, drag net, hapa net and ring net once a fortnight 3 to 6 days after the full moon and new moon and 2-3 days before full and new moon days, in addition to the regular collections made on other days at the Hooghly-Matla estuarine complex near the mangrove forests of Sunderbans.

Quantitative studies revealed that the occurrence of Penaeus monodon, P. indicus, Metapenaeus monoceros and M. brevicornis was quite high during the premonsoon season (February-June). In the postmonsoon (October-January) and monsoon (July-September) season their numbers usually decreased.

Immigration of post-larvae into the estuaries was found to be greater in intensity in high tides, spring tides, full moon and new moon days and night hours. Post-larval density per unit area was found to be influenced by the different hydrographical parameters, such as tidal circulation, temperature, salinity, rainfall, dissolved oxygen, transparency and total suspended solids.

In the fitted multiple regression model, an analysis of variance was performed to test the significance of regression co-efficients where the salinity, water temperature and total suspended solids were observed to be highly significant. The magnitude of the resource and its composition (species and size-wise) and the seasonal availability are dealt with in this account.

INTERANNUAL VARIATION IN COASTAL (MANGROVE & SEAGRASS) COMMUNITIES

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Mangroves and seagrasses often form highly productive coastal communities. There is now increasing evidence that these communities may play vital roles in the support of adjacent coastal fisheries. Any change in these communities may thus have an effect on the coastal fisheries. A review of the mangrove literature shows that, while a reasonable amount of data is available on the geographical and other physical variability of mangroves, there has been little quantitative biological data collected on a time-series basis. The best long-term data sets in this region are from litter-fall studies, but even these are mostly about a year in duration. Yet, in many areas, long-term meteorological data sets already exist and these could be used to correlate and predict biological changes at the local level. At the regional level, studies can be made to determine whether biological variations are correlated to regional physical changes like the El Nino Southern Oscillation.

It is suggested that long-term time-series programmes on litter productivity on a regional (e.g., WESTPAC) scale be initiated as a first step to fill this gap. The use of spectral analysis in the design and analysis of such projects is briefly discussed.

DISTRIBUTION AND ABUNDANCE OF THE CTENOPHORE PLEUROBRACHIA GLOBOSA MOSER IN THE NEARSHORE WATERS OF SOUTHEAST CHINA

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The geographical distribution and seasonal abundance of Pleurobrachia globosa are analysed on the basis of 806 samples taken from 91 stations in six sea areas along the southeast coast of China from April 1960 to January 1979. This ctenophore species is seen in small quantities without evident annual peak, while it is found throughout the year in southern Fujian in great quantitites with three peaks. The annual quantity decreases gradually from southern Fujian northward and appears in shorter periods. The peak numbers of annual quantity decreased as well. It is tentatively concluded that, at low temperatures (less than 25.5°C), salinity is a limiting factor for the distribution of P. globosa, whereas temperature takes over control when salinities are low (less than 27.5). T-S diagrams may be used to predict the occurrence of "blooms" of these animals and be useful for aquaculture by preventing unnecessary losses due to the predation of P. globosa.

THE INPUT OF TERRESTRIAL AND MARINE HUMIC SUBSTANCES TO THE GREAT BARRIER REEF LAGOON AND THEIR EFFECT ON TRACE ELEMENT SPECIATION

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Studies carried out over several years on a tropical estuary have shown that substantial amounts of terrestrial and marine humic compounds are transported to the inshore region of the GBRL throughout the year. These humic substances have a marked effect on the chemical behaviour of several trace elements. Whilst the terrestrial humics are mobilized by the input of freshwater in the monsoonal season and are soon precipitated on contact with seawater, the marine humics are more soluble in sea water and are produced by vast blooms of the blue-green alga Trichodesmium, which occurs throughout the GBR region. These marine humic substances exhibit high UV absorption and fluorescence.

ECOPATH MODEL OF A TROPICAL SHALLOW-WATER DEMERSAL ECOSYSTEM

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An attempt was made to characterize a tropical shallow-water demersal ecosystem off Terengganu, east coast Peninsular Malaysia, using the ECOPATH model developed by Polivina and Ow (1983). Trawling was conducted in the area to provide some of the input parameters required by the model; e.g., diet composition, total mortality, an estimate of production/biomass (P/B) ratio and mean biomass of trophic groups present in the system. Data collected allowed the construction of a preliminary model showing schematically the biomass production budget and the major prey-predator pathways present in the system. The importance of certain key parameters like P/B ratios and food consumption values for the generation of a good and acceptable model is stressed. ECOPATH is presently limited to static conditions under equilibrium. Expansion and modification of ECOPATH into a simulation model for tropical multi-species fisheries management and prediction of the abundance and composition of fish stocks with changing patterns of fishing is discussed.

ENSO - GREEN TURTLE RELATIONSHIPS

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Extensive synchronous fluctuations in annual nesting density have characterized the green turtle rookeries of the Great Barrier Reef in recent decades. Some similar fluctuations have been identified back to before European colonization of the area in the mid-1800s. These annual fluctuations are not due primarily to changes in the size of the green turtle population but rather changes in the proportion of the adult females in the feeding grounds which actually prepare to breed in any one year. Also, it has been demonstrated that there is a high positive correlation between the Southern Oscillation index (actually the November-January Darwin atmospheric pressure) and the green turtle nesting density on the Great Barrier Reef rookeries two years later. The sparse data from Indonesia suggest that there is a similar ENSO effect on the green turtle rookery of southwestern Java.

The pathway linking the ENSO effect and green turtle nesting density is not clear. A possible linkage via seagrass/algae nutrition is being investigated. Whatever the cause, this ENSO green turtle nesting density relationship has potential predictive value that could lead to improved management of sea turtle stocks.

SPECIES RICHNESS OF SOUTHEAST ASIAN MARINE LIFE: TESTING COMPETING HYPOTHESES WITH RANGE PATTERNS

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Major hypotheses explaining the unusually high species richness in southeast Asian seas can be divided into those based on overlapping ranges, high regional survival, high rates of local speciation, and combined effects of high speciation nearby with high regional survival. Each competing hypothesis has been evaluated in terms of the types of species range maps that would support it. Available data are inadequate to discriminate confidently between hypotheses. However, if efforts are directed towards determining key species boundaries within specific sampling regions, it may be possible within a few years to determine what primary factors are responsible for the high species richness of the marine biota of the area.

MULTISPECIES FISHERIES IN SOUTHEAST ASIA: A STRATEGY FOR COLLABORATIVE EMPIRICAL ANALYSIS

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The fisheries of southeast Asia comprise a single biogeographic unit, unique in the world, subjected to a broad range of fishery and environmental conditions. Within any one country, limitations in the available data in time, space or degree of taxonomic discrimination inhibit the development of a conceptual understanding of the fisheries useful for management purposes. By facilitating the international comparison of data sets, each nation in the region can contribute to a more complete analysis of the character and responses of the complex fisheries and obtain more useful advice for research costs already invested.

In a pilot study of a published research trawl data set from the Samar Sea, Philippines, a tabular sorting/divisive hierarchical classification method was used to determine which species were responsible for a division of the fishery into two subcommunities encompassing 10 to 30 and 30 to 100m depths. If widespread, such a division would suggest that trawl fishing below 30m would have limited consequences for small scale fishing above this depth.

MICRONEKTON ABUNDANCE IN THE WESTERN PACIFIC AND INDIAN OCEAN

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The micronekton is mainly composed of pelagic shrimps, fishes, euphausiids, mysids and larger chaetognaths. The total biomass abundance of micronekton is high in the high latitudes in the Bering Sea and in the Southern Ocean around the Antarctic Convergence, above 10 g/1000m^3. The biomass is less than 1 g/1000m^3 in subtropical zones, namely around 20°N and 20°S. Fish micronekton is dominant throughout all the waters studied, particularly in the northern part of the North Pacific and in the Antarctic. Shrimp micronekton is comparatively scarce in Bering Sea and in the Southern Ocean, but the biomass is comparatively high in the tropical waters. Euphausiids are the dominant component in the Antarctic where the krill Euphausia superba prevails. The mysids are a small but consistent component of micronekton in the mesopelagic waters. The trends of composition and abundance in each locality have been studied.

ARE BOPYRIDS REGULATING PENAEUS SEMISULCATUS POPULATIONS?

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Parasites have been shown to be capable of driving host population cycles, even when the parasites are apparently rare. In marine crustacean resources this has not yet been demonstrated. However nemertean egg predators have been implicated in depressing crustacean stocks after perturbation caused by the fishing industry. Across northern Australia no year-to-year variability in bopyrids on prawns was observed except in the north of Groote Eylandt. There, Epipenaeon ingens infects and sterilises over 20% of Penaeus semisulcatus in late autumn/early winter. This level of parasitism is theoretically large enough to exert a controlling influence on prawn populations. The bopyrid frequency distribution is highly aggregated and described by the negative binominal distribution ($p=9.564$, $k=0.011$). Consequently, direct prawn mortality is negligible but reproductive death is significant. The implications of the current population dynamics theory with respect to the capability of this parasite to change prawn abundance will be discussed.

RECRUITMENT OF THE ORNATE ROCK LOBSTER, PANULIRUS ORNATUS IN THE TORRES STRAIT

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The rock lobster resource of P.ornatus in the Torres Strait is shared by Australia and Papua New Guinea and it is composed of three separate technologically and culturally diverse fisheries. These include an island-based diver fishery, a trawl fishery in which a large prawn-trawling fleet had opportunistically exploited rock lobsters at particular times of the year and a tangle-net fishery.

The management regime for the resources has restricted the activity of the trawlers for two reasons. Initially an annual quota for the trawl catch was introduced Papua New Guinea to protect the tradition fishing of the indigenous people at Yule Island, at the eastern and of the Gulf of Papua, which was believed to rely on rock lobsters that have moved through the trawl grounds. This was subsequently extended to a seasonal ban on trawling for rock lobsters, introduced by both countries because of concern over the direct and often substantial impact the trawl catch has on the size of the breeding emigration. The underlying assumption has been that the size of the annual breeding emigration determines the size of the breeding stock which, in turn determines the size of the fishable resource in subsequent years.

In 1985/86 the diver fishery in both Australia and Papua New Guinea had a record catch which mainly reflected the exceptional recruitment into the fishery of a single year-class. This record level of recruitment apparently came from the 1983/84 breeding stock, which was thought to be small.

Reevaluation of the evidence indicates that because of the short run of data available, and technological changes that have occurred in the fisheries, it is not possible to detect any trends in the catches of the fisheries. However, the data do not support the hypothesis that the catches at Yule Island indicate the size of the breeding stock or are affected by the trawling in the Gulf of Papua or Australian waters. Insufficient information is currently available to determine the underlying factors affecting the fluctuations in the levels of recruitment to the stock of P.ornatus in Torres Strait.

TEMPORAL VARIATION IN TROPICAL SEAGRASS COMMUNITIES

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Tropical seagrass communities are extremely important ecologically, in the management of some fisheries and in the conservation of dugongs and green turtles. There is only limited information on seasonal, interannual and longer-term changes in tropical seagrass communities.

Four years of monitoring of five seagrass community types at Groote Eylandt in the western Gulf of Carpentaria showed significant seasonal changes in leaf production, shoot densities, above-ground biomass and leaf-area indices but non-significant changes in below-ground biomass, species composition and distribution. Interannually, there were non-significant changes in species composition and distribution for all the communities.

For nine seagrass species and two cyclones, studied in the Caribbean and the western Gulf of Carpentaria, there were no significant pre-versus post-cyclone changes in shoot densities or in patterns of distribution. For a third cyclone studied in the western Gulf of Carpentaria there were significant decreases in the distribution of seagrasses in the impacted area during the cyclone and complete removal of the seagrass communities over the 12 months following the event. In total, 145 sq km of seagrass were removed which represented 16% of the seagrasses of the Gulf of Carpentaria.

A study of the aerial-photographic records of the extensive seagrass communities of the Wanga Wallen Banks, Moreton Bay, showed non-significant changes in the distribution of seagrass over the past 25 years.

These data suggest that factors affecting the distribution of seagrass communities are complex and long-term. A major structuring force can be cyclones although they cause complex short and long-term perturbations of a varying nature.

CARBON FLOW IN A SEAGRASS ECOSYSTEM OF THE GULF OF CARPENTARIA: A HYPOTHETICAL MODEL

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In the coastal waters of the Gulf of Carpentaria, primary producers supply large amounts of organic carbon to the marine environment. Carbon is one of the major means of energy transfer and the pathways of energy flow are based on photosynthesis and plant growth. Micro-organisms are major links in the detrital marine food web, and the relationship between bacteria and the primary producers is being studied.

Most of the bacterial production is found in the seagrass sediments. In summer, the bacterial production (3 g C m^{-2} d^{-1}) was approximately 30% of the seagrass production (10 g C m^{-2} d^{-1}). This means that about 9 g C m^{-2} d^{-1} would be needed to support the production and respiration of the bacteria (if they are about 30% efficient). Hence most of the rate and efficiency of transfer of carbon between the different trophic levels will dramatically influence the production at higher trophic levels.

A COMPARATIVE STUDY OF THE REEFS OF SEYCHELLES AND VIETNAM

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According to the present author's classification, the Seychellian and Vietnamese coral reefs belong to the same ecological and geographical classes of stable monsoon platform reefs.

This leads to an expectation of reef body resorption and to an ordinary sparsity in the coral distribution. The generic coral association of approximately 50 genera is exceptionally close both between the areas in comparison and is in general conformity with the Australian Great Barrier Reef. The local coral associations are markedly specific within certain reef landscape types.

MANAGEMENT OF THE DEMERSAL FISHERIES OF THE GULF OF CARPENTARIA: IMPLICATIONS OF PRE-EXPLOITATION PATTERNS IN FISH AND CRUSTACEANS OF THE SOUTHEASTERN GULF

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A trawl survey was conducted in 1963-64 in the southeastern Gulf of Carpentaria to provide basic data necessary for the long-term management of the prawn fishery that was then developing in the Gulf. A diverse demersal community was found, with 357 taxa of fish and cephalopods, and 284 taxa of crustaceans. Basic similarities in the spatial distributions of fish and crustaceans were found, determined by the environmental characteristics of different areas and depths. Seasonal changes occurred in the depth of occurrence and in the abundance of nearshore species particularly. These changes reflect seasonal and monsoon-related changes in water temperature and salinity, together with seasonal patterns in recruitment to the demersal populations.

The history of other Indo-Pacific demersal fisheries suggests that undesirable changes to fish and crustacean communities may result from intensive fishing. The by-catch of prawn trawling in the Gulf of Carpentaria includes a substantial catch of fish and non-prawn crustaceans, together with large sedentary benthic macrofauna such as sponges. The selective removal of non-target species, and habitat modification as a result of trawling, indicate that long-term management of crustacean fisheries in the Gulf of Carpentaria should consider the demersal communities as a whole.

THE DISTRIBUTION OF *ACANTHASTER PLANCI* ON THE GREAT BARRIER REEF: 1962-1985

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The interannual variation in abundance of the outbreaking starfish, *Acanthaster planci*, on the Great Barrier Reef is described using a 24-year series of data collected by a wide variety of methods. Owing to the large size and patchiness of the Reef, the data are incomplete but still useful, provided the limitations are recognized.

Trends in the large-scale pattern of starfish population abundance are analysed to describe properly the southward migration of starfish outbreaks. Although the starfish and its coral prey reproduce annually, the growth rate of the prey is relatively much slower than the growth rate of the starfish. This hysteresis is evident in the migratory pattern of the starfish populations. Present indications are that the starfish strategy is coarse-grained with respect to its food resource and this permits cycling of the predator and prey. If the strategy becomes more fine-grained then smaller oscillations of the predator, and its prey, should be observed. The future trend is uncertain given the relatively short period for which there are reliable data.

FOOD CHAINS IN TROPICAL AUSTRALIAN MANGROVE HABITATS: A REVIEW OF RECENT RESEARCH

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This paper summarizes recent work on the structure and function of tropical mangrove food chains in Australia. The stimulus for this work was provided by: (1) the lack of knowledge of food chains in SE Asian mangrove areas; and (2) a belief that current models of mangrove food chains (based mainly on work in Florida) were inadequate for our species-rich forests.

In tropical Australia, the proportion of mangrove leaf production removed by insect herbivores ranges from 0 to 35 percent for different mangrove species, but averages less than 3 percent for the dominant forest types. When leaves are shed from trees in low-intertidal regions more than one quarter of leaf fall is shredded immediately by sesarmid crabs prior to microbial decomposition in subtidal regions of the forest. Consumption by crabs is likely to be much higher in forest regions not regularly flushed by tides.

The densities of juvenile fish are greater in mangrove habitats than in adjacent seagrass flats. The major food source of juvenile fish is zooplankton. While the densities of total zooplankton do not differ among mangrove and seagrass habitats, crab larvae, the major dietary component for juvenile fish during recruitment periods, are significantly more abundant in mangrove habitats.

RECRUITMENT AND DISPERSAL OF CORALS ON THE GREAT BARRIER REEF: IMPLICATIONS FOR MANAGEMENT

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Two large-scale experiments have demonstrated that recruitment of corals to reefs may be more geographically restricted than previously suspected.

One experiment - The Helix Experiment - was conducted on Helix Reef in the central Great Barrier Reef region examining coral recruitment at the scale of 5-10 km. This experiment demonstrated that coral recruitment is highly localized, with most recruitment occurring either on or within 1.2 km of the reef. A second experiment - the Cross-Shelf Transplant Experiment - involved three reefs spanning the width of the continental shelf in the central Great Barrier Reef region. This experiment demonstrated that: (1) coral recruitment is generally regionalized across the shelf; (2) the recruit community closely resembles the adult community; and, most importantly, (3) even if widespread dispersal of planular larvae did occur, local selective factors would cause spat mortality in such a manner that

the survivors would resemble the adult community. Thus, two factors contributing to the control of the coral community are regionalized recruitment and regionally specific mortality patterns. Management of coral reefs should take these factors into account when zoning reefs for public use. They are critical in determining the success of recolonization after natural disturbances such as cyclones or crown-of-thorns starfish infestations or man-made disturbances such as dredging or oil spills.

STATE OF PHILIPPINE DEMERSAL STOCKS: INFERENCES FROM CATCH RATES

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The present contribution uses underutilized catch-rate data to infer the state of the demersal stocks of the Philippines. Utilizing over 1 200 independent trawl hauls (culled primarily from BFAR files and existing literature) and the swept-area method, the decline of the country's demersal stocks from 1947 to 1981 is illustrated. It appears that the demersal stocks had declined to about 30% of their 1947-48 biomass levels by the early 1980s. The economic and biological overfishing problems resulting from such low biomass levels are expected to increase further if appropriate management measures are not developed and implemented in due time.

INTERANNUAL VARIABILITY IN CLIMATE AND CATCH OF PENAEID PRAWNS THROUGHOUT THE INDO-WEST PACIFIC REGION

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Many environmental factors are known to affect the survival of early life-history stages of penaeid prawns and therefore tend to control the interannual variability of recruitment and catch of commercial species. One factor of major importance to the banana prawn, Penaeus merguiensis, in the Gulf of Carpentaria, Australia, is the effect of rainfall on the emigration of juvenile prawns from mangrove estuaries.

This paper reviews the interannual variability in catch of several stocks of P. merguiensis throughout the Indo-West Pacific in an attempt to establish global links between recruitment processes which might be associated with longer-term climatic trends such as the El Nino/Southern Oscillation (ENSO) events. The causal mechanisms associated with these links and their importance to the management of tropical penaeid species is then discussed.

ROLE OF SEAGRASS BEDS AS NURSERY AREAS FOR JUVENILE PENAEID PRAWNS

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The juvenile phase of many penaeid prawn species within tropical Australia are selective in their habitat requirements. Within the Gulf of Carpentaria, at least three important commercial species are only found associated with seagrass/algae beds. The extent to which this dependency on seagrass influences the distribution and abundance of commercial catches of the two tiger prawns, Penaeus esculentus and P. semisulcatus has been studied over several geographical scales from 1983 to 1985. In general, juvenile prawn abundances of these species increase with increasing density and biomass of seagrass, although leaf height was found to modify P. esculentus distribution and substrate type within the seagrass beds modified P. semisulcatus distribution. Highly productive tiger prawn nursery areas are confined to small sheltered embayments where softer sediments and taller seagrasses prevail. The extent of the interannual variability of seagrass areas and juvenile prawn populations is also presently being studied. Preliminary results indicate relative stability of juvenile prawn numbers within seagrass beds provided that seagrass distribution is not modified by major storm events such as cyclones and strong winds.

SCALE OF VARIABILITY WITHIN AND BETWEEN CORAL POPULATIONS

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Studies of variability are often made with little prior information on what constitutes the basic unit of analysis; i.e., the population. As analyses of variation are usually substantially influenced by the scale of their sample unit, it is an advantage to maximize the flexibility of a sampling design to allow integration over many different scales. This study of the population genetics of the shallow-water coral Acropora digitifera addresses electrophoretic variation at scales of 5m to 1000km. A suite of genetic analyses suggests that spatial variation within this species is concentrated within reefs in patch sizes of 1-2km, with little variation resulting at a regional scale. Implications for recruitment are: (1) asexual propagation is insignificant; (2) patches represent the output of different reproductive groups; and (3) dissimilarity between patches results from temporal differences in recruitment.

EVIDENCE FOR, AND IMPLICATIONS OF, VERY SHORT GENERATION TIMES IN TROPICAL FISH SPECIES

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The effect of temporal changes in environmental factors on fish populations depends, in part, on the response times of those populations. Recent work on shelf-associated tropical fish species indicates generation times that for some are on the order of months rather than years. The potential exists, therefore, for rapid changes in populations to altered conditions that favor larval or juvenile survival. An apparent example of such a response, in the lizardfish genus Saurida, is discussed, based on data collected on the Northwest Shelf of Australia. Preliminary data are also presented regarding possibly short generation times in other reef-associated fish species, and some implications for management of tropical stocks are suggested.

POTENTIAL EFFECTS OF CLIMATE CHANGE ON MANGROVES WITH SPECIFIC REFERENCE TO GLOBAL WARMING AND SEALEVEL RISE

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Published projections of global warming of 1.5 to 4.5°C and sealevel rise of 56 to 245cm are used to speculate on geomorphic and ecological responses that might be expected in mangrove forest-dominated coastal landscapes. For discussion purposes we assumed a 1.0m rise in sea level over the next one hundred years; the absolute temperature rise during this period was considered to be insignificant on mangroves.

Given that mangroves-dominated coastlines lie at or very near sea level, widespread flooding of these regions is expected. The present coastal topography will control the areal extent of this flooding. In some cases, this relatively rapid rise will result in the construction of a barrier island complex (eg, river-dominated settings); in regions where barrier islands already exist, a landward shift is predicted (eg, wave-dominated settings). Estuaries may develop eg, river dominated) or enlarge (eg, bedrock valley) as pre-existing river valleys are inundated. Most scenarios indicate an overall increase in the high tide zone and therefore concomitant increases in mangrove forest coverage is expected.

The effect of a moderate sealevel rise on mangroves is variable and depends on the type of mangrove forest. Mangroves on autochthonous substrates (eg, certain overwash islands) and in environments with sustained allochtonous inputs (certain fringe and riverine forest types) may be able to track rising sea level and retain their spatial position. Contrasting types (eg, basin forests) may disappear or be changed through a replacement of the dominant species. Dwarf mangrove forests, common to arid, saline flats may experience a stimulation in productive and structural development. On a large spatial scale, however, thee will be an inland retreat of mangroves which will occupy newly-created saline intertidal areas.

INTERANNUAL VARIABILITY IN RECRUITMENT OF CORAL REEF FISHES (GREAT BARRIER REEF)

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Over the last ten years we have examined interannual variation in densities of recruits of coral reef fishes over a hierarchy of spatial scales ranging from metres (fine-scale) to hundreds of kilometres (meso/macro-scale). In this paper we briefly compare the magnitude of this variation over the range of spatial scales and compare temporal variation with spatial patterns (or lack thereof) at each of the spatial scales. We then briefly discuss the likely causes of interannual variation in recruitment and the potential significance of this variation for populations of coral reef fishes.

EPIBENTHIC CRUSTACEANS OF THE NORTHWEST SHELF

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The epibenthic crustacean fauna of the northwest shelf is one of the most diverse faunas of any open continental shelf environment. From 48 samples collected in autumn and spring 1983, at 4 locations, 357 taxa of small mobile epibenthic crustaceans were identified, most to at least generic level. These included 308 species of decapods. The richest families were leucosid crabs (24 species), and portunid and xanthid crabs (both 21 species). The most abundant crustaceans were carid and penaeid shrimps and prawns. A large proportion of the crustaceans are new records for the Australian fauna, and many are new species.

There were no significant differences in species richness (number of species) or total crustacean abundance between any of the samples. A detailed multivariate analysis of the distribution patterns of 232 taxa (23 431 individuals) showed that there were differences in species composition but less than half the common species had differences in abundance that could be related to environmental parameters. The most significant differences in abundances occurred with depth, and sedentary fauna (sponges etc.) were largely unrelated to species abundances in the samples.

TIDAL, SEASONAL AND INTERANNUAL VARIABILITY IN EASTERN AUSTRALIAN COASTAL WETLANDS

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Mangrove swamps and salt flats colonize over 17 000km^2 of the Australian coastal zone. A large fraction of this area is located in Queensland, including the Gulf of Carpentaria. The water circulation and the flushing of these wetlands varies on tidal, seasonal and interannual time scales. The tidal amplitude is generally large (of the order of a few metres) so that the water circulation in the coastal wetlands is strongly tidal. Shallow-water hydrodynamic effects in mangrove swamps enhance the asymmetry between flood and ebb-tidal currents so that, in some cases, a net longitude current oriented downstream can result and help export plant detritus from mangrove swamps. This asymmetry also helps maintain a deep stable tidal channel. Because the surface of the substrate has a slope, the efficiency of this mechanism and the extent of wetlands inundated by the tides is determined by the high-tide elevation. This elevation has a strong diurnal inequality so that the tidal flushing is often quite different on two successive tides on the same day. There is also a large inequality between spring and neap tides. Further, the sea level (hence the flushing of wetlands) is controlled not only by the astronomical tides, but also by mean-sea-level fluctuations. On the Queensland east coast for instance, there are fluctuations of up to 35cm peak to trough at time scales of one week to one month, driven by the geostrophic adjustment of sea level to wind-driven fluctuations of the currents on the continental shelf. On a seasonal time scale, there are also mean-sea-level fluctuations (driven by the wind, the atmospheric pressure and steric variations) of typically 0.2m on the east coast, but up to 0.75m in the Gulf of Carpentaria. As a result, in the Gulf, tidal wetlands are not inundated for about 6 months of the year. The first summer tidal inundation results in a readily measurable and considerable export from the wetlands of salt and nutrients. Surprisingly, the interannual variability of sea level on the east coast is only 0.05m even during an El Niño year, about 1/10 that in the ocean. The interannual variations in wetlands is thus not so much influenced by mean-sea-level fluctuations, but by

fluctuations in runoff and evaporation rates. The freshwater discharge is usually short-lived, though it can be very large. In a dry (El Niño) year, hot dry weather can prevail from May to November. Evaporation and evapo-transpiration during that period can create an inverse estuarine circulation or a salinity maximum zone which effectively isolates the estuary, and its wetlands, from the ocean. In the latter case, dissolved nutrient concentrations increase with time and this nutrient-rich water can be flushed to coastal waters as an "event" during a subsequent river flood.

MEAN CHLOROPHYLL CONCENTRATION AT THE SURFACE OF THE PACIFIC

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A map of the mean chlorophyll concentration at the surface of the tropical Pacific is presented based upon 35 000 measurements obtained since 1978 with the co-operation of crews of merchant ships. The data are mainly distributed along the ocean lanes from Nouméa (New Caledonia) to Japan, North America, Panama and Australia. Highest values are found along the equator, and at latitudes greater than 25°. Lowest values are found in the central gyres. The 1982-83 El Niño was characterized by abnormally low chlorophyll concentrations in the eastern Pacific between 10°N and 10°S, and by abnormally high concentrations in the western Pacific between 0° and 15°N.

BENTHIC ACTIVITIES AND NUTRIENT DYNAMICS IN A TROPICAL REEF FLAT

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A detailed survey of inorganic nutrients in the seagrass bed and coral reef near Port Moresby, Papua New Guinea, showed that benthic activities in the seagrass bed supports net supply of ammonium to the outer environment. Contribution of macro-benthic animals, such as sea urchins, strombid snails, burrowing shrimps, sea cucumbers and others, to the ammonium budget in the seagrass bed was estimated by a combination of laboratory experiments and quantitative assessment of benthic components in the seagrass bed. Ammonium excretion by macro-benthic animals suggests that it contributes significantly to the total ammonium budget in the seagrass bed.

In the coral reef, on the other hand, net production of nitrate was observed and vertical distribution of nitrate and ammonium in the water column and sediments supported the view that the coral debris was the site of active nitrification.

SUMMARY REMARKS ON TOPIC 3: INTERANNUAL VARIABILITY IN MARINE COMMUNITIES BY DR. ALAN LONGHURST

I would first like to thank the organizers for inviting me to participate in the Symposium. It has afforded me the opportunity to not only gain new insights but to put into perspective some of my ideas about the marine ecosystems of the region. In putting together these summary remarks I would further like to thank the Topic Convenor (Dr P Rothlisberg), the chairmen and rapporteurs of the five sessions: Crustacean Resources (Dr D J Staples); Biological Oceanography (Dr T Nemoto); Fish Stocks (Dr J McManus), Coastal Vegetation (Dr J -E Ong) and Coral Reefs (Dr P Isdale).

The papers in our sessions on international variability actually fell into five general categories. There were 15 papers that dealt with ecology and distribution, 11 about time series, 10 on recruitment and 5 that discussed the El Nino-Southern Oscillation (ENSO). They represented the three kinds of study that are necessary to get a feel for variation in time-series: studies of ecological processes and distribution of species; studies of actual time series; and studies of proxy data. All three kinds of study are needed to solve the central issue of how to separate man's influence from natural changes (eg fisheries, pollution versus ecological dynamics, ENSO, climate trends).

Distributions

These papers and some in the 'upwelling' sessions not only confirmed my impressions about the region's complexity, but also suggested sufficient broad-scale similarities to make regional WESTPAC studies relevant and valid. Two examples would be prawn fisheries, which share major species in northern Australia, Thailand and Irian Jaya, and seagrass communities with similar groups of species over the whole region of tropical WESTPAC. There is also some indication that variability occurs in a similar way over wide regions. Examples were given dealing with coral degradation, Acanthaster outbreaks, green turtle nesting and ENSO, and sea-surface chlorophyll.

Processes, including recruitment

These reports described some ecological processes that must be understood if between-year variability is to make sense. A few examples are given below in each of the topic areas.

Crustacea

Species-specific relationships have been established between the juvenile stages of several species of prawns and seagrasses in their nursery ground habitats.

A high intensity of prawn spawning between monsoon seasons is apparent in some species.

In at least one prawn species in Australia (Penaeus merguiensis) juvenile emigration from the nursery grounds is controlled by timing and magnitude of rainfall.

Bopyrid isopod parasites may control population size of some prawn species by affecting reproductive output in segments of the population.

A potential influence of ENSO events on the breeding migration of the tropical rock lobster (Panulirus ornatus) has been put forward.

Fish

An example of coral-reef fish communities being structured by single recruitment pulses ('clouds' of planktonic larvae) has been shown and these pulses may be affecting recruitment on adjacent reefs over an area of kilometres.

Congeneric and sibling species pairs of (Saurida), one fast and one slow growing, with attendant reproductive dynamics are driven differentially by frequency of disturbance.

Potential early reproductive capacity in tropical species was exemplified by a 90d generation time in some coral reef gobies.

Coastal Vegetation

The limited focus and unpredictable nature of cyclone impact on seagrass vegetation was demonstrated by two closely spaced events.

The differences between carbon-flow models developed in the Caribbean and current understanding emerging in tropical mangrove ecosystems of the Westpac region was pointed out.

The renewable nature of mangrove forests was demonstrated by a 30-year forestry cycle in managed forests in Malaysia and the concern that coastal aquaculture (prawn-pond construction) may affect this previously renewable resource was expressed.

Corals

For Acanthaster , course tracking of food/prey cycle and hysteresis was shown.

Genetic similarity of patch-reef species over kilometre scales has been measured, but this does not extend over regional scales.

Tumbled colonies of massive corals have been shown to probably be a normal event in reef-building processes.

Time series studies

Several 'before and after' studies were described. Notably, the 39-47% increase in the number of herbivorous reef fish of Moorea between 1976 and 1983; and, in the southeastern Gulf of Carpentaria, the decrease in fish numbers, in particular Paramonacanthus, between 1963 and 1985. There were several others that were based on genuine time-series; for example: a 19-year time-series of coastal Chinese ctenophores and a predictive relationship with salinity; 24 years of Acanthaster survey data showing a southward migration of outbreaks along the Great Barrier Reef; 34 years of Philippine fishery statistics which showed a 60% decrease in fish biomass; and a 10-year data set from the Great Barrier Reef demonstrated interannual variation in recruitment density of coral reef fish at several spatial scales.

Proxy Data Studies

Two examples of proxy data were given; the first related to annual rings in mangroves. These records, up to 40 years in length, are presently difficult to interpret. The second example was the coring of the massive coastal coral Porites. This has yielded records of annual bands up to 600 years long which may, by linking with other data sets, be extended up to 5 000 years. These records are already being used to trace changes in river discharge (drought, ENSO, coastal currents etc), upwelling through sea-surface temperatures with 0.5°C resolution, chemical concentrations measuring forest and pollution inputs. With additional research I feel there may be additional daily resolution in the rings.

Conclusions

What comes next? Unlike the physical oceanographers who have demonstrated large-scale collaborative studies (currently, 7 ships from 5 countries have been working in the region), WESTPAC biologists are largely on their own. Therefore, groups of scientists must establish regional standards in order to compare results. Comparative process studies of, for example, prawn recruitment, must be facilitated. Existing fishery data sets must be evaluated and compared with environmental data sets. There must be more transfer of techniques and skills from centres of excellence, of which there are some of world class here in Australia, most notably those involved in coral reef ecology/chronology and prawn ecology. These groups must continue to be nourished.

TOPIC 4: HUMAN INFLUENCES ON THE MARINE ENVIRONMENT

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KEYNOTE SPEECH [1] BY DR. ED. GOMEZ: HUMAN INFLUENCES ON THE MARINE ENVIRONMENT

The topic of human influences on the marine environment has been addressed in many fora from different perspectives. It is therefore difficult to add much that is novel to the discussions. However, in the context of WESTPAC, this symposium may be the first occasion where the broader field of marine pollution and environmental degradation resulting from man's activities is addressed. It is recognised that smaller working groups and meetings have been convened to address various aspects of marine pollution.

The marine environment has always been of great significance to the people of the western Pacific. With the rapid population increase in the region, more and more pressure is being brought to bear on the coastal environment and on marine resources of the coastal zone. However, the impacts of human activities are also extending more and more to the open sea, especially with respect to marine transport and deep-sea fishing.

Topic 4 of the WESTPAC Symposium is concerned with 4 sections viz. littoral zones and mariculture, open-shelf environments, coral reefs, and marine management. This paper will attempt to make a survey of these four areas from the viewpoint of a scientist/administrator from a developing country in the region. The treatment will show a certain bias towards the third sub-topic, coral reefs, as this is the field closest to the interests of the author. Likewise, in the treatment of the first sub-topic, the presentation focuses almost entirely on the mangrove ecosystem, due to personal involvement in this area.

Mangroves

Extent and Distribution

Mangroves are natural coastal resources that constitute a significant portion of the world's tropical and subtropical coastlines. They cover an area of approximately 1.68 million km^2 of the earth's surface (Saenger et al) They are well developed in estuaries and the composition varies depending on the exposure and morphology of the coastlines. The most extensive and highly developed mangrove communities are found in the Indo-Pacific area especially along the coast of East Africa, south Asia, southeast Asia and northern Australia including Papua-New Guinea.

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1 For the purposes of this Report, references are not included with the text of this Keynote Speech.

Uses/Functions

The mangrove ecosystem is considered as one of the most productive natural systems on earth. Mangrove systems are complex and diverse and are important to human populations. Because of its high productivity, the system serves a multitude of functions. At the ecosystem level, mangroves contribute to the high productivity of adjacent ecosystems. They act as shoreline stabilisers and as barriers against waves and storms. Mangrove swamps serve as natural habitat for a wide variety of wildlife including some endangered species, thus providing potentials for culture of economically important species. Mangrove areas also provide a place for habitation and recreation. Consequently, they have been cleared and reclaimed to give way for housing, industrial and public developments, including conversion into garbage dumps. Mangroves provide timber and wood products for construction, and for firewood and charcoal production. On the other hand, the non-timber products that can be derived from mangrove forests include tannin, nipa thatch and shingles, honey and, of recent interest, alcohol from the Nypa palm, plus many other mangrove vegetation products.

Mangrove Potentials for Exploitation

The multiple uses of mangrove resources described pose many competing demands for this resource. In the past and at present, the mangrove ecosystem plays an important role in the sustenance of coastal populations. Some of the mangrove resources are becoming increasingly important as a source of income. As a result, there is an increase in the rate of exploitation of mangrove resources.

Overview of Mangrove Exploitation

Being living resources, mangroves are self-maintaining and renewable. Mangroves maintain themselves at no cost and function without subsidies in their natural state. But their renewability is affected if the ecological processes governing the system are disturbed. With the advent of industrialisation in combination with high population increase, the ecological balance of the mangrove system is threatened. Lately, the rate and variety of human-induced stresses have been increasing to a point where a large proportion of the mangrove resources is threatened with destruction.

Mangroves are extremely vulnerable to man stresses caused by human activity. They have been so much exploited that, in many areas, they have been seriously reduced, as proven by recent statistics. Available data show an alarming rate of mangrove denudation due to various uses. In the Indo-Pacific region, about 1.2 million ha of mangrove areas or about 15% of the total mangrove zone is estimated to have been developed for the aquaculture industry (Saenger et al.) In the

Philippines specifically, based on the data from 1967 to 1975, the mangrove forests were estimated to be deforested at a rate of about 25 000 ha annually (Gonzales). This reduction in the mangrove area directly affects the ecological balance of the system. There is therefore a need to assess the different human activities that are destroying the mangrove ecosystem so that recovery mechanisms and effective management can be considered.

Human-induced Stresses

The major human-induced stresses resulting from man's direct and indirect activities to which the mangrove ecosystem is subjected include mining or mineral extraction, forest exploitation, conversion to agriculture and aquaculture, salt-pond construction, construction of channels and harbours, pollution and other coastal developments.

Mineral extraction takes place upstream, downstream and within the mangrove ecosystem such that it often results in complete destruction of the system. One of the major consequences that mining imposes on the mangrove ecosystem is excessive sedimentation resulting from the deposition of waste materials which are transported to and within the mangroves by surface waters. As a result, the system's survival is reduced and it becomes more susceptible to any further stress. In Thailand, there are approximately 37 ha of tin mines in mangroves and in non-mangrove areas (Kongsangchai). Due to the increasing demand for tin, extraction of the mineral is often done without proper planning and management. The wastes that are discharged into the mangrove areas cause severe destruction to the plants and other living marine resources in the area.

The economic importance of mangroves as a source of timber, firewood, charcoal and construction materials has long been recognised. At present, the demands for these products are rapidly rising, such that forest exploitation takes the form of timber production for firewood and charcoal-making and in large-scale exploitation, as in the production of woodchips. Progressively, more and more mangrove areas are exploited both at sustenance and commercial levels. A specific example of large-scale forest exploitation is the case of massive deforestation occurring in southeast Asian forests particularly in Tanakan Island near Kalimantan, Indonesia, where large production of woodchips is being done for export to Japan. This clearfelling woodchip operation is damaging a significant area of the forest because more than 200 000 ha of mangrove forests are currently being exploited and this operation is still rapidly increasing such that massive deforestation is likely to continue (Saenger et al.).

During the last few decades, extensive stretches of mangrove areas have been reclaimed for the purposes of agriculture and aquaculture. Although the mangrove ecosystem has long been considered to be a marginal source for the sustained development of agriculture and aquaculture, still it is being reclaimed due to a pressing need for arable land to satisfy the demands for an ever increasing human population. There are several factors that reduce the suitability of mangrove areas for agricultural and aquacultural development. But these factors are being modified by various means in order to improve the suitability of the mangrove areas to serve the purpose of increasing both agricultural and aquacultural production. In agriculture, large-scale reclamation involves thousands of hectares of mangrove areas. Unfortunately, in many areas, the development of acidic soils on the reclaimed lands renders these areas unsuitable for agriculture. Therefore, the loss is greater than the profit that can be derived. In West Africa, failure in rice production occurred due to the development of acidic sulphate soils as a consequence of resalination by tidal flood waters especially during the drier years. In the Indo-Pacific region, an estimated 1.2 million ha of mangrove forests had been converted to aquaculture ponds by 1977 by impoundment where much of the mangrove flora and fauna were destroyed and reduction in the yield of adjacent coastal fishery occurred (Saenger et al.). With the development of acidic soils, aquaculture ponds are often uneconomic to operate, making pond production an economic disbenefit while at the same time disturbing the ecological balance of the adjacent mangrove areas.

Elimination of large areas of mangroves also occurs in salt-pond construction, since this requires complete removal of mangroves for levelling, diking of land for compaction, and also in the construction of flooding canal systems. Salt production in mangrove areas is widespread along the coasts of Asia and Africa. In India, the construction of a huge chemical-salt industrial complex has adversely affected considerable areas of mangroves (Saenger et al.).

Urbanisation has also affected mangrove areas by reclamation to give way to coastal developments such as large-scale industries, port facilities, roads, airfields, housing complexes and other industrial and public developments of various kinds. In Indonesia, 75% of the major cities with more than 10.000 inhabitants are located in coastal areas. Likewise in Fiji, major urban developments take place along the coastal areas which are usually mangrove-reclaimed lands (Hamilton and Snedaker). Apart from having an appreciable impact on subsistence and commercial fishery resulting in loss of mangrove areas and the vulnerability of these areas to frequent storm damage, urbanisation can also cause pollution within and in the adjacent ecosystems. Reclamation activities are a major problem in developed as

well as in developing countries. In Queensland's Gold Coast, the original extensive mangroves in the Herang River have been replaced by Australia's largest system of man-made waterways (Saenger et al.).

Pollution in mangrove areas is usually localised and occurs near key urban areas and industrial sites. Mangrove areas are potential sites for dumping of garbage and solid wastes as well as industrial waste discharges, agricultural and domestic wastes. Oil spills from shipping activities also contribute to the vast array of harmful pollutants that are discharged into the mangrove ecosystem. These waste materials that are dumped in the mangrove areas are generally toxic and often hazardous to the living resources. Many unforseen problems arising from the disposal of wastes, apart from losing considerable areas of mangroves, have been detected. Generally, the ecological condition is affected which may result in the death of mangroves and, at lower intensities, the productivity may be reduced.

Mangrove destruction is clearly attributed to the direct and indirect activities of man. This is due to the demand for mangrove resources that has been steadily mounting, both for the products and for the land itself. The main reasons for the destruction of mangrove ecosystems lie in the fact that the users exceed the sustainable yield limit in the harvests of direct products, and conversion activities irreversibly alter the condition of the intertidal zone. At present, the condition of many mangrove areas is rapidly deteriorating due to overexploitation and poor management. An urgent need for efficient management and conservation is apparent so that mangroves can be utilised and managed for the continued benefit of man.

Besides mangroves there are other ecosystems in the littoral zone that are subjected to human influences. Some of these will be dealt with by other speakers in the course of the Symposium.

The concern for mariculture as it relates to pollution is usually one-sided. There is much concern for the impact of pollution on mariculture but hardly any studies have been conducted on the pollution caused by mariculture activities. Perhaps it is time to consider this aspect. The effect of aquaculture on habitat destruction has been referred to in the preceding paragraphs.

Open Shelf Environments

Like the mangroves and coral reefs, the open-shelf environment is not spared from degradation as a result of man's activities. It is directly degraded through overexploitation of its economically important resources such as fishes and other marine animals which account for an average of 17% of

the animal protein in the human diet (Kullenberg): Fishing is the major economic activity of man on the open shelf environment. In the Philippines, an estimated 13% of the population are dependent on fishing in various degrees for subsistence (Silvestre et al.). This significant portion of the population that is involved in fishing results from the increasing demands for fish production.

Trawls are the main type of fishing gears that are usually used in commercial fisheries. Although fishing is often confined to shallow waters, fishing operations are also carried out in deeper areas. Since pelagic species normally come close to the shallow areas when they feed and spawn, fishing is generally concentrated here, often near coral reefs. Therefore, the level of depletion of fish resources in these nearshore areas is expected to be higher than in areas where no heavy fishing occurs. In Malaysia, overfishing near the reefs due to a rapid increase in the number of trawlers has been observed (Lulofs). In Thailand, on the other hand, the introduction of crawl fishing in 1961 caused a decrease in the catch rates of demersal fish by nearly 80% in a span of 12 years (Ritragsa). This fishing method can practically catch any fish that comes across its path including juveniles when very fine mesh nets are used, thus destroying the potential fish stocks for the succeeding years.

Fishing activities are unevenly distributed geographically. For example, most trawling grounds in the Philippines are located in the Central Visayas region (Mines). resulting in a reduction in the population of economically important fishes in these accessible and frequently fished areas. Recent reports show that the rate of exploitation has exceeded the maximum sustainable yield of the fishery resources. There are complaints of declining catch rates, decreasing size of target species and low economic returns from areas receiving the highest fishing pressure. These consequences can be attributed to overexploitation along with unregulated fishing practices and gathering of fishery products in addition to the destruction of mangroves and coral reefs (NEPC). Protective management is therefore important to maintain open shelf productivity.

Coral Reefs

Extent and Distribution

Recognised as one of the most productive and ecologically diverse of all marine systems, coral reefs are valuable resources that cover about 0.1% of the earth's surface (Salvat). Along with mangroves, coral reefs are a distinctive reature of coastal areas in tropical countries where they are an important source of subsistence, coastal protection and economic development on which man depends.

Uses/Functions

Being a rich and complex system, it is evident that coral reefs have a variety of uses and functions that directly benefit man and the other ecosystems that they interact with. These functions include food production, coastline protection, sources of non-food products, aesthetic and related economic benefits, scientific and educational considerations.

The coral reefs abound with hundreds of species of fishes, invertebrates and other non-protein products that are potentially valuable as food sources for the rapidly increasing human population. Reef fishes are the major exploited food resource and they constitute a significant portion of the recorded fish catch in some developing countries (Smith). Other food sources such as turtles, invertebrates and non-protein products are also utilised by coastal people.

Coral reefs are considered as the largest biological structures on earth. They form natural and self-repairing breakwaters that protect the land from erosion, wave action, damage caused by storms and other destructive forces of the sea.

The use of corals as building materials is becoming widespread. Dead coral rocks as well as living colonies are mined for lime production, for building and road construction, for building piers, for calcium carbide production, and for cement manufacture. Corals also serve as sources of sand that are used as concrete aggregate and as fill, in building and recla. nation purposes. Traditional mining and shaping of coral blocks have also expanded in recent years wherein these blocks are shaped into distinctive tiles and facing materials (veneer) that are used in private homes and public establishments.

Reef communities provide a natural store of organisms containing compounds that are valuable as drugs that have wide application in medicine and are also used as tools for pharmacological research. The pharmaceutical products derived from coral reefs range from anti-cancer substances to contraceptive chemicals. Some of these products are also used as models for the manufacture of synthetic pharmaceuticals.

The use of corals, shells and polished turtle shells as ornaments for decorative purposes is extensive. Most of these items are being collected as souvenirs and are also used as marine aquarium decorations. They support large industries by being sold as decorative pieces aside from being used for jewellery manufacture in various parts of the world (Wells).

In 1974, the Philippines exported 7 224 metric tonnes of stony corals and 4 000 metric tonnes of ornamental shells (Mcmanus). On the other hand, the precious coral market worldwide was estimated at US$ 50 million in 1981. (Salm). The marine fish aquarium market is also rapidly expanding where fishes and some invertebrate species are of great value to the salt-water aquarist. In Sri Lanka where 50 000 people are involved in this industry, the export of aquarium fishes earns about US$ 1.1 million per annum (Salm).

Coral reef communities also serve as sites for recreation. They are the focus of tropical skin and scuba diving and an important tourist revenue due to their aesthetic appeal, biological richness and relative accessibility making them popular recreation areas for tourists.

Reefs serve as a natural scientific laboratory for the study of basic biological processes by students and professionals alike. More and more scientific researches on the ecology of coral reefs are increasing as well as field monitoring which is necessary for management.

Overview of Reef Degradation

Man is utilizing the reef's resources extensively, depending on his needs. His close affinity to the coral reefs is associated with his dependence on the reefs for its resources. As populations increase, more space, more food and raw materials as well as recreational areas are required. People tend to concentrate along the coastal areas and interact intensively with the sea.

In southeast Asia , the population was estimated as 247 380 000 as of 1977. The result is that large areas of coral reefs have been seriously damaged and reduced. As of 1982, out of 632 reef stations surveyed in the Philippines for relative coral cover, 5.5% were found to be in excellent condition, 24% were rated good, 38.3% fell under the fair category and 32.1% were rated poor. These figures indicate the extent of damage on the reefs as a result of various human-induced stresses. Such stresses affect the reef communities either directly or indirectly. Direct effects are caused by fishing and other exploitative activities of man while the indirect effects act through the impacts of pollutants usually occurring near heavily populated areas.

Human-induced Stresses and Effects

Fishing is one of the economic activities of man where fish caught from reefs constitute the major sources of protein for many island and coastal people. In the Philippines, a minimum of 10% of the country's fishery is reef-associated (Murdy and Ferraris). By employing traditional fishing methods, the renewal of the exploited fish resource is ensured. But

the rapid increase in human population leads to increased demand for food. In order to meet these demands, new fishing methods are developed which are often destructive to the reefs. Destructive methods commonly used are blasting, "muro-ami," trawling near reefs, use of cyanide, use of fine-mesh nets and spear fishing (traditional and scuba). Reduction in fish catches is directly correlated to reduction in coral cover, substrate and diversity.

Considerable tracts of corals have been destroyed by trawling, while depletion in many fish stocks has been observed due to the utilization of fine-mesh nets and traps that include many juvenile fishes as side catches. Although illegal, blasting is one of the most destructive fishing techniques that destroys the reef habitat and its inhabitants. Damaged areas are slow to recover, if they recover at all. "Muro-ami" and "kayakas" fishing techniques involve the banging of the bottom substrate with poles and rocks to drive fish into the set nets. As a consequence, corals are broken and the bottom habitat is disturbed. Likewise, the use of fish traps breaks coral colonies. Fishing operations that involve the use of small and medium-sized boats also destroy coral colonies when the anchors which are specifically deigned to latch onto corals are set down or retrieved. Besides these destructive fishing methods, aquarium fish collection, which is usually directed towards certain popular species, upsets the ecological balance of reefs due to their overexploitation. This selective method often employs the use of fish toxicants such as cyanide which are detrimental to the health of the corals and other associated reef organisms.

One of the most important causes of reef degradation is sedimentation resulting from improper agricultural and forestry practices, uncontrolled exploitation of mangroves, construction activities, oil drilling and dumping of mine tailings and effluents. Although sediments are added to the reef by natural means, man's activities in coastal areas are accelerating this process (Johannes). These activities damage reefs by increasing the turbidity of water, resulting in coral gowth retardation; in extreme cases, death of the corals.

Another form of human activity that leads to siltation and sedimentation is terrestial mining where heavy concentrations of mine tailings are discharged into the reefs. In 1982, the Philippine National Environmental Protection Council reported that 371 644 metric tonnes of mine wastes and 190 896 metric tonnes of mine tailings were dumped daily by 110 mining companies in the Philippines (Lastimosa).

Dredging or offshore mining causes sedimentation destroying the benthic flora and fauna of the reef by releasing fine sand particles which are dangerous to reef life.

Increasing demands for energy have resulted in the exposure of coral reefs to the by-products of oil exploration and production. Drilling muds reduce the survival of the coral colonies, thus retarding reef growth. Toxic chemicals present in the lubricants used during the drilling process have harmful effects on coral reefs.

The removal of corals for use as construction materials for road construction, dikes for fish ponds and even in house construction as well as for lime production destroys coral reefs because of the resultant sedimentation due to increased soil erosion. Destruction of several miles of reefs as a result of ill-planned and ill-managed dredging has been observed in Malaysia, Fiji and other countries (Johannes).

Tourism has its own impacts on reefs. Recreation activities such as scuba and skin diving, snorkelling, pleasure boating, shell and coral collecting undertaken by tourists are damaging reefs. Impacts include reef trampling by humans, breakage by anchors that are used in boating, depletion in the population of shells and corals that are collected, and habitat disturbance Recreational activities also tend to destroy the aesthetic values of coral reefs through littering and pollution from the facilities provided for tourists.

Some reef fishes and invertebrates are among the aquarium favorites that are utilized for the growing aquarium fish industry. Export of these organisms is becoming an important industry generating millions of dollars annually. It provides additional income to coastal fishermen engaged in the collection of aquarium fishes. In effect, the growth of this industry depletes the fish populations in accessible islands, and despite the trade value, methods used to catch fishes are often destructive to the coral habitat. The use of sodium cyanide as an anaesthetizing agent in fish capture also kills part of the coral colonies and corals are frequently smashed when the anaesthetized fishes that are lodged among the branches are removed. Considerable damage is being done as this activity continues. The export trade of corals and shells is also becoming widespread. Truckloads of these products find their way daily to stores and souvenir shops inspite of the ban on their gathering and exportation. Reef communities yield limited quantities of some species of aquarium fishes, shells and corals, and if these products are overexploited, the ecological of the system is disturbed. The demands for development have led to increasing industrial activities and increasing use of agricultural chemicals. Man also alters the chemical environment of the reefs by discharging pesticide spills and residues from intensive agricultural practices causing chronic effects on the reef environment (Dahl). Industrial developments also cause

destruction of the reefs through discharge of factory effluents. As demands for energy increase, there is also a corresponding increase in pollution from power plants. Discharges of heated water into the reef areas has been proven to be disastous, causing coral mortality. The same happens when the salinity of the surrounding water is changed due to discharges of over-salted water from desalinization plants.

Urban developments on the other hand, generate another type of pollutant in the form of sewage. Sewage causes reef degradation together with hydrocarbon pollution that arises from oil refineries, drilling platforms and in harbours where spillages occur. Reduction in the number of species, colony, and bottom cover can be expected. In general, the equilibrium of the reef community is disturbed. Since most pollutants arise near populated areas and where extensive commercial activities occur, reefs bordering these areas are mostly destroyed. In most cases, the cause of reef degradation is a combination of chemical and physical distrubances.

Marine Management

Mangroves

Sound mangement of mangrove resources is usually equated with high-level production on a sustained-yield basis. One of the best examples of a sustained-yield use of mangrove forests is the Matang Mangrove Forest Reserve in Malaysia, where the production of charcoal, pole and firewood is on a sustained-yield basis. The existence of sustained-yield silvicultural management makes this mangrove forest one of the best managed forest reserves (FAO). In Florida on the other hand, the best management practice that is being implemented is preservation and in line with the concept is the inclusion of the adjacent ecosystem for preservation (Odum et al.).

Understanding the complexity of the mangrove ecosystem, including natural forces and human influences that alter the system, is essential for the conservation and wise utilization of this resource. Lack of proper management in the past and at present has arisen partly from man's misconception that mangroves are nothing but wastelands, such that he is unaware of the damaging consequences that may occur, and partly from overexploitation of the mangrove resources. In recognition of the potential value of mangroves, there is a need to devise adequate measures to optimize the conservation of this resource while integrating the socio-economic and ecological values as well.

Open Shelf Environment

The aim of protective management for the open-shelf environment is to ensure the conservation of the aquatic resources while maintaining fish production to a considerable

degree. This may be in the form of regulation of fishing so that the fish resources are harvested rationally. Another approach is to ban commercial fishing operations and similar exploitative activities in areas where overfishing occurs until their productivity has recovered. In extreme cases, total absence of fishing can be an effective long-term management. The significance of the open-shelf environment to the fishing industry can be enhanced by balancing the exploitation of fish resources with an efficient management.

Coral Reefs

Due to countless reasons whether caused by ignorance or lack of appreciation of the importance and value of coral reefs, human influences threaten to destroy these valuable resources. In the Philippines and Indonesia, most of the traditional methods of utilization which have no severe impact on the reef ecosystem have been rejected leaving uncoordinated approaches toward the use of reef resources (Soegiarto and Polunin). The increasing human population and economic pressure have brought about social change which has led to the abandonment of the traditional methods. Excessive harvesting of reef resources, widespread pollution of different kinds, and development of tourism have resulted in deterioration of many reefs. Unfortunately, coral reefs have been taken for granted and are not given the attention they deserve as an ecosystem. They are continuously being exploited, damaged and destroyed, such that a sound management of this resource is needed.

The main objective of reef management is generally to maintain and create proper balance between uses, protection and conservation of the reef resources to ensure their continued benefits while maintaining their basic environmental quality, in order to sustain the long-term economic and cultural needs of the people. In implementing sound management, a thorough understanding of the complexity of the reefs, their present status, how they are changing and how humans interact with these complex ecosystems is necessary. Reef management may range from functional, where resource use occurs, to preservational where entry is prohibited.

The establishment of marine reserves and parks has been done for the protection and management of reefs. These protected areas constitute a defined space where specific purposes of use or entry are prescribed for any of the types of reserves that are established. These protected reef areas are designed to meet the objectives of nature conservation and human utilization. Aside from establishment of areas that are protected from any human activity, other approaches such as periodic closure, yield and equipment constraints and impact limitations can serve as alternatives to further ensure the conservation of the reef resources (Kenchington). Since no single solution to the management of coral reef problems has been developed, strict compliance to the current conservation measures can help, unti a more effective and reasonable mehtod of mangement can be achieved where social, political, cultural and economic aspects are integrated.

SHORT-TERM GEOCHEMICAL PROCESSES AND POLLUTION OF ESTUARIES

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Human impacts result mainly in disruption of geochemical processes, the latter regulating the migration of substances in the river - sea system.

Investigations conducted in the estuaries of the Pacific marginal seas (South China, Japan and Okhotsk Seas) enabled us to evaluate space - time variability of dynamic physical, chemical and biological processes with periods from several hours to one year.

The data obtained were used to create mathematical models describing variability of hydrochemical parameters and behaviour of contaminants.

AN EVALUATION OF THE EFFECTIVENESS OF ARTIFICIAL BARRIERS FOR SMALL-SCALE CROWN-OF-THORNS STARFISH MANAGEMENT

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Several workers have recently concluded that manual removal or destruction programmes for controlling Acanthaster planci populations have been largely ineffective (Yamaguchi, 1976; Moran, in press; Zann, personal communication). The need to preserve small areas of live coral for tourism and scientific purposes prompted investigations into the use of fences as artificial barriers to exclude starfish, since it has been shown that migration of starfish into control areas contributes significantly to the poor success of these controls (Kettle, unpublished report to GBRMPA). Trials of 13 enclosures constructed from 10 commercially available fencing and netting materials, and utilizing several different designs, were conducted recently in the lagoonal area of the John Brewer Reef, Townsville. Starfish placed within these enclosures were recorded. Several enclosures demonstrated high retention rates of starfish. Rigid steelmesh enclosures (mesh sizes 7.5cm x 5cm and 1cm x 1cm), 1 metre in height and having 60cm down-curved overhangs at the top were highly efficient in retaining starfish. By contrast, flexible fishing net materials, buoyed at the top, weighted onto the substrate and having no overhang, had high escape rates of starfish. Fouling and degradation rates of the various materials are being monitored. These results suggest that artificial barriers are useful for limiting starfish movement. Barriers used in conjunction with manual removal may be superior to the current method of repeated manual clearing.

EFFECT OF TIN DREDGING ON THE CORAL REEFS OF PHUKET ISLAND, THAILAND

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The effect of tin dredging on the coral reefs of the west coast of Phuket Island was monitored from November 1982 to May 1986. The study was conducted by photographing permanent transect lines every 6 months at Bang Tao Bay and Kamala Bay. The time interval coincided with the periods of northeast monsoon (November-April) and southwest monsoon (May-October). Dredging activity was carried out only during Northeast Monsoon. It is found that the condition of the reef along the northern side of Bang Tao Bay, which has been dredged constantly for the last 15 years, has improved significantly in comparison to the condition during the survey in 1981, whereas the reef along the southern part has not changed since 1981 in terms of coral cover. In Kamala Bay, where dredging activity was conducted during the dredging seasons of 1983 and 1984, it is found that corals on the lower part of reef slope were smothered by sediment. The damage on the upper part was rather minimal. After dredging activity ended, the reef in the bay showed some sign of recovery. It is observed that the chances of damage by sediment and the ability to recover depend upon the distance of tin dredges from the reefs and the movement of water within the area which brings the sediment to the reefs as well as remove the sediment during the southwest monsoon season.

THE INTERDEPENDENCE OF BIOLOGICAL AND ECONOMIC OBJECTIVES IN FISHERIES MANAGEMENT

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The regulation of Australian fisheries can be justified on the grounds of improving, or maintaining, a given level of social welfare. In this context, social welfare is expressed in terms of economic, biological and social objectives. All three objectives are important when deliberating on management strategies for Australian fisheries.

From the economic theory of marine-resource exploitation it can be shown that an overlap exists between biological, economic and social objectives of marine-resource management. The underlying relationship between these three objectives is the level of effort expended in the fishery. Whilst the regulation of effort can be used to achieve biological objectives, economic analyses are required to ascertain whether or not the regulation achieves the other objectives and to what extent. By the use of a simple, static model of economic behaviour in the Northern Prawn fishery the impact of biologically and economically based regulations are examined.

MANAGEMENT OF CORAL REEF ECOSYSTEMS - THE SRI LANKAN EXPERIENCE

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The gap between the ideal and the practical is well illustrated in the case of the declaration of Sri Lanka's one and only Marine Sanctuary - the Hikkaduwa Marine Sanctuary - under the Fauna and Flora Protection Act in 1979 and the non-implementation up to now of Sanctuary Regulations. Among the reasons for the non-implementation of the Sanctuary Regulations are:

(1) Declaration of a Sanctuary in a popular tourist area dependent on the coral reefs to attract tourists.

(2) The heart of the Sanctuary being a traditional harbour for fishing craft.

(3) The authorities not being geared to manage the declared Marine Sanctuary due to lack of equipment and personnel trained in the management of such areas.

Decision-makers of many developing countries face a similar plight where conscience calls for controls on the exploitation of coral reefs, while socio-economic conditions demand even greater exploitation and create problems of enforcing controls. The following are discussed:

(1) the reasons for the degradation of coral-reef ecosystems of Sri Lanka;

(2) the steps being taken to stem the degradation of coral reefs through the establishment of multiple-use zoned marine parks, initially in vulnerable areas; and

(3) the need to give priority to the application of political/socio-economic criteria in addition to scientific criteria in site selection for marine parks and protected areas.

DISTURBANCE IN CORAL COMMUNITIES - ASSESSMENT AND PREDICTION

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Sudden changes in the composition of the predominant biota of a location may be indicative of degradation or of normal variability. Such shifts in predominance have been associated with recent disturbances on the central Great Barrier Reef, namely, outbreaks of the crown-of-thorns starfish, a mass bleaching of corals (the expulsion of symbiotic zooxanthellae, resulting in the death of corals) and a severe tropical cyclone. In each case, the disturbance has resulted in a shift from coral to algal dominance.

This paper summarizes assessment of damage to coral communities and initial attempts at predictive modelling of a disturbed coral population. There were marked differences in the patterns of coral mortality caused by the three disturbances. Coral mortality attributable to starfish was more uniform with respect to species, depth and aspect than that attributed to either bleaching or the cyclone. Mortality attributable to bleaching was selective among coral species, declined with depth and was unrelated to aspect. Mortality attributable to the cyclone was difficult to quantify, since much of the coral was already killed by the starfish. However, there was a clear effect of aspect and depth on the amount of dislodgement and breakage of live and dead coral. The model predicted that one coral population could retain its abundance and size structure in the long term, despite moderate disturbance every 1-3 decades. The predictions were more sensitive to parameter values for growth rate and survivorship than regularity in recruitment.

BAIT COLLECTION AND THE CUNJEVOI (PYURA STOLONIFERA)

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Australia's mainly coastal population spends considerable recreation time on seashores. A main activity is fishing and the associated collection of bait. Rock fisherman in New South Wales commonly use the cunjevoi as a main bait for the drummer and as a supplementary bait for other fish. Pyura is a large solitary ascidian that occupies much space low on the shore and filters intertidal water for food. Preliminary data will be presented from a study of the patterns of bait collection on several shores and the consequence of these for the dynamics and distribution of the ascidian. In particular, the sorts of information yielded by the sampling strategy and a pilot experiment simulating bait harvesting will be related to the sorts of management questions pertinent to this resource system. General aspects of management-related research on ecosystems will be addressed.

MANAGEMENT OF MARINE ENVIRONMENTS - A MICRONESIAN PERSPECTIVE

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Just as the study of microbiology reveals the cellular basis of life, so a Micronesian perspective on use of marine resources is instructive on the basis of marine management in a microcosm. The microcosm of this paper is a small group of islands in western Micronesia.

Marine management in Yap involved amelioration of the impact of runoff from the land as the result of an adaptive agricultural system. In the marine area per se, appropriate methods and timming of fishing effort were based on a developed body of knowledge of the marine environment. Some 38 named fishing methods have thus far been documented in an ongoing effort. Nine of these methods, involving the use of stone fish weirs, hand nets, large nets, leaf sweeps, poison and a local version of FAD are described in order to illustrate Yapese low energy input, "nature intensive" marine technology.

The basic principles of Yapese use of marine resources involved sharing and apportionment of marine resources. These principles are illustrated with reference to the nine fishing methods. The emphasis on sharing of but apportioned resources among specific groups appears to be a Micronesian mechanism which avoids resource depletion. The current availability of new fossil fuel and capital intensive technologies and orientation towards a dollar economy supports a trend toward fishing for individual profit which is less sustainable and poses greater potential for resource depletion. A neotraditional system of marine management is needed but scientific expertise has not yet addressed this problem within a Micronesian context. Efforts and support are needed for en situ science committed and adapted to the welfare of micro-nesias - small islands - everywhere.

CIGUATERA - ITS ASSOCIATION WITH HUMAN ACTIVITIES ON CORAL REEFS

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Human activities have been strongly implicated in the occurrence of ciguatoxic fishes on coral reefs throughout the South Pacific. Shipwrecks, harbour works, dredging and vessels at anchor have been found to precede ciguatera outbreaks. This link is often explained by the proliferation of the presumed elaborator of ciguatoxin, the dinoflagellate, Gamburdiscus toxicus, on macroalgae colonizing new surfaces. However, studies along the Queensland coast have not found a clear relationship between macroalgae, G. toxicus or reef disturbance.

Epidemiological data can be used to demonstrate that there is a close connection between the occurrence of toxic fish and factors such as distance of coral reefs from shore and from major centres of population. Both of these factors relate to the popularity of certain areas to line fishermen. These fishermen commonly clean their catch at sea. It is hypothesized that the disposal of the viscera of reef fishes amplifies the natural accumulation of ciguatoxin in the food chain increasing the risk of human intoxication.

DEVELOPMENT OF A COST-EFFECTIVE TECHNIQUE FOR ASSESSING DEMERSAL CORAL REEF FISH STOCKS IN THE TROPICAL WEST PACIFIC

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Thirteen per cent of the world's estimated 600,000 square kilometres of shallow coral reefs occur in the southwest Pacific region. The number of people who rely on reef-fish populations for food and recreation has increased dramatically over the last two decades to the point that some reef fish stocks are showing signs of significant depletion.

Results from our surveys on the Great Barrier Reef demonstrate that the abundance of a 'keystone' predator species is closely related to distance from major human population centres. Removal of this predator through fishing has the secondary effect of changing the species composition of the demersal fish community.

While the secondary changes in community structure are apparently unpredictable, it is possible to calculate a measure of community flux that can be used for the management of 'keystone' predator target species.

HUMAN INFLUENCES ON THE MARINE ENVIRONMENT

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The WESTPAC region represents one of the most populous regions of the world, with the majority of the membership dominated by developing countries. Nowhere else is the dependence on living resources by coastal populations so critical. Hence, the pressures on the marine environment from fishing, in addition to pressures from coastal development and from other uses of non-living resources, are at a critical level.

The impacts of human activities on mangrove resources may be used as one of the most striking examples of man's influence on the nearshore environment. Present studies on stresses and on management efforts present a good example. Man's activities in the open-shelf areas range from extraction of resources to their use for navigation and the disposal of wastes, but the attention now focussed on coral reefs may serve best to highlight the conflicts between resource users and resource managers. The mitigation of stresses is perhaps the major task facing managers concerned with the marine environment.

THE OPEN SHELF ENVIRONMENT: REVIEW OF HUMAN INFLUENCES

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For present purposes, the marine environment has been classified into three physical zones - the Littoral Zone, the Open-Shelf Environment and Coral Reef. Since the boundaries are arbitrary, there will inevitably be some overlap, but for this review the subject matter will be related to the area between low water of ordinary spring tides and the edge of the continental shelf; i.e., to a depth varying to 200 metres.

Human influences may have a dual role in affecting the marine environment, firstly in a causative manner and secondly in providing a remedy, in which case the emphasis moves into marine management.

While the effects of human influence may sometimes, except to the purist, be considered to be beneficial, e.g., those associated with mariculture or habitat "improvement" for stock enhancement purposes, for the most part the connotation has been one of detriment, encompassing the consequences of exploitation of living resources in excess of sustainable levels, habitat modification from mechanical and physical interference and pollution from substances resulting from man's activities.

Habitat modification may result directly from harbour and marine developments, dredging, blasting, mining, aggregate extraction and dumping, seabed pipelines and cables, and effluent discharges. In a category of special significance to the Open Shelf are the consequences of fishing practices which may directly or indirectly modify the environment, together with localized problems from abandoned fishing gear. Faunal and floral assemblages may become modified by fishing and aquacultural activities, and non-indigenous organisms may be deliberately or accidentally introduced or translocated.

Polluting influences include chemicals from effluents, dumping and other human activities, nutrients, oils and dispersants, thermal pollution, radioactive wastes and so on.

Such actual and potential sources of human influence and their consequences will be reviewed, in the expectation that contributed papers will provide more detailed examples and case histories of the more important topics included.

'PHYSIOGRAPHIC UNIT' OF THE REGIONAL ECOSYSTEM AS THE ACTUAL SITE OF HUMAN INFLUENCE, AND THE SEASONAL VARIABILITY OF THE ECOLOGICAL PROCESS

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It is important to recognize the shape and areal limits of the "physiographic unit" of a coastal ecosystem for the study of a given regional ecosystem and for the purposes of marine management. Such a unit is composed of a recess of coast line between two headlands; e.g., semi-enclosed and open bays. All ecological processes, including human effects, occur within the confines of this single unit more or less independently of neighbouring units.

Ecological processes in a given locality within the physiographic unit are strongly influenced by the "location factor" which is thought to be a combination of major topographical features of the bay, local bottom topography, movement of sea water, inflow of land water, etc. Ecological processes show a prominent seasonality, and even in low latitudes, where the temperature shows only little change, the amount of precipitation and the direction and intensity of wind change greatly in different monsoon seasons. In Tokyo Bay, there are two gyres of sea water within the bay. In the season of the summer stratification, the red tide tends to develop in the central areas of one of the gyres in the inner half of the bay, and in the bottom layer of this area, the oxygen deficiency caused by an excess of organic matter makes the bottom almost azoic. This azoic area spreads from this location over the whole bay due to pollution, and shrinks to the original area when human impact is lessened. In Jakarta Bay, the water is rather stagnant in the season of the eastern monsoon, and polluted water of the bayhead flows out along a submarine ridge with wall-like topography. In the western monsoon season, a drop of salinity can be found only in the southeastern corner of the bay, where quantities of land water flow in, and the rough seas cause coastal erosion.

THE MANAGEMENT VALUE OF TRADITIONAL FISHING RIGHTS SYSTEMS IN NORTHERN AUSTRALIA, WITH EMPHASIS ON TORRES STRAIT

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The exclusive right to obtain sea food from adjacent coastal waters has been held traditionally by various Aboriginal groups and Torres Strait Islanders in northern Australia. Some researchers who have worked in other parts of the world regard such rights as an aid to contemporary fishery management. Others hold them to be an impediment. These differing positions reflect the varied nature of the different traditional fishing rights systems studied, and neither position constitutes a valid generalization. Each traditional fishing rights system must be assessed individually in this regard.

Three basic questions should be answered to make this assessment: (1) Does the system contribute, or have the potential to contribute, to the conservation of sea food stocks? (2) Is the system compatible with government fisheries policy? (3) How strongly is the system held today?

The Torres Strait Islanders traditionally exercised two complementary systems of fishing rights. According to the foregoing criteria, one system plays a useful, if minor, role in fisheries management, while the other does not. Home-reef fishing rights (fishing rights in the shallow waters surrounding inhabited islands) function to allocate marine resources in the vicinity of villages, and to conserve local populations of non-migratory species. Extended fishing rights (fishing rights in more distant waters within the Strait) are no longer observed. Their re-establishment, currently being attempted by one Islander community, would conflict with measures set up to allocate and manage fisheries under the provisions of the Torres Strait Treaty. Traditional fishing rights systems of Aboriginal groups in Northern Australia should be similarly evaluated. Moral and legal questions must also be addressed, however, not just the utilitarian issues discussed here.

EFFECT OF SEWAGE ON THE ALGAL FLORA OF THE LITTORAL ZONE

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Drainage from urban wastes, including sewage, is frequently poured into the ocean with minimal pre-treatment. Industrial debris, heavy metals and pesticides are obviously damaging to the organisms living near such outlets. The effect of sewage is less known. Studies have shown that, with limited amounts of sewage, many species decrease or disappear, a smaller number thrive. With increased amounts of sewage even the more tolerant species can also disappear.

My studies, over several years, of the effect of new sewage outlets at an oceanic and an estuarine location, have demonstrated this effect in zones around an outlet and have shown that the volume and pre-treatment of sewage appear to control the degree of damage caused.

MANAGEMENT OF MARINE ENVIRONMENTS

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The major aspect of the natural environment that can be managed is the impact of human activity. Management of marine environments has generally developed from management of single activities such as fishing or shipping. In many parts of the world it has grown on the basis of managing the commons which until comparatively recently were considered virtually inexhaustible. Sustainable management of marine resources is becoming increasingly important to the welfare of human societies.

A key to developing successful management strategies for marine environments lies in understanding the extent and impact of human activities. A key to implementing such strategies lies in generating appreciation of impacts and the long-term economic importance to resource users and governments of the maintenance of marine environments.

A range of management options is discussed with the assumptions and information needs that underlie them or flow from their adoption.

MONITORING THE STATE OF SEA WATER WITH THE USE OF MUSSELS FROM FOULINGS OF NAVIGATION BUOYS IN THE FAR-EASTERN SEAS OF THE USSR

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In order to obtain comparable results in monitoring of the chemical composition of sea water with indicator organisms, selection of such organisms, for example molluscs, must be standardized with reference to age, sex, physiological state, depth of habitat, hydrological situation etc. Use of mussels from fouling communities inhabiting hydrographical buoys meets the requirements of such standardization. Since 1981, we have been studying the content of heavy metals in the mussel Mytilus edulis growing on hydrographical buoys set annually for the navigation period along the shores of the far-eastern seas. Collection of mussel yearlings in autumn at removal of the buoys provides a uniform sampling representative of a vast distance along the shores.

A comparison of the content of zinc and cadmium in mussels from buoy foulings along the northwestern shores of the Sea of Japan has shown that the hydrochemical situation in the region remains practically invariable: the mean concentrations of zinc and cadmium in soft tissues of mussels were, in December 1981, in the range of 98-118 and 1.7-2.0 ug/g dry matter and, in December 1984, 95-108 and 1.6-1.8 ug/g dry matter, respectively.

MANAGEMENT OF MIGRATORY ISLAND BIRDS - AN INTERNATIONAL CONCERN

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Recent surveys and banding studies of Great Barrier Reef sea birds indicate that some species range widely through the SW Pacific Ocean. Similarly the Torresian Imperial Pigeon migrates annually between northern Australia and PNG. These species may cross a number of political boundaries in their movements and are subjected to a variety of pressures from human interference. The Great Barrier Reef and Coral Sea islands may contain the major breeding stocks of several species of birds.

Increasing visitor pressure may in future degrade some Great Barrier Reef colonies. Responsibility for management of this resource must increasingly involve the user countries. A co-operative approach to determine region-wide status and pressures and to implement management procedures is called for.

RESPONSES OF CORAL REEFS TO INCREASED SEDIMENTATION AND DOMESTIC SEWAGE

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Studies of the responses of coral reefs to human influences strongly indicate that the imposed stresses are frequently chronic rather than critical. Their effects may be tolerated over extended time. Actual "destruction" of such reefs is still commonly caused by natural phenomena such as storms, fresh-water runoff or perhaps even crown-of-thorns starfish infestation. The continuing chronic stress then makes it unlikely that natural recovery will occur. The principal case history examined is that of Kaneohe Bay, Hawaii, where sewage (prior to 1978) and sediment runoff imposed long-term chronic stress. Considerable progressive coral reef community modification occurred over very extended time. Sewage caused the community to shift towards heterotrophy accompanied by substrate burial. However, most dramatic shifts seem to have occurred episodically as the result of major runoff events.

SEA TURTLES: A SHARED INTERNATIONAL RESOURCE

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Six species of sea turtles occur widely in coral reef and inshore coastal feeding grounds of the eastern Indian Ocean and western Pacific Ocean regions. There are few major breeding sites for each species within the region. Sea turtles can make long migrations, in excess of 2500 km, from a feeding ground to a traditional nesting beach. Turtles from the same breeding area will be drawn from many widely scattered feeding grounds. For many nations of the region, sea turtles are important to the coastal communities as a food source (meat, eggs) or for trading. Major declines in populations as a result of over harvest have occurred in many countries. In addition, there appears to be an increasing harvest pressure on remaining sea turtles. During its migration, a turtle may be available for harvesting by hunters from several nations. Also, when all feeding grounds for the turtles breeding at the one locality are considered, it becomes obvious that many nations are harvesting from the one stock of turtles.

Consider, for example, the green turtles harvested in eastern Indonesia for sale in the Bali markets. Tag recoveries show that these turtles could originate from rookeries as far east as Raine Island in the Great Barrier Reef or as far west as the Turtle Islands of Sabah and southern Philippines. An over harvest of the turtles at this feeding ground can affect breeding at these distant rookeries. Similarly, an over harvest of eggs at the Philippine turtle islands will reduce turtle numbers in the Indonesian feeding ground. An over harvest by PNG and Australian indigenous fishermen of migrating turtles passing through Torres Strait on route to Raine Island could also affect turtle numbers in Indonesia. Sea turtles must be recognised as a shared international resource and managed accordingly.

GIANT CLAM MARICULTURE IN THE LITTORAL ZONE

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New biological data and the recognition that natural stocks of giant clams are declining dramatically through over-fishing have resulted in investigations of the mariculture of giant clams. Research at James Cook University has focussed on the mariculture of Tridacna gigas, the largest and fastest-growing species of giant clam. A number of biological problems have been overcome, including selection of broodstock, spawning induction and heavy mortality of the early juveniles during the nursery phase. In a comparison of growth and survival of T. gigas juveniles in four positions for holding them during the ocean-nursery phase, the littoral benthic position gave near maximum growth rates and very high survival. A protected fringing reef gave much better growth rates than an exposed fringing reef despite more oceanic conditions at the latter site. Initial

testing of the juvenile clams' tolerance of intertidal exposure suggests that they can tolerate 4 hours mean exposure per day without strongly adverse effects. Large-scale systems for mariculture of T. gigas in the littoral fringing reef environment are now being developed.

EFFECTS OF WATER POLLUTION ON AQUACULTURE DEVELOPMENT IN THAILAND

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This paper describes aquaculture development in Thailand during the past decade. Fresh-water and brackish-water aquaculture has a tendency to increase steadily while mariculture production falls sharply. After reviewing the water pollution problems both in term of oxygen-depleting wastes and persistent chemicals, it is believed that such problems become more or less a limiting factor for aquaculture development in the Inner Gulf of Thailand.

IRON ABSORPTION BY CHATTONELLA SPP., RED TIDE ORGANISMS IN LITTORAL ZONES

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Iron is known as one of the micro-nutrients to enhance the growth of marine phytoplankters. Soluble iron is also required for the culture of Chattonella spp., Raphydophyceae. The requirement for the maximum growth in batch culture is about 1μM as EDTA-Fe. The half-saturation constant for uptake of EDTA-Fe is estimated by the authors to be about 0.5uM.

Chattonella red tides appear frequently in the Harima Nada, eastern part of the Seto Inland Sea, Japan. In sea water of the Harima Nada, soluble iron was usually found in the range from 0.04 to 0.1μM/1. Concentrations of total iron range from 0.7 to 1.4μM/1.

On the occasion of the red tide due to C. marina in July 1983, 24-32% of total iron in the water column from the surface layer to 5m depth were absorbed by C. marina. The high utilization by C. marina leads us to speculate the presence of an active absorption mechanism of iron in Chattonella.

The presence of siderophores in C. marina and C. antiqua were ascertained.

THE IMPACT OF TRAWLING ON THE FISHING ACTIVITIES OF TORRES STRAIT ISLANDERS

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Initially, the fish communities and turtle populations of an area (SE Gulf of Carpentaria) currently being fished were compared with the same area prior to the advent of trawling (1963-64) to estimate the long-term effects of trawling. There were non-significant changes in turtle catch rates.

For the fish communities, statistical comparisons of species richness/site, abundance/site and the relative importance of different species were made using matched pairs of sites and groups of sites generated using log-book effort values and numerical classification of species abundance values. There were significant decreases in the abundance/site, significant increases in the number of species/site and significant changes in the relative importance of different species.

In the second segment of the study, catch statistics (traditional and artisnal) were collected from the island community (Yorke Island) centred in the trawl grounds to measure the marine resources important to Torres Strait islanders. The most important resources were: scombrids, siganids, carangids, serranids, mullets, labrids, lutjanids, haemulids, lethrinids, scarids, painted lobsters, green turtles, strombids, tridacnids and trochids. The relative importance of each taxon and its constituents varied seasonally and depended on a variety of biological, social and economic factors.

In the third segment of the study, trawl cruises were undertaken seasonally in the Torres Strait to: measure the level of overlap between the traditional/artisnal fisheries and commercial trawling; and the seasonal effects of trawling on fish communities. The commercial by-catch from September to February includes significant catches of lobsters (Panulirus ornatus) and reefal fishes, e.g., holocentrids, scarids and siganids, whereas at other times juvenile lutjanids and haemulids occur in noticeable numbers. Seasonally, there was a decrease in fish abundance which correlated with the seasonal distribution of, and was probably due to, trawling effort.

IMPACT OF A DRAMATIC INCREASE IN FISHING PRESSURE ON AN ASSEMBLAGE OF CORAL REEF FISHES

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Fishing is the most important exploitative activity on coral reefs of the western Pacific. Despite this there are few direct tests, utilizing manipulative or natural experiments, of the impact of fishing on assemblages of coral reef fishes. This paper reports on a natural experiment that led to a dramatic increase in fishing pressure within a 750m-long marine reserve in the central Philippines. This reserve had been previously protected from fishing for ten years (1974-1984). Before

fishing began (in early 1984) the site had a significantly higher abundance of fishes, particularly those considered to be favoured targets of fishermen (e.g., serranids, lutjanids, lethrinids), than similar sites that were fished. Abundances were estimated using a visual census technique. The dramatic increase in fishing pressure involved fishing by up to 100 fishermen using traps, handlines, gillnets, spears and occasionally more destructive, non-selective fishing methods, such as explosives and drive nets. Fishing began after protective management broke down and continued for a period of 18 months before the reserve was recensused. Fishing pressure decreased the abundance of many target species significantly. Several surprisingly large decreases in abundance of small, numerically dominant, planktivorous species appeared also to be a direct consequence of the increase in fishing pressure, despite the fact that they were not favoured targets. This is attributed largely to the effects of the non-selective methods. Thus, fishing pressure had a far wider impact on the community of fishes than the predicted decreases in abundance of target species.

LITTORAL ZONE: MANAGING HUMAN INFLUENCES ON LINEAR SYSTEMS

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Littoral zones are rarely very wide, are invariably long and are undergoing continual changes. Consequently, they are dynamic and largely linear systems in that no-man's area which separates the landward and seaward segments of the broader coastal zone. On the one hand, these systems are shaped by a combination of terrestrial and marine processes, while on the other, they enclose populations which largely want to live near, enter into, or pass through these systems. As a result, these systems are subjected to intense natural stresses as well as such man-induced pressures as the modification of the littoral environment and the direct exploitation of intertidal systems. Management of these systems has been largely unsuccessful; however, management of the man-induced pressures on these systems is both possible and necessary if long-term net benefits are to be derived while the littoral resources are safeguarded. The development of an appropriate methodology for management of littoral pressures is urgent. It cannot await the collection of all the data on the system that may be relevant but must be sufficiently flexible to be able to absorb new information as it becomes available. More importantly, its implementation must involve a form of "mutual coercion" mutually agreed on by the majority of those groups responsible for the pressures.

THE NORTHWEST SHELF OF AUSTRALIA: TOWARD COMMUNITY LEVEL FISHERIES MANAGEMENT

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The diverse fish community on the continental shelf of NW Australia has been exploited since 1959. The history of exploitation is summarized, and changes in fish community structure during this exploitation are inferred from research survey data. Possible reasons for the observed changes are discussed, including the direct modification of the demersal habitat by trawling.

Some present management questions involve evaluation of several broad fishery options, each of which requires that a different configuration of the fish community be achieved and maintained. There are high levels of uncertainty associated with the biological and economic consequences of any attempt toward manipulation of community structure, partly as a result of uncertainty about dynamics of the resource. A methodology for evaluating potential management actions, which includes such uncertainties, is briefly described. It is applied to the NW shelf fishery and used to define harvesting strategies that are expected to be informative of the community's dynamics and economically beneficial.

PRESSURE FROM INTERNATIONAL TRADE IN SEA-SHELLS, CORALS, AND AQUARIUM FISHES ON CORAL REEF ECOSYSTEMS: THAILAND CASE STUDY

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International trade in sea-shells in Thailand is expanding while corals which used to be exported in the past, are now imported, due to the law preventing export which was brought into effect recently. The trade in salt-water aquarium fishes in Thailand is still not in great demand. Data and information concerning the collecting areas and processing procedure are discussed together with the potential pressure from these collections on the reef ecosystem.

HUMAN INTERTIDAL DISTURBANCES IN NEW SOUTH WALES

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Methods are discussed and outlines of surveys and experiments are presented that examine the effects of human recreational activities on the distribution, abundance and structure of coastal biological communities.

Survey techniques were developed that involve counts and interviews of people visiting the seashore. The numbers and species of organisms removed for food and/or bait are determined, as are the numbers of fishermen and scavengers frequenting the shore. Data from pilot studies using these methods assessed the various impacts of human recreation during different times of the year, on weekdays and weekends and on sunny and overcast days.

Comparisons are currently being made of the effect of humans over a large spatial scale, examining several stretches of shore along the New South Wales coast. The marine communities at these locations are also being censused using methods developed in previous pilot studies. From these data, information on the effects of humans will be obtained and manipulative field experiments will be designed to assess the long-term importance of these influences. These will involve artificial removal of crabs, cunjevoi, limpets etc. from certain places, and comparing the communities there with those in untouched controls. Alternative harvesting strategies will also be simulated. Several experiments are currently underway that assess optimal harvesting strategies for kelp plants, in addition to the consequences of such harvesting for the rest of the community.

We anticipate that the major results of this study will be the acquisition of sufficient sampling and experimental data to enable us to produce plans for the management and protection of these communities, and of coastal habitats, with respect to human use.

CORAL REEF RESEARCH OF THE INDONESIAN-DUTCH SNELLIUS-II EXPEDITION

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The Snellius-II Expedition in eastern Indonesian waters, the centre of the world from the point of view of coral reef scientists, naturally included reef research. Most issues of the programme were purely scientific but, because of the great economic importance of the reefs, quite a lot of attention was given to aspects of exploitation, monitoring and management.

It was a ship-based expedition of short duration, which has disadvantages as well as advantages. Operational and methodological aspects will be discussed, particularly from the reef-management point of view.

Eastern Indonesia is a large area with an enormous surface of coral reef, a great variety of reef communities and many different ways of exploitation. Relative to the magnitude of the management tasks, the available research capability is still underdeveloped, quantitatively but particularly qualitatively. Training and development of feasible research and monitoring methods were important topics of the expedition.

Methods included aerial photography, field reconnaissance under water, standardized reef transect studies, taxonomic inventories of algae as well as several groups of animals, sea grass community studies, and studies of socio-economic aspects, particularly fisheries.

FISHERIES ASSOCIATED WITH CORAL REEFS IN PNG : THE POLE-AND-LINE TUNA BAITFISHERY AND ARTISANAL SMALL-SCALE FISHERIES

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Each year during the operation of Papua New Guinea's (PNG's) domestic pole-and-line tuna fishery, an average of 900 tonnes of small, largely schooling, pelagic fish were harvested for bait. The target species were stolephorid achovies and sprats but, in addition, more than 300 other species have been recorded from baiting operations which are concentrated in reef-fringed, coastal lagoons. These lagoons are also the sites of small-scale fisheries carried out by coastal residents who complained their catches of larger reef-associated fish were adversely affected by the baiting operations.

Presented here are brief descriptions of the bait fishery and the artisanal reef-associated fishery. Trophic relationships have been examined in an attempt to determine to what extent the bait-fish resource is a shared resource between the fish exploited by the coastal fishermen and the tuna fishery.

DAY-TO-DAY MANAGEMENT OF THE GREAT BARRIER REEF MARINE PARK

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Day-to-day management of the Great Barrier Reef Marine Park is undertaken by the Queensland National Parks and Wildlife Service (QNPWS), on behalf of the Great Barrier Reef Marine Park Authority (GBRMPA). The QNPWS also carries out daily management of Queensland Marine Parks located in the Great Barrier Reef region, and is responsible for all aspects of the management of national and environmental parks. Park management duties include surveillance and patrols, enforcement, research and monitoring, management planning, and a particular emphasis on public education and liaison with park users.

As zoning of the remaining Central and Southern Sections of the Great Barrier Reef Marine Park nears completion, an increasing area of marine park is coming under day-to-day management. The QNPWS faces particular challenges with management of the most easily accessible and heavily used areas, for example the Whitsunday Islands area, where usage of numerous national park islands and adjacent marine park areas is rapidly increasing with the expansion of the tourism industry.

IMPACT OF TRAWLING ON DEMERSAL FISH STOCKS FROM THE NORTH AUSTRALIAN SHELF

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This project focusses on the by-catch fish species composition from the foreign vessel demersal fishery in the Arafura Sea, Timor Sea and north-west shelf. There are two fishing operations in the fishery - Taiwanese pair-trawlers operational since 1971 and Thailand sterntrawlers. The Thailand venture entered the fishery in late 1985 and is presently utilizing almost unfished stocks to the north of the Goulburn Islands, Arafura Sea. The comparison between unfished and exploited demersal fish assemblages allows an examination of the impact of trawling on open-shelf fish stocks to be made.

SUMMARY REMARKS [1] ON TOPIC 4: HUMAN INFLUENCES ON THE MARINE ENVIRONMENT BY DR. ED. GOMEZ

Thirty-one papers and two poster sessions were given on this Topic. The variety of subjects was notable, but the principal emphasis was on coral reefs or the many kinds of organisms associated with them, and on fisheries. Six papers and one Poster were presented on various aspects of coral reefs.

The Indo-Pacific region, in the tropical zone, is the world's major depositary of coral reef structures, and interest at this Symposium, under Topic 4, centred on the main factors affecting the reef ecosystem. The most important effects are the natural ones.

Done told us about the effects of three of these factors: storm surges, mass bleaching (a lost of zooxanthellae) and crown-of-thorns starfish predation. However, fresh-water run-off may also have serious adverse effects.

Bell/Kettle/Stamp showed us a method (barriers) of controlling starfish infestations, and **de Silva** illustrated the acute difficulties of managing coral reef areas in Sri Lanka in the face of competing objectives: conservation and exploitation for touristic purposes. This is also the problem facing those charged with managing the Great Barrier Reef, as **Dinesen's** Poster showed us.

Kinsey illustrated two kinds of human impact on coral reefs: sewage discharge and sedimentation, due to human activity. These effects tend to be chronic and, while not always killing the reef, tend to keep it in a perpetual state of ill health. The reef therefore tends to serve no good purpose or achieve any clear objective, at all.

Gillespie/Lewis/Holmes/Burke pointed out the relationship between outbreaks of ciguatera poisoning (by affected fish) and several human activities, including an apparently harmless one such as anchoring ships in the vicinity of a coral reef.

Many of these aspects were studied also during the Snellius II Expedition, as **van der Land** explained to us.

There were seven papers and a Poster presentation on fisheries, as one form of significant human influence on the marine environment.

It is quite clear that it is rarely possible, at present, to harmonize biological (e.g., conservation, maximum sustainable yield) and economic (e.g., control of fishing effort, maximization of price, etc.) objectives, as well as social objectives, as **Collins/Brown** showed us for the northern prawn fishery in Australia.

Three papers discussed social aspects of local fisheries. **Power/Harris** estimated the effects of trawling on the fish and turtles of the south-east corner of the Gulf of Carpentaria and, therefore, on the life of Torres Strait islanders. The addition of one human influence (trawling)

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1 A text not having been made available, these remarks are developed here from notes

on another (local artisanal fishing) was of great interest, since the trawling drastically altered the composition of the fish communities, hence the availability of traditional species to the islanders. The relationship between traditional fishing rights and non-traditional (i.e., recent, more modern methods of exploitation, such as trawling) as a basis for management of the resources were compared for us by **Johannes/MacFarlane**, but the answers are still far from simple, since, here again, biological, economic and social (even moral) objectives cannot be readily harmonized. **Sainsbury** also concluded that management could probably best be based on the fish community itself, in north-western Australia, but the necessary manipulation of the community structure by control of fishing (including fishing methods) is still fraught with uncertainty at our present level of understanding of such communities.

Russ/Alcala showed us the effects of a dramatic increase in fishing pressure on a small marine (coral reef) reserve in the Philippines after it was opened up for about a year and a half. The effects were far more widespread than expected: although preferred species declined in abundance, there were some very large reductions in non-target species, which they attributed to the wide variety of fishing methods used.

In spite of the difficulty of assessing the effects of fishing and other forms of human influence on coral-reef fish stocks, **Goeden** was able to offer a relatively simple technique for assessing the abundance of what he calls "keystone" predator species, but the problem of secondary changes in community structure remain to be elucidated.

Two papers dealt with the effects of bait collection on coral-reef resources. The bait taken for use in tuna pole-and-line fisheries around Papua New Guinea adversely affects local artisanal reef fisheries; so here too, we have a conflict of interests that needs to be studied and resolved.

Fairiveather concentrated on the effects on a genus of ascidians (and their associated littoral community) of exploiting them as bait for inshore drum fish. Such local and limited studies may still provide insight to the general question of the effects of exploitation on other kinds of marine organism.

Houston/Russell's Poster showed an interesting comparison of exploited and unfished demersal stocks.

The need for many more detailed studies of the effects of exploitation of fish communities is the obvious conclusion to be drawn from these papers.

It was therefore somewhat disappointing that only two papers dealt with non-fish living resources of considerable importance: sea birds and marine turtles.

King showed us that many of the birds living on and off the Great Barrier Reef range widely throughout the south-western Pacific; since some of them undertake major migrations, there is a real need to study the abundance and distribution of these birds and the human influences on them, not least on the Great Barrier Reef itself.

As **Limpus** explained to us, a similar argument applies to the marine turtles of the Indo-Pacific Convergence, the more so since, far more than the birds, turtles are exploited directly by human beings. There is an urgent need for at least Australia, Indonesia, Papua New Guinea and the Philippines to address seriously the question of managing the existing stocks.

There were four other papers on biological aspects of Indo-Pacific resources, but they all have in common the problem of degradation of the environment or over-exploitation of living resources. Thus, **Lucas** described the development of giant-clam culture as a result of natural stocks being depressed by over-fishing.

Jones found a negative effect of untreated sewage on littoral algae; a partial solution appears possible through greater treatment of the sewage before discharge.

There was only one paper on red tides and that was specifically on the absorption of iron by Chattonella.

Thus, **Okaichi/Montani/Hiraki/Tokuyasu** suggest that the mobilization of iron is likely to promote Chattonella blooms. It appears necessary to increase our attention to red tides and other kinds of phytoplankton blooms and to discriminate better between natural and human influences on their generation.

Finally, from the biological standpoint, **Sudara** reminded us that the increasing international trade in shells, corals and aquarium fishes is the cause of additional human pressure on coral-reef and other littoral resources and ecosystems.

Turning to the changes in the marine environment of a non-biological nature, and before summarizing the question of marine environmental management, four papers dealt with various aspects of marine pollution.

Anikiev/Ilychev described for us how quickly the marine environment responds to the imput of pollutants. The latter, in making their way to the sea, often through rivers and estuaries, also greatly affect the natural geochemical processes.

The persistence of pollutant supply to coastal waters also limits possibilities for developing aquaculture in Thailand, as shown by **Menasveta**. Here again, we see the need for a choice, or a better choice, to be made between the use of sea water (or brackish water) for growing fish or for receiving industrial/agricultural wastes.

Likewise, **Chansang** and her co-workers, stressed the need for a balanced choice between conserving coral reefs, as sources of food and pleasure, and dredging the sea bed for tin, in Thailand. Perhaps by careful choice of dredging sites in relation to the site of the reefs and the coastal currents (as carriers of dredge sediment), an optimum arrangement could be made.

It is, in many cases, clear that increased use, as well as better understanding, of mussels (and other organisms) as sentinels of pollutant input to coastal waters is desirable. **Kristoforova** stressed, however, the

importance of standardization of such organisms by several criteria, such as sex, age, etc.

The culmination of these varied presentations is, of course, the assessment of human influence on the marine environment, and the management criteria that may be derived from such assessment.

Gomez stressed the critical level of human influence in the WESTPAC region, in general, whereas **Hancock** stressed the effects on the open shelf, in particular through fishing, including abandoned fishing gear, and aquaculture, but a much more unexpected effect is the introduction or translocation of allochthonous species.

Horikoshi pointed out the value of the concept of "physiographic unit" as a basis for assessing human influence, since such a unit, of which bays are a good example, often provides a real, quasi-bounded system in which the various factors (e.g., sources of pollutants, seasonal current patterns, etc.) of human influence can be reasonably well quantified and therefore assessed.

Human recreational activities have an effect on the distribution, abundance and structure of inter-tidal biological communities, and **Underwood/Kennelly** pointed out ways of assessing the effect through experimentally controlled intervention in parts of the ecosystem so as to allow comparison with parts not subject to intervention.

There were, finally, three papers dealing with actual management issues. **Saenger** stressed the special problems of the littoral zone which is subject to considerable natural stresses as well as human stresses in certain places. While management of the natural stresses is very difficult, it should be possible to control those due to human activity. This appears to be essential and measures must be taken, in certain cases, immediately, rather than waiting till all necessary data have been gathered, and a full understanding achieved.

Falanruw, on the other hand, looked at an indigenous marine management system in Micronesia and assessed the effects of new, energy-intensive technology. She suggests that a neo-traditional management system, generally suitable for islands, is now needed.

Kenchington also agreed, with Saenger and others, that the management of human activities was the comparatively easy first step towards full and effective management of the marine environment. However, the search for a full understanding of the marine environment, and the effects of human activities on it, is still the ultimate goal, and we are still a long way from this understanding.

OVERALL SYMPOSIUM REVIEW

Prof. Revelle reviewed the main conclusions to be drawn from the Symposium (a text not having been made available, the review is developed here from notes).

The present Symposium has revealed an impressive range of scientific activity in the Indo-Pacific region, on the one hand, and the need for even greater efforts to elucidate the main phenomena and processes, on the other. A summary of each of the four Topics was already presented by the respective Keynote Speakers or Discussion Leaders. Nevertheless, there are several broad conclusions of a general interdisciplinary nature or specific to particular topics, notably with respect to advanced methodology.

In the field on **marine geology and geophysics**, the following questions still need to be answered:

- What is the timing and the nature of the events that, according to some current hypotheses, precede continental separation-updoming, extension, rifting, etc.? Do all these events occur in every case when continents break apart?

- Is the oceanic crust that is formed immediately after separation different from the crust formed during the steady state of sea-floor spreading? Is the rate of generation of volcanic material at this time markedly large, giving rise to prominent basement highs?

- Are the various structural and stratigraphic features usually associated with breakup, such as the "outer highs", the characteristic seaward dipping reflectors, and the break-up unconformity, all related and how exactly do they originate?

- What is the nature of the crust under passive margins? And why is the earth's magnetic field near many passive margins so smooth?

- Has the crust under the margins evolved from continental crust and, if so, has it evolved by extension and consequent thinning or are massive intrusions of material from the mantle a more important cause of alteration? Or, did at least a part of the "transitional" crust underlying the margin evolve not from continental crust but from the earliest oceanic crust?

- How did the passive continental margins move up and down through time, how did this affect sedimentary processes, and what has been the thermal history of the sediments? (Even if the thicknesses and the lithology of the sediments on the margins are known, a knowledge of their thermal history is essential for determining whether any hydrocarbons present might have matured to form oil and gas.)

- What is the structure of the region lying between the deep-sea trench and the island arc?

- What have been the vertical motions in the zone between the volcanic arc and the deep-sea trench?

- How can the back-arc basins (the basins lying on the continental side of the volcanic arc) have been formed by extensional tectonics (as has been suggested by many scientists) in a setting that, in a regional sense, has been predominantly compressive. It appears that many of the back-arc basins opened up by sea-floor spreading for perhaps 10 to 15 million years. The enigma is not only that the extension took place in a zone of convergence, but also why it started and why it stopped.

- Are hydrocarbons as likely to be found in the active margins as they are in the passive margins?

- What is the role of pore waters in the subduction process?

- What are the processes involved in massive slumping on the continental margin (for example, off active river deltas)?

Great improvements in seismic instrumentation are needed to understand the details of the structure of the crust and the upper mantle. As with sedimentary layering, the application of continuous reflection profiling to igneous rocks will be very useful, but the acquisition and processing of seismic data must be improved. Long seismic arrays will be particularly useful for obtaining information on the lithology of the crustal rocks. To determine igneous stratigraphy and structure, as well as hydrothermal systems, a combination of seismic experiments, drilling, and examination of cored samples of rocks and pore water, and the performance of "downhole" experiments, will certainly be an important part of marine geology and geophysics in the next few years.

Direct observations and sampling from manned submersibles will continue to be most effective in the detailed investigation of high-temperature hydrothermal vents, with their exotic ecosystems, and mineralization at spreading centres.

Better imaging devices are needed to learn more about the detailed morphology of the sea floor. Side-scan sonars, such as GLORIA (Geological Long-Range Inclined ASDIC) developed by the Institution of Oceanographic Sciences in the United Kingdom, have proved to be valuable for reconnaissance. GLORIA is towed near the surface and thus has great range in deep water; but, its resolution is less than that of a device towed closer to the sea bottom. A side-scanning sonar device that could be towed at different specific depths appropriate to the requirements of specific experiments would be very useful. For example, some of the capabilities of the commercially available SEA BEAM, which measures time of travel of narrow sonic beams reflected at various angles, thus determining bathymetry along a swath several kilometres wide, and from DEEP TOW, of the Scripps Institution of Oceanography, which tows a number of scientific instruments close tc the ocean bottom, could be incorporated in a versatile, well instrumented side-scan sonar towable at a variety of depths. The SEAMARC, developed at the Lamont-Doherty Geological Observatory, and similar instruments, are first steps in this direction.

To investigate plate subduction better, more precise determination of earthquake hypocentres is essential. For this purpose, extensive seismic networks with permanent ocean-bottom seismometers will have to be deployed around the subduction zones. With considerable research and development effort in the technology of submarine acoustic geodesy, real-time monitoring

of distance changes across trenches, for instance, could bring about a major breakthrough in the understanding of plate dynamics.

The complete mapping of the magnetic anomalies and thus of the age of the ocean floor provides a measure of the horizontal growth rates of all existing major ocean basins. This knowledge and that on rates of subsidence of the seafloor will allow the palaeogeography and palaeobathymetry of the world ocean for the past 150 to 180 million years to be determined. Attempts at such three-dimensional, quantitative reconstructions are available today only for the Indian and Atlantic Oceans because they are surrounded by passive margins and because they contain their entire history since the initial rifting phase.

While processes along subduction and plate-collision zones probably pose the biggest problem for reconstructions of the oceanic palaeogeography, zones of abnormal bathymetry should also be investigated in much more detail than hitherto. How do plates move vertically when crossing swells in the asthenosphere? How fast are they uplifted? How do intraplate volcanism and other thermal events affect the subsidence of oceanic crust? Which volcanic processes result in construction of aseismic rises, which lead to guyots only? Why are the remnants of the Mesozoic Pacific densely covered by large volcanic edifices, and what happened to those aseismic rises and plates located on the part of the Mesozoic Pacific plates which have been accreted to South and North America? Why did the volcanic and thermal activity of the Pacific Plate decrease significantly during the Cenozoic?

Research will be needed to define better the magnitude of eustatic sea-level changes, to determine rates and timing of sea-level rises and falls, and to understand the response of shallow as well as deep oceanic depositional environments to sea-level changes. This research will probably be conducted mostly along passive and active continental margins, in the sedimentary basins of the adjacent continental platforms and in anomalously shallow oceanic regions (microcontinents, aseismic rises and atolls).

Studies of eustatic sea-level changes with time will be directed mainly towards finding mechanisms capable of rapidly generating brief sea-level changes; these have apparently occurred when the volume of ocean water remained stable and when no substantial ice accumulations on the Earth's surface were known.

The interaction of tidal currents, waves and wind poses several problems. Offshore and in large inlets there is the question of submarine dune formation by combined tidal and wave action; knowledge of the displacement rates of these structures is important for maintenance of shipping channels. Nearshore, the interaction poses problemsalso of stability or instability of barrier island chains and tidal inlets, the influence of seasonal changes in wave attack and storm surges on growth and erosion of beaches, etc. Reclamation of land in lagoons and estuaries and the accompanying changes in tidal prism, which are also reflected in the growth and decay of tidal deltas and the stability of coastlines, presents another important set of problems.

Biological factors have been shown here to be important in the high-energy environment, especially as stabilizers; e.g., mangroves and the vegetation of intertidal flats and dunes. Losses of vegetation generally lead to increased instability of the sedimentary structure.

Most problems of the high-energy environment can only be solved by combined efforts of physical oceanographers, sedimentologists and coastal engineers.

Sediments of the continental margins are emplaced by slides, slump, debris flows, turbidity currents, contour (thermohaline) currents and pelagic fallout. A combination of seismic and sedimentological data are required to distinguish between these mechanisms, and detailed downhole studies are needed to show the make-up of different continental margins in terms of depositional mechanisms, particularly in relation to the tectonic situation. Analysis of continental-margin sediments of all types (particularly carbonates) from deep-drilled holes provides evidence for changes in sea level.

Submarine fans are important features of the lower rise of several continental margins. The sedimentary facies of these features are of great interest. The mineralogy and sedimentology of pelagic sediments often reflect the pathways and dynamics of aeolian delivery to the sea surface. Spectral analysis can be now applied to several sedimentary properties downcore to detect frequencies of climatic significance.

Recent heat-flow and sedimentological work on mid-ocean ridges suggests convection of pore water in sediments. Sedimentological aspects of this, including sediment porosity and permeability, geochemistry and diagenesis, will be important items on the agenda of sedimentary geochemists for the next decade.

Much has been done to define broad areas of the deep-sea floor where ore-grade manganese nodules occur. These studies have demonstrated that ore-grade nodules are not uniformly distributed in economically interesting areas, but that quite large variations, particularly in abundance, can occur locally. It is essential to investigate these variations in greater detail for two main reasons. First, an understanding of what causes local variability in manganese nodule grade (content of Ni, Co, Cu) and abundance is essential to understanding the origin of these deposits. Secondly, an understanding of the factors determining local variability in nodules can aid in the development of exploration methods and in mine-site evaluation.

Over the past decade, near-shore minerals such as placers and phosphorites have received much less attention, scientifically and economically, than deep-sea mineral deposits such as nodules and metalliferous muds. However, two factors are likely to lead to an increasing interest in near-shore deposits over the next two decades: the increasing price of certain noble metals (e.g., gold and platinum) is likely to make attractive previously uneconomic noble-metal placers, and developments in exploration and extraction techniques will benefit the search for less valuable placers such as cassiterite and heavy-mineral sands.

For the understanding of the relationship between the oceans and climatic phenomena in the short term (weeks to months), studies are needed on the fluxes at the air/sea interface, on the strength and position of currents and fronts, and on the heat budget and thermal structure in the upper layers of the ocean. Upwelling zones are examples of the obvious effects of air-sea interaction on the local climate and on the biota in the sea and the adjacent lands.

The prediction of large-scale events in the atmosphere and in the ocean often depends on the understanding of phenomena that occur thousands of kilometres away: the timing and strength of the monsoon in India depend at least partially on the behaviour of the Somali Current, and the El Niño phenomenon off Peru is governed by perturbations of the pressure field, hence trade wind and equatorial current systems in the Pacific Ocean. Probably, the throughflow from the Pacific to the Indian Ocean is similarly governed.

The critical areas in which further research is needed are:

- The relation of the large-scale thermal anomalies in the upper ocean to the ocean circulation and atmospheric processes, and their feedback to the atmosphere through large-scale air-sea interaction.
- The transport and storage of heat (and salt) in the ocean, and their role in climate variability.
- The storage of carbon dioxide in the oceans.
- The origin and dynamics of oceanic eddies.
- The structure and dynamics of oceanic fronts.
- Vertical mixing in the ocean (including convective overturn).
- The microstructure of the ocean, particularly in the thermocline region.

Certain special problems in marine ecology will call for particular attention to such matters as the interaction of large bird populations with their food sources in nekton, plankton and benthos, and long-range migrations of marine mammals, notably turtles, and fishes, notably tunas.

In dealing with the cycling of organic matter in the oceans, it will be necessary to determine the products of primary production. The bioactive substances that are vital to communication within and among species are virtually unknown at present, and further study of them will certainly be rewarding. The same is likely to be true of the organic molecules on which the lower organisms of the food web subsist; the molecular weight distribution of this material is unknown.

However, most sampling techniques for oceanic organisms have substantial limitations to the range of phenomena they can effectively discriminate. These sampling inadequacies limit the expansion of knowledge but there are some areas where there appear to be special opportunities for significant progress during the next few decades. Aspects that particularly need investigation are: the role of different size fractions among planktonic primary producers, particularly very small cells and cyanobacteria; the fluxes of dissolved organic matter to and from primary producers; the role of bacteria in the plankton; the role of the length of incubation and chamber dimensions in producing artefacts during measurement; the contribution of non-planktonic primary producers to the organic carbon flux of the water column in coastal and estuarine regions.

The dynamics of phytoplankton blooms, the patterns of succession in phytoplankton communities and the factors determining the species composition of the communities are basic to our understanding of the primary production functions in ecosystems. Reasonably precise taxonomic identifications can be made of many, but not all, protozoa to genus level. Taxonomic studies of bacteria involve the isolation and culturing of cells, as well as the problems of taxonomic criteria.

Questions concerning the vertical profile of productivity, the significance of patchiness, the dependence of the survival of planktonic larvae on minimum cell abundance in the water column and the relationship of chlorophyll and cell maxima to the production maximum can be effectively answered only by using continuously profiling techniques. Sensors capable of measuring nutrient concentrations would dramatically improve our capability to test hypotheses about the spatial relations of biological processes in the photic zone. The use of fluorometers and particle counters in undulating towed instruments or in moored arrays will provide breakthroughs for work on the space and time changes that are important in the ocean on scales from minutes to years.

The role of micro-organisms (bacteria, yeasts, protozoa and fungi) in the food web of the shallow and deep pelagic zones and in benthic environments in the production and degradation of particulate organic carbon and in the utilization of dissolved organic matter needs to be quantified, as it may be central to understanding of the flux of organic carbon through marine ecosystems. Similarly, little is known of the role of bacteria in conditioning detrital material, improving its palatability and availability in the water column. Midwater communities living below the normal range of diel migration (i.e., 1000-1500 m) rely almost completely on the rain of sinking particles as their energy source; if pellets are rejected at shallow depths, their palatability may have greatly improved through bacterial action, by the time they sink deeper.

Enzymatic correlates of primary production and bacterial growth rate show great promise for understanding these processes because they are instantaneous determinations and avoid artefacts from container size and length of incubation. Epifluorescence microscopy, microautoradiography, and transmission and scanning electron microscopy will be increasingly used to make relatively accurate determinations of bacterial and protozoan biomass.

There is still much to be learned through the intercomparison of different types of ecosystem. Data on rates at which processes are taking place and on the fluxes of materials and energy are difficult to obtain but are necessary for ecosystem modeling.

During the next two decades there will be an increasing use of enclosed marine microcosm systems to investigate problems in theoretical ecology, ecosystem dynamics, species succession, etc. The development of numerical models may be enhanced if they can be tested experimentally in such living models.

Even at scales of a few metres there are important unresolved problems associated with the development of blooms, the survival of grazers and the success of recruitment by larval fish which must encounter threshold concentrations of food. In the vertical sense, knowledge of the

microlayering of organisms, especially in the photic zone and in proximity to the thermocline, is basic to an understanding of the dynamics of primary production and its utilization.

At mesoscales (10^1 to 10^3 km), the rapid advance in physical research is being followed by striking progress in biological studies. Despite considerable physical research on eddies, it is still uncertain to what degree eddies (as opposed to closed current rings) behave as advecting parcels of water that retain their identities. Research on the biological transformation of eddy communities depends on better physical understanding of the phenomenon.

The ecosystems of shelf seas and inshore areas differ from those of the open ocean in the relatively greater influence of three factors: the long-term variability of the climate, the direct effects of exploitation of living resources and the chemical effects of man's activities. To distinguish between these influences is difficult but is of great scientific interest; it is also essential for proper environmental management.

The variability in the energy flow within the ecosystem and the physics of the system is dominated by the inputs at the boundaries. A thorough knowledge of the size and variability of the inputs is therefore just as important as a knowledge of the internal properties.

At present, programmes to study coastal processes associated with, for example, climate, weather and fisheries, tend to set up independent monitoring and surveillance activities that ignore the interactions and so overlook essential elements of the system they are endeavouring to define. This is an area where greater interdisciplinary interaction is badly needed.

Pelagic sampling techniques (namely, water bottles, pumps and nets) all sample limited segments of the size spectrum of organisms and discriminate only very limited sections of the important space-time scales. Efforts to integrate over the whole size range of organisms encounter severe difficulties because of the incompatibility of the sampling scales. Adequate quantitative sampling is not possible for: (a) larger nektonic animals, which are too infrequent and too active to sample adequately; (b) gelatinous organisms, which are destroyed by conventional samplers: (c) aggregations of small organisms (marine snow), which are disaggregated by sampling; and (d) micro-organisms and microzooplankton, which are unidentifiable after preservation. A zone that is particularly difficult to sample at present is close to the seabed, particularly in areas of rough topography. Development of techniques involving large-particle counters, acoustics, photography and direct observation will be needed.

Most of the many benthic sampling techniques available at present are only semi-quantitative at best. Trawls, dredges, corers, box-corers, grabs, traps, camera, and television systems all have advantages and disadvantages, but when operated remotely from a ship, they lack the precision and control that can be achieved by sampling from a submersible or, in shallower water, by divers. There is a need for survey capabilities so that areas may be detected where natural experiments may be followed, such as turbidity slumps, large accumulations of organic remains and hydrothermal vents. There is a need for remote experimental stations which can be placed in position and left to carry out a sampling programme, and for improved methods of measuring sedimentation and resuspension. Techniques to follow chemical fluxes in and out of the sediments, and

methods to measure microbial turnover rates and fine distribution patterns are also highly desirable.

The major bottleneck in the development of descriptive biological oceanography is the sorting and identification of catches. Biology is at a substantial disadvantage compared to many of the other branches of oceanography as to the quantity of useful data extracted from sampling programmes and the speed with which the data are worked up. A few attempts have been made recently to develop methods of sorting catches initially by sieving or flotation techniques. A modicum of success in reducing the tedium of processing samples would have an immense influence in accelerating the working up of material. Another serious problem is in the rapidly diminishing resources of taxonomic skill, which are being allowed to erode away through the lack of even minimal funding.

Remote sensing by aircraft and satellite appears, at least in the short term, to have less to offer open-ocean biology than other branches of oceanography. The only biological parameter that can now be measured is surface chlorophyll, and its measurement is dependent on visual wavelengths, therefore requiring clear atmospheric conditions. The other main uses of the present remote-sensing technology in the field of biological oceanography would seem to be: (i) the location of fronts and areas of upwelling; (ii) the setting of biological observations and experiments within the large-scale context of the physical environment; iii) the tracking of large organisms, notably turtles and certain fishes, that spend some time at or close to the surface; and (iv) survey of the extent and variations of coastal ecosystems such as mangroves and salt marshes.

Further development might include free-drifting automatic stations similar to present anchored systems, capable of monitoring a range of suitable parameters (e.g., chlorophyll levels, particle spectra, nutrient concentrations) within the photic zone over long periods, and which could be tracked and interrogated by satellite.

Regarding **Man's impact on the marine environment**, there remains a real need for: the evaluation of useful biological indicators to assist in distinguishing man-made from natural fluctuations; study of the bacterial transformation of compounds exotic to the marine environment; study of the mechanisms of transport and dispersion of pollutants; an evaluation of the sublethal effects of various pollutants on marine communities, of the effects of non-toxic substances (e.g., silt) on biota, and of the effects of excess nutrients on the structure and functioning of marine communities. Also, the quite serious effects in some places, of the extensive removal of old coral reefs and coralline coastlines, and of inshore gravel, sand and mineral (e.g., tin) mining, need to be further studied. As noted above, marine turtles and sea birds, are also greatly affected by Man's increasing use of the coastal zone, so that a sound scientific basis still needs to be developed to achieve rational management of the coastal zone and of the most affected species. Similar arguments apply to the effect of increased exploitation of mangroves on economically useful species that use such areas, especially for breeding or nursery purposes.

Chemical speciation studies are also needed to permit an accurate evaluation of the biological availability of the trace metals. Improvements in research on the relation between the inorganic and the complexed organic states require a better insight into the component biochemicals of sea water

with complexing potential and a better understanding of the interaction between trace metals and organic coatings of particulate matter, particularly where such metals are mobilized by human activity.

It has also become clear that the description of humic materials and the determination of their structure and properties will continue to be a subject of great interest to the marine chemist. Again, much of this type of substance is mobilized by Man.

As to technological and methodological advances in general, research vessels will continue to be used for scientific work at sea, but more specialized vessels and other platforms are becoming increasingly used, especially for geophysical studies of the sea floor. The Glomar Challenger is a particular example of this, while moored and drifting buoys, acoustic arrays, and bottom-mounted instruments are examples of unmanned platforms.

Satellites are being increasingly used for remote active and passive sensing, for tracking drifting buoys and for data acquisition and retransmittal to ground stations. Aircraft are also useful for remote sensing and for deploying autonomous instruments

Satellites can cover the globe in a matter of days, but they only observe the sea surface. However, it is at the sea surface that quasi-synoptic global sampling by satellites is most valuable, since the surface parameters generally have much shorter response times than the ocean interior.

SEASAT, the first oceanographic satellite, demonstrated the feasibility of measuring surface winds, significant wave height, and sea-level changes. SEASAT, NIMBUS and other satellites have also mapped distributions of sea ice, sea-surface temperature, chlorophyll and other biological properties.

Forecasts of sea-surface state, for use in real-time ship-routing and offshore operations could be greatly improved by the use of satellites carrying microwave sensors providing data on sea-surface winds (with a radar scatterometer), surface wave heights (with a radar altimeter) and the two-dimensional surface-wave energy distribution (with a synthetic aperture radar). This would require, however, the development of sufficient real-time data-handling facilities. Satellite measurement of sea-surface elevation in conjunction with measurements of the wind stress could revolutionize our understanding of oceanic circulation. An adequate number of satellites with repeated ground tracks every week or so, with 100 to 400 km between tracks, and sampling intervals along the track of about 10 km, would provide the missing global view and enable us to develop an image of the mean global ocean circulation that is so tightly constrained by sea-level and wind-stress curl that many previous ideas of the mean circulation will undoubtedly be abandoned.

Although infra-red and passive microwave techniques for measuring sea-surface temperature have allowed us to see fronts, current meanders, eddies, etc., their accuracy is not enough for the quantitative study of sea-surface temperature anomalies and large-scale ocean-atmosphere interaction.

Ocean colour measurements from satellites, supported by infra-red measurements to aid in the identification of water masses, have been

successfully used to map distributions of chlorophyll and other coloured substances in the ocean surface layers. Satellites are also valuable in the study of the patchiness of biota.

Acoustic transmission is being used to probe the ocean itself or to send data through it. Instrumented floats at depth have been tracked acoustically for years using near-shore and moored receivers. Tracking systems with receivers suspended from surface buoys and linked to a satellite system are being developed for service in the near future. Acoustic tomography - the multipath transmission, reception and analysis of acoustic signals to synthesize the density and velocity fields of the ocean - may allow indirect measurement of heat content, heat flux and vorticity, on the medium to large scales. Acoustic Doppler current profiling from ships is now in use and will probably improve in range and resolution. Upward-sensing sonars provide useful information on surface waves and downward-sensing sonars help map internal waves.

Even more sophisticated acoustic techniques based on the reception, by appropriately spaced receivers, of backscatter from a series of sonic pulses, with real-time data processing, can be used to measure the displacement (in the three space dimensions) of the scatterers. As a navigational tool, it gives ship velocity relative to the seabed, and, bottom-mounted, can give sea-ice movement.

It is now well within present capability to deploy, for long-term observations, substantial arrays of current meters in dynamically or kinematically important areas of the ocean circulation such as the Kuroshio, or the overflow regions. Experience indicates that several years of observation are necessary to reach statistically significant conclusions about the most important physical phenomena.

Undulating instrument packages which measure simultaneously temperature, conductivity, oxygen, chlorophyll and particle-size spectra can now be used to achieve better integrated time and space sampling. Similar rapid in situ sampling methods for other chemical parameters such as nutrients, are also needed, but still we need to develop the capability to integrate satellite measurements of such parameters as wind stress, surface temperature and colour.

Data handling by computer is now essential to cope with the new high-data-rate instruments; apart from central storage at data centres, smaller computers can simplify the data management.

In summary, we can see that ocean processes cover a wide range of time and space scales, The larger scales are financially and logistically the most difficult to use and usually require collaboration among many institutions in different countries, thus benefiting greatly from international planning and co-ordination. Remote sensing by satellites, and by acoustical techniques within the ocean, has a critical role because these techniques are the main, if not the only, means of covering all scales from days to decades, from kilometres to the whole earth. Such data will remain largely unusable unless we have the "ground truth" or in situ measurements for their calibration and analysis, and the understanding required for their synthesis

A greater level of international collaboration in marine science is now clearly necessary because the dimensions and locations of marine processes do not correspond at all to existing national boundaries; in some regions, the ocean circulation and the distribution of fishes, sea birds and turtles, for example, are common to the several bordering countries, and their investigation can be effectively accomplished only through regional collaboration.

The further development of marine scientific research, in the Indo-Pacific region as elsewehere, will depend heavily on the development of sampling, analytical and data-processing techniques and capacities, and on greatly increased international co-operation.

CLOSING ADDRESS

The Hon. Barry O. Jones, MP, Minister for Science, then gave the closing address to the Symposium.

Distinguished guests, Ladies and Gentlemen.

I welcome the opportunity, in such distinguished scientific company, to have a part in your deliberations and regret that my ministerial commitments prevented me from involvement in your Symposium earlier in the week.

Geographical Focus

It is the geographical focus of this Symposium which I believe is of particular interest and significance.

There is growing recognition that by the end of the century the Asia-Pacific ring will be the major economic sphere of influence in the world. Certainly, in terms of technological development it is already a major centre of world influence. we must also remember that almost half of the Earth's nearly 5 billion people live in Asia.

Korea and Japan have already proved to be manufacturing and technological giants. Singapore and Hong Kong are established as world financial centres, and as market places for the diverse range of technological products developed in Asia. China, with its vast population and its thirst and capability for large scale development, provides innumerable opportunities for development and consumption of manufactured technology.

In most countries of the region, science and technology have been recognised as important elements in national development and many governments in the region have developed policies and programs to encourage research in fields of recognised national importance.

Australia has already established strong ties with many countries in the region, encouraging scientific co-operation and industrial exploitation of research and development successes. We have a long history of aid and co-operation in agricultural research.

We have also co-operated with countries of the region in research programs in the marine sciences, meteorology, Antarctica, remote sensing, micro-electronics, biotechnology and scientific instrumentation.

However, the impacts of government to government, and even researcher to researcher contacts are long term. Although they do lead to better relations and understanding between countries, their economic impact is difficult to identify, let alone measure. International co-operative research projects can be developed which have direct commercial aims. If these projects are properly directed and financed they can result in identifiable economic benefits shared by the participating countries.

For the past three years my Department has been giving increased attention to this type of program, and has sought the involvement of Australian research organisations, universities and industry in their development, funding and management of research projects. So far, the ASEAN countries, Malaysia, Singapore, Thailand, Indonesia, the Philippines and Brunei have shown greatest interest in co-operating with Australia in this way.

As Minister for Science, I have signed Memoranda of Understanding with the Malaysian Science Minister, the Hon Datuk Amar Stephen K.T. Yong and the Indonesian Minister of State for Research and Technology, Professor Dr Ing B J Habibie. I look forward to concluding similar agreements with Thailand and the Philippines over the next few months.

My Department is also involved in other fields of international co-operation in scientific activities such as:-

- the establishment of a meteorological service in the Solomon Islands.

- administering scientific exchanges, workshops, services and joint research projects under formal science and technology Agreements with China, Japan, the Soviet Union, the United States and others.

- a major participation in the conference and exhibition held as part of the First ASEAN Science and Technology Week, in Kuala Lumpur, last April.

- managing the ASEAN-Australia Micro-electronics Design Project.

- co-operation between the meteorological services of Australia and the People's Republic of China under an MOU which provides for co-operation in tropical cyclone and monsoon research, numerical weather prediction, satellite meteorology, exchange of staff, exchange of scientific and technical information, and collaboration on significant research projects.

I have no doubt that reference has been made earlier this week to the two marine science projects in Coastal Living Resources and Tides and Tidal Phenomena being conducted by five ASEAN countries - Indonesia, Malaysia, the Philippines, Singapore and Thailand, with technical advice and assistance being provided by personnel from the Australian Institute of Marine Science and Flinders University respectively. Both projects include development and use of Australian hardware and software and other specialised equipment and both projects also include training and education components.

It is against this background of a very dynamic region, undergoing major economic, social, political and scientific changes, that this Symposium is being held. I have outlined briefly some of the international co-operation programs which

Australia has put in place over the past 2-3 years as part of its response to the change and dynamism of the region, and to establish its own scientific and technological future in such a region.

Scientific Significance of the WESTPAC Region

Most of you present here this afternoon however, have come to the Symposium not so much because of the economic dynamism of this region, but for the unique scientific challenges it holds.

I understand that your discussions this week, relating to marine geoscience have confirmed that the WESTPAC region offers exciting opportunities for elaborating the scientific understanding of plate tectonics. That one geoscientist described the region as a "geological dog's breakfast" suggests that the research tasks will be neither easy nor short-term - but they will be a scientific challenge!

Today ocean-atmosphere interactions are one of the major pre-occupations of oceanographers and meteorologists worldwide. The WESTPAC region, and the Indo-Pacific Convergence that it contains, have become a particular focus of attention because it is here that some of the major global interactions have their genesis. The unique features and complexities of the oceanographic systems of the region and the fact that they have far-reaching efforts on the climate in several continents, points strongly to continuing, indeed increasing, international scientific scrutiny in years ahead.

Much attention has been given at this Symposium to marine biology and fisheries. This is not surprising, because fisheries are a most important element in the economic fabric of many member-countries of WESTPAC. The discussions have confirmed that there is a paucity of long term data sets of appropriate environmental parameters which may be affecting a variety of fisheries stocks. Until these data sets are available it is difficult to assess the impact of human-induced stresses on those stocks and their long term future. The Symposium deliberations have also confirmed that the established fisheries management strategies developed for single species fisheries in temperature waters, have very limited application in the multi-species fisheries of WESTPAC's predominantly tropical and semi-tropical waters.

Human influences on the marine environment are of increasing interest to countries of the region because, for the most part, these influences adversely affect the productivity of their marine resources. Speakers at this conference have emphasized the problems of increasing population pressure reinforced by the vicious cycle of debt repayment and poverty leading to over-harvesting of resources on an ever-widening scale. The scientific challenge is to understand the extraordinarily complex ecosystems involved and to develop management strategies which are not only scientifically sound, but also socially and economically acceptable - in a word, implementable.

Of course, meeting these challenges demands not only a multi-disciplinary approach, but also, and perhaps more importantly, a multi-lateral international effort.

Whatever boundaries might be drawn on maps, those extending over the sea can never alter the fact that the oceans are a single domain, and their waters are in constant change. Any attempts therefore at gaining an understanding of the physics, geology, chemistry or biology of the marine environment, ultimately require co-operation between nations and between disciplines.

Co-operation is like motherhood, - it is hard to find someone who is opposed to it.

But, just because we all support the idea of co-operation, that does not necessarily make it easy to achieve - even at the national level, let alone bi-laterally, regionally or globally.

Multi-lateral co-operation requires patience, persistence, flexibility, and continuing good-will. In the final analysis, it often also requires some person or country to take a lead in exploring options, encouraging, persuading and then taking a bold step to make demonstrable progress. We all know that success builds on success.

This Symposium is a case in point.

Although it has not been possible for me to be present throughout this Symposium, discussion last evening and this morning with participants has enthused me with the boldness of this enterprise.

It has been an ambitious initiative to have brought together recogised world experts and to focus their attention in a multi-disciplinary context, on the marine domain where the Pacific and Indian Oceans converge.

I am sure each of you will confirm that it has been a success. Not only has your debate addressed the challenges within disciplines but also their relevance on to the other and beyond that to the users of the research as well as to the particular needs of the user, often in situations of great social and economic complexity.

I mentioned patience as a necessary ingredient to successful multi-lateral co-operation. WESTPAC has made some real progress in its short life. This Symposium bears witness to that. World renowned speakers in a wide range of fields acknowledging by their presence, not only the scientific importance of the region, but also acknowledging the role which IOC WESTPAC can play as a catalyst.

WESTPAC has come a long way, but it is now at a watershed. I am told that this point was made by Dr Greg Tegart, Secretary of my Department, when opening this Symposium. I wish to emphasise it.

I said that we may not always achieve rapid progress, but at all times we should be moving forward.

WESTPAC will move forward, only if it receives the support of member governments. That support will be forthcoming, only if member states judge that WESTPAC firstly, can be of value to them in pursuing their objectives in marine research; and secondly, that they are getting value for money.

IOC is not a funding body. It does not have funds of its own to support research programs. Rather, and I quote from the IOC statutes:-

> "IOC works through the concerted efforts of its member states."

It is a co-ordinator and encourager. It is a catalyst which provides a mechanism for addressing research problems which by their nature demand the concerted participation of several countries. The necessary funds, vessels, skilled manpower and support facilities must come from the participating member states or by negotiation from some third-party funding agency.

Worldwide, taxpayers and Governments increasingly are demanding value for money - including value for the dollars spent on scientific research. In Australia there has been a recent Government review of CSIRO, our largest research organisation. A review of research in our Higher Education Sector also is currently underway. These reviews are directed at getting better value for money.

Similarly value for money is being demanded by governments for the manpower and funding resources committed to involvement in multi-lateral international activities and organisations. For mere survival, IOC and WESTPAC must continue to review what it is that they are doing and, perhaps more importantly why they are doing it. In carrying out such reviews they must be clear about, and sensitive to, member country interests, priorities and aspirations.

I understand that WESTPAC has developed a comprehensive framework of working groups in the principal fields of marine science of interest to member countries. This Symposium has laid out a scientific menu. Taken together, these two elements provide a sound basis on which to build scientific co-operation.

Member countries must now decide how best WESTPAC can assist them to achieve their social and economic goals through co-operation in marine science research. Each of you scientists here this afternoon has a part to play. You alone have had the opportunity to get the comprehensive overview provided by this Symposium.

Member governments will meet at WESTPAC IV in Thailand in mid-1987 to discuss the future of WESTPAC. Those who advise government and those who are within government welcome your

enunciation of the problems and priorities and the role which WESTPAC should have. I urge you to make your voice heard when you return home.

May I commend the IOC and its WESTPAC Program Group for convening this Symposium. It has been a stimulating experience and will I trust, set a precedent for future discussion of this kind.

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No.	Title	Publishing Body	Languages
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37 Suppl.	Papers submitted to the IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
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41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitorng of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
42	IOC/UNEP Intercalibration Workshop on Dissolved/Dispersed Hydrocarbons in Seawater Bermuda, USA, 3-14 December 1984 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
44	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
44 Suppl.	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities - *Submitted Papers* Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
45	IOCARIBE Workshop on Physical Oceanography and Climate Cartagena, Colombia, 19-22 August 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
46	Reunión de Trabajo para Desarrollo del Programa «Ciencia Oceanica en Relación a los Recursos No vivos en la Región del Atlantico Sudoccidental Porto Alegre, Brazil 7-11 de Abril de 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	Spanish
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence Townsville, 1-6 December 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English