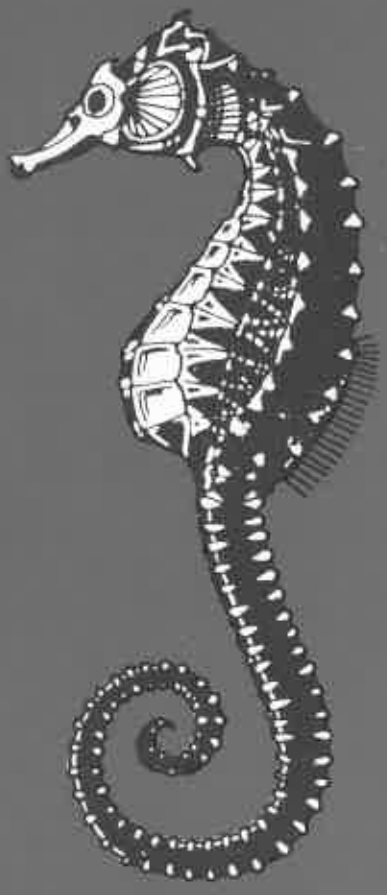
AUSTRALIAN MARINE SCIENCE BULLETIN



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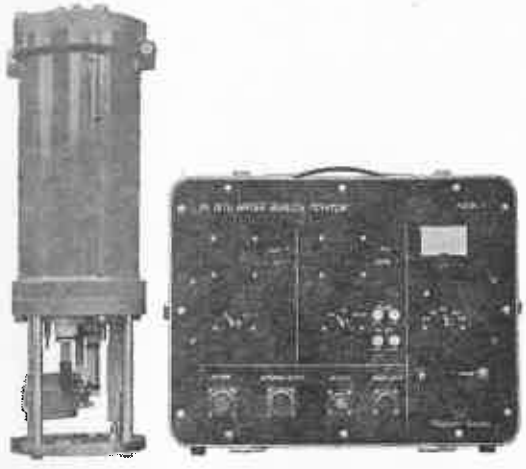

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NEWS

Science in the Oceans — Australia's Achievements and Objectives At the ANZAAS Congress three afternoons (30, 31 August, 1 September) will be devoted to an open forum designed to develop a wide-ranging discussion, centred on keynote speakers, to examine the present status, objectives, and available capabilities in 'blue water' oceanographic and nearshore marine studies in Australia, and to ask the question 'Whither?'

The open forum will comprise three sessions chaired by Dr G. Humphrey, Marine Biochemistry Unit, CSIRO; Professor K. Stark, Professor of Systems Engineering, James Cook University; and Mr B. S. Newell, Project Director Gippsland Regional Environmental Study, Ministry for Conservation, Victoria.

Session 1: The Oceans and Australia's Continental Shelf. For three or four topics of scientific and resource interest (e.g., Oceanographic research; Fisheries; Offshore mineral resources), speakers will review the present status of research; foreshadow problems which need to be tackled; and examine whether we are equipped and competent to carry out these tasks. In particular, this session will also focus on questions and recent developments related to the Law of the Sea, and will consider the added scientific responsibilities should Australia make claims.

Session 2: Nearshore Australia — Zone of Human Interaction. This session will attempt to examine the activity in nearshore marine environmental research, and keynote speakers will present reviews, including objectives, scientific results, and implementation of recommendations, of two contrasting studies — Botany Bay and Westernport Bay.

Session 3: Priorities and Programs for the Future. A number of speakers will make brief presentations on important and even controversial issues such as national needs, planning, and oceanographic research; recent planning for continental shelf dynamics and sedimentation studies; marine research and teaching institutes, and their development in Australia; ship resources and needs; and co-operative international programs. This session will give many people the opportunity to raise issues of importance to Australia's future effort in marine studies.

Poster sessions which will give workers in all fields of marine science an opportunity to present technical and research results or any general material will be held in conjunction with the open forum. Times when the authors can be in attendance at their display to explain or elaborate their work will be arranged. For allocation of space, please contact the Convener, Mr M. A. H. Marsden, Geology Department, University of Melbourne, Parkville, Victoria, 3052.

The Marine Ecology Session of the 48th ANZAAS Congress will be held on 1 September 1977 under the chairmanship of Professor F.H. Talbot, School of Biological Sciences, Macquarie University. The program is:

9.15- 9.50: Dr A.C. Heron (CSIRO Division of Fisheries and Oceanography).
Life-history strategies in varying environments.

9.50-10.25: Mr G.D. Parry (University of Melbourne).
Life-history strategies of intertidal limpets.

10.25-11.00: Dr P.J. Leviten (University of Sydney).
Habitat partitioning, release and compression can be consequences of a model of population dynamics which does not assume resource limitation.

11.30-12.00: Dr P.F. Sale (University of Sydney).
Relative importance of competition and chance in determining community structure for reef fishes.

12.00-12.30: Dr R.H. Bradbury (University of Wollongong).
The beginnings of a general theory of community structure.

12.30- 1.00: Professor F.H. Talbot (Macquarie University).
Chance and space in coral reef fish colonisation.

Further information can be obtained from: Greg Parry, Zoology Department, University of Melbourne, Parkville, Victoria, 3052. Telephone: 341 7042.

The International Decade of Ocean Exploration (IDOE) will end as scheduled in 1980. Plans are now under way to design the ocean research program that will follow the IDOE. The goal will be to identify promising directions for marine research, their potential contributions to national ocean interests over the next five to ten years, and the management approach most appropriate for carrying out these programs. The basis for this planning effort will be four workshops in each of the major oceanographic disciplines, physical, biological, chemical, and geological. A final workshop, planned and organised by the U.S. National Academy of Sciences, will bring together the recommendations from these workshops and report them to the National Science Foundation in late 1977. The Office for the IDOE invites the interest and participation of the scientific community in planning for the post-1980 program. Comments, recommendations, and requests for additional details may be sent to: Head, Office for the International Decade of Ocean Exploration, National Science Foundation, Washington, D.C., 20550, U.S.A.

These comments and suggestions will be available as part of the background for these planning activities.

The 'Technomar 77' Exhibition will be held in Geneva from 17 to 23 September 1977. Technomar 77 is devoted to marine-oriented topics with special regard to oceanography and marine research, utilisation of sea resources, desalination plants and related technology, ship-building, maritime communications, harbour and port facilities construction and planning, sea pollution control and related fields. The organising committee welcomes the participation of Australian public and private organisations in 'Technomar 77'. Further enquiries to the Embassy of Italy, Canberra.

The XIII International Botanical Congress is to be held in Sydney in August 1981.

The Marine Pollution Studies Group, originally a section within the Fisheries and Wildlife Division, Ministry for Conservation, Victoria, and the **Marine Chemistry Unit**, Department of Agriculture, Victoria, have recently been moved into the central administration of the Ministry. New administrative arrangements are being studied and it is expected that details of the new structure within the Ministry will be announced later this year.

Dr James A. Blake, of the Pacific Marine Station, University of the Pacific, California, is working at the Marine Pollution Studies Group, Melbourne, with Dr Jerry Kudenov on the systematics and larval development of spionid polychaetes. He arrived in February and will be here for about six months.

Dr Leon Collett, AMSA's Assistant Secretary and until recently with the N.S.W. State Fisheries, has taken up his duties with the Marine Pollution Studies Group as Project Leader of the Gippsland Lakes Study. Dr Collett will be responsible for the development of the marine ecological research projects for the Lakes to be carried out by the

Group's staff. He will work closely with Mr Brian Newell, Project Director of the Gippsland Regional Environmental Study.

Ms Dione Gilmour, a producer with the ABC's Natural History Unit, has been invited to help plan and research some programs in a thirteen-part BBC television series on evolution. In April she left for a three-month stay with the BBC's Natural History Unit and Oxford Scientific Films, who are located near the historic university town.

Dr Jack Greenwood has been in Britain on six-months' study leave from January to June 1977. He was situated at Cambridge University, working primarily with Dr Barnes on the plankton at Scott Head Island.

Mr Brian Lassig, a postgraduate student in the Department of Zoology at the University of Queensland, has received an award from the Great Barrier Reef Committee, which enabled him to attend the International Congress on Coral Reefs held in Florida in May, when he presented a paper on his studies on habitat selection by coral-inhabiting gobies.

Mr Roly McKay, of the Queensland Museum, was able to join the Japanese Fisheries Agency Research vessel *Kaiyo Maru,* which trawled on the Norfolk ridge. A number of new species of fish were added to the museum collection.

Mr D.J. Rochford has been appointed Chief of CSIRO Division of Fisheries and Oceanography. He will assume his responsibilities on 15 August 1977.

Professor Jim Thomson will be in Britain in July, when he expects to finish off an almost complete revision of Mugilidae in a few weeks at the British Museum (Natural History). From then until he returns to Australia in December, he will work with an interdisciplinary group concerned with water pollution in France.

Dr J. Verseveldt, a world authority on octocorallian taxonomy, visited the Roche Research Institute of Marine Pharmacology during March and April of this year. Octocorals or Alcyonarians form a section of the Coelenterate Class Anthozoa. They are for the most part colonial organisms having polyps with eight pinnate tentacles. The term 'soft corals' often loosely applied to this group should more correctly not pertain to the gorgonians, sea pens or blue coral, but to the remainder. Occurring predominantly in warm, tropical waters they occupy a large proportion of coral reef biomass. Dr Verseveldt and RRIMP scientist Phil Alderslade examined in detail 73 preserved specimens at the Research Institute. Of these, 25 are thought most likely to be new species, but further investigation by Dr Verseveldt is required in the Netherlands, where he has type reference material, before this statement can be confirmed. Even in the remaining 48 species there are several tentative identifications, and follow-up studies with type material are required. This situation typifies the problems currently faced in this field of taxonomy. During the visit, Dr Verseveldt and Mr Alderslade spent several days at the Australian Museum, assisting in the identification of its collection to the level of genus, reclassifying much of the material. Mr Alderslade and Dr Jim Lowry, of the Museum, will continue to work on this task. Dr Verseveldt, together with Professor Frederick Bayer of the Smithsonian Institution, is undertaking to standardise the as yet still confusing mixture of terminology involved in octocorallian taxonomy. It is hoped that the visit by Dr Verseveldt, together with the contacts established at Australian museums, universities and at AIMS will stimulate collaborative study of the field of octocorallian taxonomy in Australia. Phil Alderslade will pursue this aspect as his research project within RRIMP, where the practice of collaboration of their scientists with colleagues in research and teaching institutions is well established.

Mrs Carden Wallace has resigned from the Queensland Museum after six years as Curator of Lower Invertebrates, but she is maintaining her research on the coral genus Acropora.

THE GREAT BARRIER REEF COMMITTEE POSTGRADUATE RESEARCH GRANTS, 1977

Applications are called for *The Great Barrier Reef Committee Postgraduate Research Grants* intended primarily to encourage field work on the Great Barrier Reef as part of the study for a higher degree at a recognised tertiary institution in Australia.

Value and Tenure

Each award is of $A300 per year. It is tenable for one year but may be renewed, subject to a recommendation of the Selection Committee based on the progress report, for the second year or in exceptional circumstances for the third year. Usually three students will be awarded grants in any one year. The University of Queensland and Great Barrier Reef Committee Heron Island Research Station will provide free accommodation and bench space at Heron Island for the grantees.

Eligibility

Any postgraduate student enrolled or about to be accepted for a higher degree (Master's or Ph.D. program) to work on any scientific aspect of the Great Barrier Reef at an Australian University or Institute of Advanced Education is eligible. The applicant must have or anticipate having the normal institutional support for the degree work and an academic supervisor willing to accept responsibility for the proper supervision of the program and the spending of the grant.

Conditions of the Awards

(a) The grantee shall submit a report on the supported program, endorsed by the supervisor, to the Council of the G.B.R.C. within six weeks of the termination of the grant (unless the grant is renewed).

(b) The grantee shall submit a progress report, endorsed by the supervisor, when applying for renewal or upon request by the Council during the course of the study.

(c) The supervisor of the grantee may be asked to comment further on the grantee's report.

(d) If the approved program was not initiated or was terminated for any reason during the calendar year any unspent amount of the grant should be returned to the G.B.R.C.

Application for Grants

(a) Closing date for receipt of application is 30 September 1977.

(b) Applicants should write to the Honorary Secretary of the Great Barrier Reef Committee (Dr Peter F. Sale, School of Biological Sciences, University of Sydney, Sydney, N.S.W., 2006) stating name, age, present degree enrolment, supervisor's name, a research plan approved by the supervisor and enclosing a certified academic record and any other relevant information which they may wish to furnish.

(c) Applications must be accompanied by a statement from the supervisor —
   (i) approving the research plan, and
   (ii) undertaking responsibility for the proper spending of the grant by and for the student alone in accordance with the relevant Institution's practice regarding expenditure for postgraduate research.

(d) **Applications for renewal**
Should be accompanied, in addition, by a progress report of the support program with endorsement of the supervisor. Award for the second year is not automatic upon application and award for the third year may be made only in exceptional circumstances.

MARINE BIOLOGY AT THE UNIVERSITY OF ADELAIDE

by A. J. BUTLER and D. P. THOMAS
University of Adelaide

Zoology Department

In the Zoology Department Paul Zed is writing up his Ph.D. thesis on the environmental physiology of the western king prawn. Dave Bayliss is about to begin writing up his work on interactions between the gastropod *Lepsiella vinosa* and two species of barnacles in a mangrove swamp. Bob Ainslie has finished a thesis about oxygen transport in three species of abalone.

Steve McKillup is analysing the genetic and ecological consequences of avoidance responses which differ between populations of the marine snail *Nassarius pauperatus,* and Alice Kay is continuing her program of field experiments on the dynamics of sessile fauna of jetty piles. Alan Butler is analysing preliminary records of epibiota of the bivalve *Pinna* and, jointly with John Brewster, preliminary data on growth rates and population structure of *Pinna* at one site. Subsequently Mick Keough will study the dynamics of the epibiota of *Pinna* as a Ph.D. project and Alan will concentrate on the ecology of *Pinna* itself. Peter Davis (Department of Medicine) and Alan Butler are also working on the concentration of heavy metals by *Pinna*. Both will soon be off on study leave for the rest of 1977.

Dierdre Coombe is planning a Ph.D. project on the interactions between colonial ascidians when the colonies abut. Jeremy Browning grew tired, after last year, of working on the evolution of haemoglobin function in skates and is now working instead on their circulatory systems, as well as those of cephalopods. Mike Coates is still working on the haemoglobins, and Chris Bell has joined him to look at possible urea recycling in elasmobranchs.

Botany Department

Marine botanists are still recovering from yet another Biology of Marine Plants summer course. Professor Womersley spent the latter part of 1976 on study leave which took him around the world to catch up with various phycologists in the Northern Hemisphere. We understand he is now contemplating joining the crowd which will be assembling in August at Santa Barbara, California, for the ninth International Seaweed Symposium. Steve Skinner is well under way with his study of tiny brown algae (and would be grateful for any samples). Dave Thomas has finally reached the stage of writing up his thesis on estuarine epiphytic diatoms.

AIMS

Research Programs

Research programs at the Australian Institute of Marine Science (AIMS) fall into the following areas:

1. Tropical marine food webs
   (a) Mangrove ecosystems
   (b) Inshore primary production
   (c) Zooplankton behaviour and physiology.
2. Reef-building organisms and the Great Barrier Reef
   (a) Coral taxonomy and morphology
   (b) Calcification in corals and coralline algae
   (c) Descriptive reef morphology.
3. Tropical marine pollution
   (a) Heavy metal detoxification mechanisms
   (b) Organochlorine compounds in reef biota.

In addition to the programs noted above, AIMS is also interested in studies on microscale currents in and around coral reefs, and oil pollution in tropical ecosystems.

Visiting Scientist Program

A visiting scientist program whereby investigators from other institutions spend some weeks to several months at AIMS conducting research exists to supplement in-house research. Some financial assistance, including travel support, may be available, depending on other sources of funding available to the investigator; space and assistance may also be provided for scientists on fellowships from other institutions. Priority is given experienced scientists in fields which would contribute to the overall research objectives of the Institute. Further information, including details of on-going research programs and the visiting scientist program, may be obtained from the Director, AIMS, Private Mail Bag 3, M.S.O., Townsville, Queensland 4810.

Monograph Series

The first volume of this series is now available; two more volumes are planned for publication in 1977. A summary of each volume follows.

Volume 1. Scleractinia of Eastern Australia, Part I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae. J. E. N. Veron (AIMS) and M. Pichon (James Cook University of North Queensland).
The first of four volumes describing and cataloguing the scleractinian corals of the Great Barrier Reef region. Emphasis is placed on the study of environmentally induced skeletal growth form variations, termed 'ecomorphs', and clarifying the complex intraspecific variations which have created a long history of confusion in the taxonomy of corals. Collections have been made from representative areas of the Great Barrier Reef. Six genera of 18 species are included.

Volume 2. A Review of the Physical Oceanography of the Great Barrier Reef and the Western Coral Sea. G. L. Pickard (Director, Institute of Oceanography, University of British Columbia, Canada), J. R. Donguy, D. Henin and F. Rougerie (all from Section d'Oceanographie, ORSTOM Centre de Noumea, New Caledonia).
An extensive review of available published and unpublished information on the physical oceanography of the region, including that at ORSTOM; Bureau of Meteorology (Melbourne); and CSIRO Division of Fisheries and Oceanography (Cronulla, N.S.W.). Because the two regions are sharply different topographically (the first being a reef-studed strip of shallow coastal water, generally well mixed vertically, while the second is chiefly 1000 to 5000 m deep with marked water structure in the vertical), they are treated separately. Subjects covered include: topography, climate, water properties (surface and subsurface), and circulation.

Volume 3. Scleractinia of Eastern Australia, Part II. Families Faviidae, Trachyphyllidae. J. E. N. Veron, M. Pichon, and Maya Wijsman-Best (Curator of Coelenterates, Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands).

The Faviidae is one of the most important families of hermatypic corals. It is the biggest in terms of number of genera and ranks next to the Acroporidae in number of species and overall abundance in most reef biotopes throughout the Indo-Pacific. The taxonomic history of this group has been long and complex because of their abundance and diversity and also because of the wide variations in skeletal structure shown by many species. The result has been a succession of exceedingly complex and obscure synonymies and an enormous number of nominal species. The present volume is based on a study of approximately 3600 specimens combined with extensive field studies throughout the region. Sixteen genera of 63 species are involved.

Requests for Volume 1, enclosing payment of $4.70 plus postage (60c within Australia, 80c surface mail overseas), may be sent to the Australian Institute of Marine Science, Private Mail Bag 3, M.S.O., Townsville, Queensland, 4810.

GIPPSLAND REGIONAL ENVIRONMENTAL STUDY

by B. S. NEWELL
Environmental Studies Section, Ministry for Conservation, 240 Victoria Parade, Melbourne, 3002

The Gippsland Regional Environmental Study (GRES) is one of three marine environmental studies being conducted in Victoria. The first concerned Port Phillip Bay and was carried out by the Melbourne and Metropolitan Board of Works and the Fisheries and Wildlife Division. The study was designed to predict the environmental effects of discharge of sewage effluent into the Bay at Carrum. Eventually the sewage outfall was diverted into Bass Strait at Cape Schank, but the study continued because there were other environmental concerns, notably the effects of discharges from the Werribee Sewage Farm and the Yarra River and the effects of industry around Corio Bay, a bay in the south-west of Port Phillip Bay.

The first phase of the Port Phillip Bay study lasted from 1968 to 1970 and is continuing on a much reduced basis. The results seem to indicate that most of the Bay is in a healthy condition and that deterioration is confined to a few areas adjacent to noxious discharges.

Phase 1 of the Westernport Bay Environmental Study, directed by Dr Shapiro, was inaugurated because of the plans to develop a deep-water port in the Bay and to industrialise the western shore. As with the Port Phillip Study, the initial emphasis was on aquatic problems but it was soon realised that what happened in the Bay reflected what was happening in the catchment.

Phase 2 of the Westernport Study is being concentrated on critical areas such as the seagrass and mangrove beds and on the effects of land-use on the ecological and physical stability of the Bay.

The Gippsland Regional Study is being managed by the Environmental Studies Section of the Ministry for Conservation, Victoria. The Section consists of a Director of Studies, three Regional Project Directors, and sixteen Core Group Staff whose expertise ranges through biology, engineering, data processing, chemistry, economics, sociology and soil science. The function of the section is to supervise contract research work. This involves determining what work needs to be done, who is best qualified to carry it out, how the work should be done, its cost and the interpretation of the results for management purposes. Some in-house research is also conducted by the section.

The lessons learnt in organising the Port Phillip and Westernport studies have been applied in the initial organisation of GRES. The sort of questions that must be asked before seeking Government support for a study are:

- What is known about the region at present?
- Are there any environmental hazards or conflicts?
- What proposals are there for resource development?
- What are the likely future conflicts and development hazards?

We can illustrate this process in the case of GRES. For example, it can immediately be said that there are five major resource uses in the catchment: water-use; brown coal mining and power generation; agriculture and fisheries; tourism; and forestry.

Water-use

Of the 365 million megalitres per year of water flowing into the Gippsland Lakes ,about 10% is diverted for man's use. About 304 000 Ml/year are used for irrigation and 72 000 Ml/year for all other purposes such as industry and urban consumption. By the year 2000, if the Loy Yang Power Station project is fully developed, some 22% of inflow to the Lakes will be diverted. This would be increased to 28% if all proposed irrigation extensions are implemented. Most of the water to be diverted flows into Lake Wellington and, in fact, the reduction in flow to Lake Wellington in the year 2000 could be 34%. All these figures are based on average annual flows. If account is taken of year to year and seasonal fluctuations in rainfall and river-flow, the constant diversions form a variable proportion of inflow. In fact, in a 'typical' February, total diversions by the year 2000 would amount to 67% of inflow to Lake Wellington. To this must be added the losses due to evaporation, which in February are about 15% of the inflow. The effect of such massive diversions would be to concentrate the runoff loads in a smaller volume so that there would be poorer flushing and a tendency to a higher concentration of pollutants. It is likely that the temperature range would widen and oxygen levels decline. Higher salinities, which might affect peripheral vegetation (e.g. rushes), deposition of silt and the distribution of plants and animals, will occur in Lake Wellington. Reduction of inflow will also affect the wetlands where the thousands of water-birds associated with the Lakes make their home.

Brown Coal Mining and Power Generation

The Victorian Government Statement of Planning Policy No. 9 states clearly that resources of brown coal in the Latrobe Valley will be exploited and that this resource will have priority over other land-uses. Work on the Loy Yang Power Station will start soon and by 1992 the 4000 Megawatt Station should be complete. The obvious and immediate environmental impact of this is, of course, the alienation of land at the open-cut mine and restoration of the site. The secondary environmental impacts are caused by the need for clean water and the discharge of warm and saline wastes.

In addition to power stations, there is the possibility that liquefaction and gasification plants, using brown coal as raw material, will be constructed. At present these processes are only marginally economic but technically feasible. It is also possible that extractive by-products, such as hydrocarbons, char and solvent-refined-coal could be produced.

Agriculture and Fisheries

Agriculture is historically and traditionally an important activity in Gippsland. In the catchment some 800 000 ha are farmed in 5120 holdings. The value of produce in 1973-74 was $73.5 million. The future of agriculture is hard to foresee in the present world economic climate, but it must be accepted that there will always be a need for food and it is likely that production will increase in future. This is more likely to be obtained by expansion of irrigation rather than of the total cultivated area. The environmental impact of farming is, of course, removal of the original environment, but farming can also, with bad practices, result in erosion and in deterioration of rivers. The Gippsland Lake fisheries are very small (in value about $200,000) and are unlikely to change in magnitude in the foreseeable future unless aquaculture is introduced.

Tourism

The Lakes catchment in its alpine region and the eastern lakes area is an important tourist and recreational resource. In 1974-75 some 360 000 visitors spent 2.4 million nights and $12.5 million in the catchment.

Such a valuable industry, with minimal environmental impact (when controlled) would seem worthy of encouragement and development.

Forestry

Saw-log and pulpwood production are important activities for the largest area of the catchment. Saw-log production in the last year of records was 330 000 m^3 worth $24.5 million. By contrast pulpwood production amounted to 175 000 m^3 worth $5 million. The plans to increase this to around 460 000 m^3 by 1983 have obvious implications for forest diversity, wildlife and erosion. Much of the predicted increase in pulpwood production must come from pines so there is a potential conflict in land-use for native forests and agriculture.

These five resource-uses, as well as most other aspects of life in the catchment, involve a large number of Government agencies. For example, within the Ministry for Conservation alone, five agencies have data-gathering or regulatory roles in the region. The agencies and their roles are:

National Parks Service — protection of unique flora and historic sites, provision of recreational facilities and restoration.

Land Conservation Council — recommendations on the use of public lands.

Soil Conservation Authority — erosion control, 'land capability' systems.

Fisheries and Wildlife Division — commercial and recreational fishing, wildlife reserves and game shooting.

Environment Protection Authority — regulation of emissions.

Several other Ministries also concerned with the region include:

Ministry of Fuel and Power (State Electricity Authority) — brown coal and water exploitation.

Department of Agriculture — land-use.

Forests Commission — saw-logs, pulpwood, unique flora, wildlife and recreation.

Ministry of Water Resources — irrigation and river improvement (State Rivers and Water Supply Commission) and the Thomson Dam (Melbourne and Metropolitan Board of Works).

Department of Public Works, Ports and Harbors Division — dredging, foreshore protection and maintenance of the Lakes as a port.

Department of State Development — industrialisation, urbanisation and tourism.

Ministry of Transport (Country Roads Board) — roads.

Town and Country Planning Authority — ultimate responsibility for land-use, promulgation of draft planning policies.

The Ministry recognised the accumulated knowledge and expertise residing within the above agencies and some other government institutions and with some individuals. It was therefore resolved to conduct a preliminary planning exercise called 'The Desk Study' in which about 80 individuals from more than 40 institutions took part. The participants chose to contribute to one of six sections:

Existing systems. This section was devoted to collecting all information describing the Gippsland catchment.

Resource uses and demand pressures. This section assessed the present rate of exploitation of resources and the likely future rates.

Critical parameters. This group selected population, energy and water as the fields containing most critical issues and potential conflicts.

Interrelationships. The work of this group was to examine how any one activity (e.g. water-use) affected other activities.

Options. Several dozen possible activities or courses of development were suggested and their probable consequences were estimated.

Comparison of options. This group examined the working papers of all other sections to present a summary comparison of the issues facing the study.

At present the reports of the six sections and the 120 working papers are being edited into an integrated report which will describe the catchment, present the principal environmental conflicts and make recommendations for the conduct of GRES.

A condensed version of the Desk Study Report in the form of a 50-page illustrated popular brochure is being prepared by a Consultant. The purpose of this will be to present the region and the study in concise readable form to the public, administrators, industry, councillors and politicians.

During the course of the Study, some 1200 references to sources of information about the catchment were accumulated. These have been catalogued by Royal Melbourne Institute of Technology and printed as an 'Information Directory'.

Even at this stage, it is fairly safe to say that the recommendations for GRES will result in investigations in three main areas: water-use, land-use, and socio-economics.

The water-use studies will cover quality and quantity of river-flows, the chemical system of the Lakes including pollution, circulation and material transfer in the Lakes, sensitive species of flora and fauna in the Lakes and rivers, suspended solids, siltation rates and erosion, wetlands and waterbirds, lakeshore vegetation, weed and plankton growth and eutrophication and, finally, fisheries.

The land-use studies should cover the sensitive species and areas for native flora and fauna and erosion and runoff.

The socio-economic field will consist mainly of offering co-ordination of information and investigations in demography, employment, education, services, transport and communications, tourism and recreation.

Some 21 tasks or investigations have already been started, of which about seven are complete. These tasks are:

Aerial photography. A large part of the lakes and the surrounding land surfaces have been photographed from the air to fill gaps and update existing aerial maps.
Mapping. Several new maps of the catchment or parts thereof have been commissioned from Crown Lands and Survey or the Ministry's Central Draughting Office.
Geology. An officer seconded from the Mines Department has completed a review of the geology of the catchment.
Groundwater. The same officer has also reviewed the limited data available on the groundwater resources of the region.
Climate. The Commonwealth Bureau of Meteorology has compiled a climate summary for the catchment covering rainfall, temperatures, winds, frosts, etc.
Residents survey. Fifty residents of Paynesville were asked for their views on present use of the Lakes and various proposed developments in the catchment such as subdivisions, the Thomson Dam and Loy Yang Power Station.
ABC TV film. The services of the Oxford Scientific Film Unit were obtained for a reconnaissance of the catchment. A scenario for four half-hour TV films depicting the natural history of the area is being compiled.
Terrestrial vegetation. The University of Melbourne, Botany Department, has completed a survey of the native trees and flora in the southern half of the catchment.
Aquatic vegetation. The University of Melbourne, Botany Department, has also surveyed the type and extent of submerged plants throughout the Lakes.
Sediments. The University of Melbourne, Geology Department, has surveyed the bottom deposits of the Lakes.
Lakes chemistry. The Latrobe Valley Water and Sewerage Board conducts sampling and analysis of water at 23 stations throughout the Lakes each month.
Input streams. The SRWSC is gauging and sampling the lower reaches of all eight rivers flowing into the Lakes.
Thomson River invertebrates. The National Museum is surveying the distribution, species occurrence and habitat of invertebrates throughout the Thomson River course.
Fishes of the Tambo and Thomson Rivers. The Fisheries and Wildlife Division is comparing the fish species, numbers and distribution in the Tambo and Thomson Rivers.
Pattern of recreational fishing. The Fisheries and Wildlife Division is conducting a census of amateur anglers on the Lakes to determine numbers, places fished and quantities and types of fish caught. The results will be compared with data on commercial fishing.
Tourism and recreational survey. The Gippsland Institute of Advanced Education is reviewing all existing data and ongoing studies on tourism in the region and will attempt to produce methods for analysing and interpreting these data.
Pilot surveys of benthos. The Marine Pollution Studies Group has made a brief reconnaissance of the bottom-dwelling animals in the Lakes.
Bioassay of Phytoplankton. The Marine Pollution Studies Group has investigated the trace element requirements of phytoplankton algae in the Lakes. It appears that nitrogen is probably the limiting element.
Directory of terrestrial vertebrate fauna. An officer of the Studies Section is compiling a list of all current research into this topic.
Natural runoff. An officer of the Studies Section is editing all available data on runoff in the Latrobe catchment to estimate the proportion of plant nutrients provided by uncultivated areas.
Ninety Mile Beach profiles. The Geology Department of Monash University is measuring beach profiles from Corner Inlet to Lakes Entrance to determine regions of dune instability and sand movement.

MARINE BIOLOGICAL RESEARCH IN THE SCHOOL OF BIOLOGICAL SCIENCES OF THE UNIVERSITY OF SYDNEY

by D. T. ANDERSON
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Marine biological research has increased substantially in the School of Biological Sciences, University of Sydney, during the last few years. Eighteen members of staff, thirty-seven research students and currently six honours students are working in this area. The following paragraphs provide a synopsis of people, projects and publications in marine biology in the School during 1977.

Intertidal ecology

Dr Tony Underwood is investigating factors affecting the density and distribution of intertidal gastropods. He is currently attempting to relate food availability, density, dispersion patterns and non-larval dispersion to growth rates, mortality and intertidal zonation. Studies are also being carried out on aspects of community structure, the effect of wave action on patterns of distribution at different levels on the shore and the effect of gastropod grazing on algal distribution. Tony is supervising the following research student projects in intertidal ecology:

- Bob Creese (Ph.D.) — population ecology of patellid and acmaeid limpets, and taxonomy and distribution of acmaeids;
- Michael Moran (Ph.D.) — predator prey interactions between carnivorous whelks *(Morula, Dicathais)* and barnacles *(Tetraclita, Chthamalus, Chaemaesipho)* and *Galeolaria.*
- Kerry McFadyen (M.Sc.) — population biology of the small littorinid *Littorina infans.*
- Eugene Benham (M.Sc.) — population biology of two intertidal species of the carnivorous naticid snail, *Polinices.*
- Duncan Mackay (Hons. 1976) — role of homing behaviour in the population ecology of the limpet *Cellana tramoserica.*
- Elisabeth Denley (Hons. 1977) — factors affecting survivorship of juvenile barnacles *(Tetraclita)* in relation to zonation, competition and predation.

Coral reef ecology

Dr Peter Sale is studying the ecology of reef fish communities with particular reference to the mechanisms allowing coexistence of closely related species, and the importance of patterns of recruitment in determining species composition at particular sites. He is supervising the following research student projects on reef fishes:

- Robina Cummins (Ph.D.) — behavioural ecology of a guild of gobioid fishes which live in commensal association with burrowing alpheid shrimps.
- David Williams (Ph.D.) — ecology of planktivorous pomacentrid fishes, with particular reference to patterns of feeding in coexisting planktivores.
- Peter Doherty (Ph.D.) — recruitment of juvenile fishes to coral reef sites.
- Rand Dybdahl (M.Sc.) — behavioural interactions between two coral reef blennies which constitute a Batesian mimic pair.

In addition, Peter Sale, with Miss Paulette McWilliam and Professor Don Anderson, is investigating aspects of the ecology of coral reef zooplankton at Heron Island and One Tree Island, with particular reference to the reef-generated plankton, its diversity and distribution and its role as a food source for reef planktivores.

Mrs Sue Talbot (with Professor Frank Talbot of Macquarie University) is carrying out similar studies on the lagoon plankton of Lizard Island, with particular emphasis on the mysid populations of the lagoon and the Outer Barrier.

Dr Roger Bradbury, Queen Elizabeth II Postdoctoral Fellow in Marine Sciences (now on the staff of Wollongong University, is investigating the phenomenon of patchiness in corals, and also the interactions among different components of the reef system, especially fishes, corals and molluscs.

Dr Paul Leviten, Queen Elizabeth II Postdoctoral Fellow in Marine Sciences, is studying the effects of fish predation and habitat complexity on invertebrate diversity and abundance on coral reefs.

Rob Day (Ph.D., supervised by Professor Charles Birch) is investigating the distribution and diversity of opportunistic settling organisms (algae, ascidians, bryozoans) on coral reefs.

Dr Tony Larkum is investigating the role of benthic algae in the productivity of coral reefs.

Estuarine Biology

Dr Gordon Grigg is working on the ecology and natural history of the crocodile *Crocodylus porosus* in the Northern Territory, and is also carrying out physiological studies on the cardiovascular system, ionic and osmotic regulation and thermal regulation in crocodiles. Research students associated with this project are:

Bill Magnusson (Ph.D., supervisor Dr Graeme Caughley) — nesting biology and ecology of *Crocodylus.*

Janet Taylor (M.Sc., supervisor Dr Gordon Grigg) — food and feeding of juvenile *Crocodylus.*

Dr Pim Lanzing is investigating the biology of estuarine fishes in N.S.W., with present emphasis on the luderick, *Girella tricuspidata.* He is supervising the following research student projects:

Geoff McDonald (Ph. D.) — ecology of the goby *Favonigobius lateralis.*

Bill Douglas (Hons. 1977) — regulation of colour patterns in flathead, family Platycephalidae.

Margaret Conacher (Hons. 1977) — grazing of fishes in *Posidonia* beds.

Angela Ivanovici (Ph.D., supervisor Underwood) — measurements of physiological stress in estuarine molluscs, using adenylate energy charge and other biochemical parameters.

Andy Heron (Ph.D., seconded from CSIRO Cronulla, supervisor Dr A. W. Meats) — population ecology of the marine cladoceran *Penilia.*

Peter Cameron (M.Sc., supervisor Underwood) — seasonal pattern of density, distribution and settlement of bivalve and gastropod larvae of Port Hacking.

Neil Carrick (M.Sc., working at the Australian Museum, supervisor Anderson) — distribution and population studies on benthic gastropods, with special reference to the turritellid genus *Gazameda.*

Peter Collis (M.Sc., supervisor Dr A. C. Hodson) — benthic faunal studies in the Hawkesbury estuary.

Lyle Vail (M.Sc., supervisor Sale) — settlement and community structure of bryozoan communities in Sydney Harbour.

Vicki Wadley (M.Sc., working at CSIRO, Cronulla, supervisor Underwood) — seasonal changes in community structure of the benthos of Port Hacking.

Lucy Hodgson (Hons. 1977, supervisor Anderson) — feeding mechanism of the Sydney rock oyster *Crassostrea.*

Mangrove Biology

Dr Bill Allaway is working on the influence of oil and dispersants on mangroves in Botany Bay. He is also supervising the work of:

Penny Goulter (Hons. 1977) — nutrient flow in the mangrove *Avicennia marina.*

Graeme Wells (M.Sc., supervisor Dr P. Myerscough) is investigating species distribution and abundance in mangroves of the river systems of northern Australia.

Pamela Muggeridge (Ph.D., supervisor Anderson) is studying the reproductive biology and population biology of the mangrove littorinids *Littorina scabra* and *Bembicium auratum* at Patonga, N.S.W.

Ross Yates (M.Sc., supervisor Underwood) is examining the distribution, density and reproductive biology of four species of mangrove crabs *(Paragrapsus, Heloecius, Sesarma Australoplax).*

Invertebrate Biology

Professor Don Anderson is making a comparative study of the feeding mechanisms of barnacles of the eastern Australian coast.

Associated work is being done by:

Janet Kunze (Hons. 1977, supervisor Anderson) — feeding mechanisms in relation to habitat in six species of hermit crabs (Paguridae).

Dennis Tafe (M.Sc., working at CSIRO Cronulla, supervisor Meats) — feeding mechanisms and particle size selection of planktonic copepods.

Parasitism, Symbiosis and Commensalism

Dr Rosalind Hinde is studying the relationship between saccoglossan opisthobranch molluscs and the active chloroplasts accumulated in the digestive gland of these animals.

Elisabeth Egan (Ph.D., supervisor Anderson) has investigated the relationship between the ascidian *Pyura pachydermatina* and its entozoic associates, *Gononemertes* (a nemertean) and *Pachypygus* (a copepod).

The parasitologists are:

John Walker (M.Sc., working at the School of Public Health, University of Sydney, supervisor Anderson) — host parasite relations between the gastropod *Velacumantus* and various trematodes for which the snail is an intermediate host.

Paul O'Connor (M.Sc., supervisor Lanzing) — parasitic isopods infesting the luderick, *Girella tricuspidata.*

Eric Friese (M.Sc., working at Taronga Park Zoo, supervisor Grigg — host parasite relationships between the variable leatherjacket and the leatherjacket louse (Isopoda).

Developmental Biology

Professor Don Anderson is continuing his interest in the reproductive biology and life cycles of intertidal invertebrates of the New South Wales coast. Recent investigation have dealt with the development of the turbellarian *Notoplana australis,* the marine caddis fly *Philanisus plebeius* and the starfishes *Patiriella calcar* and *Patiriella exigua.* Other developmental projects supervised by Don are:

Sue Franklin (Ph.D.) — developmental biology of the coral reef holothurians *Stichopus* and *Leucospilosa.*

Carolyn Lawson-Kerr (Ph.D.) — embryonic and larval development of the cirripede *Ibla quadrivalvis.*

Roger Nurse (M.Sc.) — embryology of the thalassinid decapod, *Callianassa.*

Bob Rose (M.Sc., supervisor Hinde) is working on the reproduction, embryonic development and larval development of saccoglossan and nudibranch molluscs.

Genetics

Professor Barry Latter is investigating genetic variation in 12 species of Australian prawns of the genera *Penaeus* and *Metapenaeus,* using electrophoretic techniques.

David Killingly (Hons. 1976, supervisor Latter) has employed similar techniques on the ascidian *Pyura praeputialis,* comparing estuarine and coastal forms.

Marine Botany

Dr Tony Larkum is currently working on the growth and productivity of seagrasses on the N.S.W. coast, especially in Botany Bay. He is also investigating photosynthesis in red algae and preparing a handbook of the algae of N.S.W. (with Drs M. A. Borowitzka and R. King). Students being supervised by Tony are:

Ray Ritchie (Ph. D.) — energy relations of *Enteromorpha* growing in spray-zone tide pools.

Ron West (M.Sc.) — productivity of *Posidonia* in Botany Bay and Port Hacking.

Ken Black (M.Sc) — past and present growth limits of *Posidonia* in Botany Bay.

K. Harada (M.Sc.) — growth, productivity and the effects of caging of algae on experimental sandstone blocks.

George Andrew (M.Sc.) — growth and seasonal changes in benthis sub-littoral and littoral algae in Sydney waters.

Associate Professor Roger Carolin and Dr Peter Myerscough are investigating the vegetation of sand surfaces in the Myall Lakes area of N.S.W., the sands being old marine deposits now occupied by terrestrial flora. Roger is also supervising:

Margaret Campbell (M.Sc.) — taxonomy of some of the red encrusting algae of the N.S.W. coast.

Recent Publications and Papers in Preparation

Anderson, D.T., Fletcher, M.J. and Lawson-Kerr, C. (1976). A marine caddis fly, *Philanisus plebeius*, ovipositing in a starfish, *Patiriella exigua. Search* **7**, 483-4.

Anderson, D.T. (1977). The embryonic and larval development of the turbellarian *Notoplana australis* (Schmarda, 1859) (Polycladida: Leptoplanidae). *Aust. J. Mar. Freshw. Res.* **28** (in press).

Anderson, D.T. and Lawson-Kerr, C. (1977). The embryonic development of the marine caddis fly *Philanisus plebeius* (Trichoptera, family Chathamidae). *Biol. Bull., Woods Hole* (accepted).

Anderson, D.T. and Lawson-Kerr, C. The seasonal reproductive cycles of *Patiriella calcar* and *Patiriella exigua* (Asteroidea, Asterinidae) and the embryonic development of *P. exigua.* (In preparation.)

Bradbury, R.H. and Loya, Y. (1977). An heuristic analysis of hermatypic corals at Eilat, Red Sea. *Am. Nat.* (in press).

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Bradbury, R.H. (1977). Complex systems in simple environments; a demersal fish community. Submitted to *Mar. Biol.*

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Bradbury, R.H. Ecological constraints and tropical ecosystems (in preparation).

Borowitzka, M.A. and Larkum, A.W.D. (1976). Calcification in the green algae *Halimeda.* Parts II-IV *J. exp. Bot.* **27**, 880-907.

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Creese, R.G. and Underwood, A.J. (1976). Observations on the biology of the trochid gastropod *Austrocochlea constricta* (Lamarck) (Prosobranchia). I. Factors affecting shell-banding. *J. exp. Mar. Biol. Ecol.* **23**, 211-28.

Day, R. (1977). Two contrasting effects of predation on species richness in coral reef habitats. Submitted to *Mar. Biol.*

Grigg, G.C. and Alchin, J. (1976). The role of the cardiovascular system in thermoregulation of *Crocodylus johnstoni. Physiol. Zool.* **49**, 24-36.

Grigg, G.C. Metabolic rate, Q_{10} and respiratory quotient in *Crocodylus porosus*, and some generalisations about low RQ in reptiles. Submitted to *Physiol. Zool.*

Grigg, G.C. (1977). Ionic and osmotic regulation in the estuarine crocodile, *Crocodylus porosus.* In *Australian Animals and their Environment* (Editors, H. Messel and S.T. Butler) (Shakespeare Head Press: Sydney).

Grigg, G.C. (1977). Thermal relations of the estuarine crocodile, *Crocodylus porosus.* In *Australian Animals and their Environment* (Editors H. Messel and S.T. Butler) (Shakespeare Head Press: Sydney).

Grigg, G.C. and Cairncross, M.H. Some respiratory properties of the blood of *Crocodylus porosus* (in preparation).

Grigg, G.C. Ionic and osmotic homeostasis in a natural population of *Crocodylus porosus* (in preparation).

Grigg, G.C. Ionic and osmotic regulation by *Crocodylus porosus* (in preparation).

Hinde, R. (1977). The metabolism of photosynthetically fixed carbon in isolated chloroplasts of *Codium fragile* (Chlorophyta: Codiales) and in *Elysia viridis* (Mollusca: Sacoglossa). Submitted to *Biol. J. Linn. Soc.*

Hinde, R. Chloroplast symbiosis. In *Australian Species of Elysia* (in preparation).

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Lanzing, W.J.R. Reassessment of chromatophore regulation in two species of flatfish (submitted).

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Larkum, A.W.D. (1976). Some recent research on seagrasses in Australia. In *Seagrass Ecosystems: A Scientific Perspective* (Eds. C.P. McRoy and C. Helfferich). (Marcel Dekker, Inc., New York).

Larkum, A.W.D. (1976). Botany Bay: National Asset or National Disaster. *Operculum* **5**, 67-75.

Larkum, A.W.D. and Weyrauch, S.K. (1977). Photosynthetic action spectra and light-harvesting in *Griffithsia monilis* (Rhodophyta). *Photochem. Photobiol.* **25**, 65-72.

Larkum, A.W.D., Borowitzka, M.A. and Day, R. Production, seasonal changes and succession in turf algae of a coral reef (in preparation).

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Leviten, P. (1976). Effect of habitat complexity on population density and species richness in tropical intertidal predatory gastropod assemblages. *Oecologia* **25**, 199-210 (with A.J. Kohn).

Leviten, P. Resource partitioning by predatory gastropods of the genus *Conus* on subtidal Indo-Pacific coral reefs: The possible importance of prey size. Submitted to *Ecology.*

Leviten, P. Resource partitioning and character displacement without competition (in preparation).

Leviten, P. The influence of enrichment on the stability of predator-prey models (in preparation).

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Magnusson, W., Grigg, G.C. and Taylor, J.A. Definition and distribution of suitable nesting sites of *Crocodylus porosus* in Arnhem Land and the Cobourg Peninsular, Northern Australia (in preparation).
Moran, M.J. and Sale, P.F. (1977). Seasonal variation in territorial response and other aspects of the ecology of the Australian temperate pomacentrid fish, *Parma microlepis*. *Mar. Biol.* **39**, 121-8.
Sale, P.F. (1976). Reef fish lottery. *Nat. Hist.*, **85**, 60-5.
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Sale, P.F., Potts, D.C. and Frankel, E. (1976). Status of *Acanthaster* studies in 1975. *Search* **7**, 334-8.
Sale, P.F. (1976). Changes in diversity of reef fish communities along a local gradient of environmental predictability. *Bull. Ecol. Soc. Am.* **57**, 24.
Sale, P.F. (1976). The effect of territorial adult pomacentrid fishes on the recruitment and survival of juveniles on patches of coral rubble. *J. exp. Mar. Biol. Ecol.* **24**, 297-306.
Sale, P.F. (1977). Maintenance of high diversity in coral reef fish communities. *Am. Nat.* **111** (in press).
Sale, P.F. (1977). Reef fish and other vertebrates: a comparison of social structure. In *Contrasts in Behaviour* (Ed. Reese, E.S.). (Wiley-Interscience, New York) (in press).
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WIND DRIFT AND SURFACE CURRENTS IN THE OCEANS

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One method by which we can get to know something about ocean surface currents is that of keeping track of a drifting object such as a bottle, a plastic card, an iceberg or a drifting derelict ship. Many glass balls, used by Japanese fishermen as floats for their nets, and debris from wrecked Chinese junks have been found along the west coast of North America, from which it can be inferred that a surface current runs from west to east across the Pacific Ocean.

From accidental discoveries like this only qualitative conclusions can be reached; there are too many uncertain factors to permit any quantitative deductions. The time when the object began its journey may not be known, or how long it had been lying ashore before being found. This is illustrated by the following incident. In 1856 the brig *Grifton* was badly damaged in a storm in the Bay of Biscay and in order that necessary repairs might be carried out, she was anchored off a small cape opposite Gibralta. When the captain returned from a hunting trip ashore, he found the sea had risen and it was necessary to ballast the lifeboat with some large rocks found on the beach. One of these 'rocks' turned out to be a small keg barnacled beyond recognition. Inside the keg the seamen found a tarred coconut and in the nut a message, written in Gothic characters on old parchment, from Christopher Columbus to the King and Queen of Spain. This message, which reported the loss of the *Santa Maria* and the mutiny on the *Nina*, had drifted at sea and lain on shore for 358 years.

Observations of drifting pieces of volcanic pumice have been used to calculate the average speed as well as the direction of certain ocean currents. In 1952 Barceno Volcano erupted on San Benedetto Island in the Pacific Ocean off the coast of Central America. Some of the pumice emitted was picked up in Hawaii 264 days later and some more on Wake Island 562 days later. The speed of the North Equatorial Current of the Pacific Ocean, calculated from these figures, averaged 16 km a day.

Probably the longest drift on record was that of a bottle released on 20 June, 1962, at Perth, Australia, and recovered almost five years later near Miami, Florida. It has been estimated that the bottle had travelled some 25 000 km at an average speed of about 16 km per day. The route is unknown, but it was most probably around the Cape of Good Hope, north along the west coast of Africa, across the Atlantic to northern Brazil, north along the South American coast into the Gulf of Mexico, and through the Florida Straits to Miami.

If the object projects appreciably above the water, its movement may be determined just as much by the wind as by the surface current of the ocean. Wind and surface current may have different effects on a drifting object. On 22 June 1892, the schooner *Fred Taylor* broke in two in a collision with the *S.S. Trave*, off Nantucket Island on the east coast of the U.S.A. Both sections continued to drift for about six months but in opposite directions; the bow drifted northwards and eventually went aground on the Maine Coast, north of Boston, while the stern drifted in a south-westerly direction and finally sank in the mouth of Delaware Bay. Altogether, the two sections

drifted some 800 km apart. What had happened was that the forepart of the ship projected well above the surface of the ocean and was driven northwards by the prevailing south-westerly winds, while the stern, which had settled deep into the water, was carried along by the surface current which was running towards the south-west.

The Ekman Spiral

The direction of surface drift in the oceans is not necessarily the same as the direction of the prevailing winds. This was first investigated theoretically around the turn of this century. About 1900 Nansen was evaluating the results of his investigations into the movements of polar ice, in which he had drifted in the ice-bound *Fram* through the Arctic Ocean during the years 1893-96. He noticed that when the wind had blown in a certain direction for a long time, the icebergs did not follow the wind direction but drifted some 20-40 degrees to the right. He came to the conclusion that the action of the earth's rotation, known as the Coriolis force, was responsible for the surface layer of the ocean being deflected to the right of the wind direction, and the icebergs, which have 90% of their bulk below the water surface, moved in the direction of this surface current. He reasoned further that deeper layers of water probably deviated to the right even more than the upper layer, because, just as the upper layer is deflected by the earth's rotation to the right relative to the wind direction, so are the deeper layers of water deflected towards the right relative to the upper layers, and therefore deviate from the wind at an even greater angle than the upper layers.

At Nansen's suggestion a young physicist, Ekman, studied the problem mathematically in 1902. The outcome was a theory of wind-drift currents on infinitely deep water taking account of the earth's rotation. The motions were considered in a plane of infinite extent with winds of constant velocity having blown for a very long time.

The structure of Ekman's pure wind drift currents shows that the surface current points in a direction of 45° relative to the wind. In the Northern Hemisphere the surface water moves in a direction that is 45° to the right and in the Southern Hemisphere 45° to the left when looking in the direction towards which the wind is blowing. For positions below the surface, the current speed decreases exponentially with the depth and varies even more in direction.

Ocean Currents and Navigation

The direction and velocity of surface ocean currents were at first determined from the drift of ships which currents had thrown off their course. Derelict ships, which seamen came upon for many years, also gave an idea of the direction of the currents.

A hundred and fifty seven drifting derelicts were found in the North Atlantic Ocean from 1887 to 1909. In 1910, Captain Hartreux made a special study of these derelict drifts. In his study, he concluded that most of the distance travelled by the derelicts was due to wind which makes their travels of less interest as indicators of surface currents than are the journeys of drift bottles and drift envelopes.

Of special interest is the drift of the half-wrecked sailing vessel *Fanny Wolston*, the travel of which gave evidence of a slow circulating motion of the waters of the Sargasso Sea. In 1891, after a gale, the crew abandoned the schooner not far from Cape Hatteras in North America. During the next three years she was seen 46 times in various parts of the Atlantic. In July 1892 she was sighted off the Azores, where she remained until February 1893 zigzagging to and fro under the influence of the winds and the changeable currents of the area. She then drifted back toward America and from December 1893 to February 1894 she made to-and-fro movements between Cape Hatteras, Bermuda and the Bahamas. After this time she was carried north-eastward by the Gulf Stream, finally sinking in October 1894 after having described a great elelipse and several smaller circuits totalling nearly 13 000 km.

Mariners were familiar with the effect of sea current many centuries ago. For instance, Columbus, who sailed to America in the stream of the North Equatorial Current, has been quoted as saying that the water 'moved westwards together with the sky'. And in the 1760s mariners from the United States knew of the existence of the Gulf Stream; on their way from America to England they sailed with it, while on their homeward run they steered clear of it. As a result they crossed the Atlantic Ocean much quicker than the vessels under English captains. This was noticed by the authorities, and Benjamin Franklin, then U.S. Postmaster-General, was instructed to find the reason. After questioning the seamen involved, he drew up the first scientific chart of the Gulf Stream which was shown as a mighty river flowing across the North Atlantic.

Drift Experiments off Great Britain

A well-known experiment carried out with drift bottles in the North Sea was that of Dr Fulton during the years 1894-97. His work was done for the Fishery Board for Scotland and from the results supplied by the 16% of his 2074 bottles and 1479 labelled wood slips which were recovered, he produced a chart showing the existence of a great cyclonic surface current system in the North Sea.

Fulton's work has been continued on a large scale right up to the present time. Up to 1950 Scottish scientists had put out more than 53 000 bottles. The results of these experiments, which were mostly made in the northern North Sea, have been the subject of a number of reports by Dr Tait of Aberdeen. His reports have shown the seasonal fluctuations in the strength of the ocean current which passes through the Faroe-Shetland Channel into the North Sea and the existence of great eddies in this Sea.

In addition to drift bottles, plastic envelopes have been used on a large scale since the conclusion of the Second World War for the same purpose. Scientists in Britain have used them in the North Atlantic Ocean to find out something about the spread of fuel oil with which ocean tankers often contaminate the seas and beaches of Western Europe, and endanger the lives of countless sea birds.

For instance, the Institute of Oceanographic Sciences division in Surrey uses watertight plastic envelopes containing printed cards requesting the finders to return them to the Institute with information about the date and place of their discovery.

Drift Experiments in the Southern Ocean

As early as 1902, Dr Bruce liberated a number of drift bottles to determine the direction and speed of the surface currents in the Southern Ocean. Two bottles were

found in Victoria and at least one reached New Zealand only to remain undiscovered for 50 years. In September of 1952 it was found more than 200 feet above the present high-water line some three miles south of Rangitiki River in North Island.

Surface drift experiments in the Southern Ocean have been carried out by the Flinders University of South Australia since the late 1960s. For instance, during the last half of December 1969, three batches of 1000 cards each were released from the Japanese Ice-breaker *Fuji* at 40°S, 50°S and 60°S and approximately 110°E. By the following August cards from two of the three batches had been found. Forty-three cards released from a position of 40°S and 115°E had arrived on the south-west coast of Western Australia, the first arriving in the middle of March, some 87 days later and 1000 km from their point of release. These cards gave a minimum mean surface drift speed of about 11 km/day.

In contrast to the north-east drift of these cards, some of the group released three days later at 50°E, 110°E drifted quickly eastward so that two of them arrived approximately 129 days later and 3200 km away at Macquarie Island; their mean speed was about 25 km/day. By August a total of 13 cards from this batch had been found on this small island which is less than 33 km long.

Batches of 500 cards were also set free along longitude 132°E between Australia and Antarctica from the U.S. Navy oceanographic ship *Eltanin* during the summer of 1969-70. Most of them were released close to the Australian mainland; however, two cards from a group released at 50°S on New Year's Day also arrived at Macquarie Island. The first of these was found 104 days after release having travelled 1800 km at a speed greater than 17 km/day. Two cards of another group released at 45°S on 20 January 1970 were found five months later near Hobart having drifted some 1200 km with a mean speed greater than 8 km/day in a north-easterly direction.

Compared to the relatively fast and probably fairly direct drift to Macquarie Island, the motion of cards closer to the south coast of Australia is much slower and more random. In fact, some cards released within 400 km of the coast were not found until some strong westerly storms blew them ashore some four months later.

The existence of north-west long-shore currents in the region west of Kangaroo Island seem to be confirmed by the north-westward motion of floats released south-west of Kangaroo Island at 132°E and 37°S. Some of these floats found their way to Mt. Hope and Port Lincoln, on Eyre Peninsula, and others found their way onto the north shore of Kangaroo Island and even into St. Vincent's Gulf.

Most of the cards released close to the mainland by the *Eltanin* were found progressively further eastward with the passage of time as the prevailing westerly winter winds had a longer time to act. Several of a batch released at 41°S on 22 January 1969 arrived on King Island in Bass Strait after more than 130 days, giving a mean drift of at least 8 km/day. Later still some were found on the coast of Tasmania, west of Strahan.

Some Interesting Cases of Drift

A derelict which added greatly to knowledge of Arctic currents was *La Jeannette*. She passed through Bering Strait to make a study of the Polar Basin and was trapped by ice to the south-east of Wrangel Island on 6 September 1879. Nearly two years later, in June 1881, she sank north of the archipelago of New Siberia. However, in July 1884, Eskimos found on the easternmost parts of Greenland broken boxes of biscuits and other debris from her. This discovery proved the existence of a marine surface stretching from Siberia to Greenland; the ice carrying these materials must have travelled round the north of Franz Josef Land and Spitsbergen and passed not far from the North Pole.

From a knowledge of the drift of *La Jeannette's* stores, and upon a consideration of drifts of other wreckage in the Arctic Ocean, Nansen decided to make the celebrated drift in the vessel *Fram*. After being frozen-in to the north of the New Siberian islands on 29 September 1893, the *Fram* drifted slowly to the north-west with the ice and by the beginning of 1896 she was within 4 degrees of the North Pole. She broke free from the ice on 28 June 1896, to the north of Spitsbergen.

The Soviet ice-breaker *Sedov* is famed for the following great drift in the ice of the Arctic Sea. After being frozen-in in the Laptev Sea on 23 October 1937, fifteen of her crew volunteered to remain aboard. She drifted first to the north and then to the east, through a region not explored up to that time, for more than three years before breaking free of the ice.

It is also of great importance to know everything possible about the drift of free icebergs in seas frequented by shipping. The tragic loss of the *Titanic* in 1912 led to the organisation of the present day Ice Patrol which reports the movement of Arctic icebergs which drift as far south as the Azores in the North Atlantic Ocean. Less well known is that oceanographers in the U.S. Coast Guard periodically prepare charts of currents, based upon hydrodynamical computations, to help them predict how icebergs will travel.

Probably the most publicised ocean drifts of all time were those accomplished by Thor Heyerdahl and his companions, firstly across the Pacific Ocean on the balsa-wood raft *Kon-Tiki* and then across the Atlantic Ocean, in the reed boat *Ra II*. Though Heyerdahl used the winds in that both his vessels had sails of a sort, much of his progress in both cases was in the nature of a drift. Less well known is the fact that some 40 years before these drifts, Franz Romer crossed the Atlantic alone in a collapsible rubber boat, a feat of courage and endurance far exceeding any similar adventure reported since.

Finally it is of interest to note that during the years 1560 to 1800 any person who uncorked a bottle washed ashore on the coast of Britain could have been punished by hanging. This situation arose when, in 1560, a boatman found a sealed bottle on Dover Beach. Being illiterate he took the message he found inside to the local judge. It turned out to be a secret report saying that the Dutch had seized the Russian Arctic Island of Novoya Zembya. After this incident Queen Elizabeth appointed an official 'Uncorker of Bottles' and until this office was abolished in the reign of King George III, any unauthorised person who opened a bottle brought ashore by the sea was committing a capital offence.

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