TABLE OF CONTENTS

ARCHEOLOGY ........................................................................................................... 3
BIOCHEMISTRY ......................................................................................................... 5
BOTANY ..................................................................................................................... 7
CHEMICAL OCEANOGRAPHY/ CHEMISTRY ............................................................ 9
CONSERVATION ....................................................................................................... 11
ECONOMICS ............................................................................................................. 13
ECOTOURISM ........................................................................................................... 16
EDUCATION .............................................................................................................. 18
ENGINEERING ......................................................................................................... 21
ENVIRONMENTAL CONSULTING ........................................................................ 23
FISHERIES: MANAGEMENT, CONSERVATION AND RESEARCH ..................... 25
FOOD TECHNOLOGY ............................................................................................... 29
GEOGRAPHY ............................................................................................................ 32
GEOSCIENCE ........................................................................................................... 37
LAW ............................................................................................................................ 39
MARICULTURE .......................................................................................................... 41
MARINE BIOTECHNOLOGY ..................................................................................... 44
MATHEMATICS, STATISTICS and COMPUTING ................................................ 46
MICROBIOLOGY ....................................................................................................... 48
PARASITOLOGY and PATHOLOGY ......................................................................... 50
PHARMACOLOGY ..................................................................................................... 52
PHYSICAL OCEANOGRAPHY .................................................................................. 54
REMOTE SENSING ................................................................................................... 58
TAXONOMY ............................................................................................................... 60
ZOOLOGY ................................................................................................................... 62
Maritime archaeology is the scientific study of artefact assemblages, sites and structures, which are associated with past human activity and now lie underwater, either beneath the sea or in inland waters. The field has grown considerably in Australia since 1970 and maritime archaeologists are now employed by museums and government agencies in every state and territory. The majority of underwater archaeological sites in Australia are shipwrecks, but prehistoric settlements, sunken land sites, or remains associated with other human activities such as crashed aircraft, are also studied. Maritime archaeologists are trained in the broader discipline of archaeology but usually have special expertise in ships, shipbuilding and maritime history. Most maritime archaeologists working for museums are involved in research, excavation and display, while those employed by government agencies undertake surveys, assessments of the significance of archaeological sites or artefacts, and management of cultural resources. There are also some opportunities in associated areas such as conservation of materials, technical support, photography and in the protection of declared historic shipwrecks.

A National Shipwrecks Program is co-ordinated through the federal Department of the Environment and Heritage. The program aims to increase knowledge, use, appreciation and enjoyment of Australia's historic shipwreck heritage, while also ensuring the continued conservation, protection and preservation of these wrecks and relics.

A career in maritime archaeology normally requires a university degree, preferably in archaeology, history or a related discipline. Many universities offer these curricula. There are a growing number of postgraduate courses in maritime archaeology offered in Australia (particularly Flinders University in Adelaide), including graduate certificate, diploma and Masters programs in addition to affiliated museums. However, postgraduate studies in maritime archaeology towards higher degrees (masters and doctorate awards) can
potentially be undertaken in any university that has a department of archaeology.
Biochemistry is the study of all chemical processes associated with living organisms. In the sea, chemical signals are transmitted within organisms, between organisms and through the water column across a range of distances. Interactions between organisms can be particularly important in close associations, for example, in the symbiotic interactions of microalgae with corals and giant clams, bacteria and microalgae with sponges, and clown fish with sea anemones.

An important area is investigation of biosynthetic pathways, which are the chemical pathways for manufacturing all substances and compounds that organisms produce and are made of. Understanding biosynthetic pathways is fundamental to understanding life itself. Marine biochemistry is not confined to organic chemistry but is also concerned with inorganic elements involved in life processes, which includes study of bioaccumulation of specific elements such as heavy metals and other pollutants.

Biochemists play an important role in the study of the greenhouse effect and global warming by examining the role of photosynthesis in marine plants, especially tiny phytoplankton, in removing carbon dioxide (CO2) from the atmosphere. They also examine the processes that release CO2 from the oceans back into the atmosphere.

The fate of substances produced by photosynthesis is also an important field of investigation. Although photosynthesis does not occur below depths of about 100 metres because of insufficient light, organic production is still considerable in deep water because of the utilisation of dissolved organic matter, mainly by bacteria. This dissolved organic material mostly derives from photosynthesis in surface waters but in special cases can also arise from deep-sea hydrothermal vents. Marine biochemists study the nature of all life process chemicals in the oceans.

Another important field is biogeochemistry. This includes study of the biological and chemical processes involved in the transport of material through the water column to the sediment, its long term storage and modification in the sediment, and whether and how it is subsequently
released. Marine biochemists also study the effects of human activities, including increasing nutrient and sediment loadings in the oceans. Marine biochemical research is mainly conducted in universities, federal government agencies such as CSIRO and the Australian Institute of Marine Science, and in some state and local government agencies.
Marine botany involves the study of a broad range of organisms including flowering plants, algae and fungi. With the exception of fungi, these organisms are all photosynthetic and are therefore restricted to the well-lit upper ocean and inshore regions. Life in the oceans is almost entirely dependent on these photosynthetic organisms, which are known as primary producers. Different kinds of primary producers occur in different marine habitats. In the open ocean the producer organisms are minute, often single-celled, algae called phytoplankton, while larger attached seaweeds, seagrasses, saltmarsh plants and mangroves usually dominate the shallower waters of coastal and estuarine regions.

Some research focuses on the organisms themselves. Examples include investigations of the evolutionary relationships and classification of marine algae and plants using techniques such as molecular biology and ultrastructural research, studies of basic physiological processes such as salt tolerance and photosynthesis, and cataloguing the biodiversity of the unique Australian marine flora.

The ecological relationships of marine plants are studied to understand fundamental processes such as succession and competition, the formation of population 'outbreaks' or blooms, ecosystem productivity, the transfer of energy to higher levels in food webs, and the role of algae in nutrient cycling. Plants play particular roles in specific environments, for example seagrasses and mangroves help to stabilise shorelines, and calcareous algae are major contributors in the formation of coral reefs. Interactions between organisms such as competition, consumer interactions, symbioses, and the production of chemicals that influence the behaviour of grazers or settling larvae also attract considerable attention. At the global level there is great interest in the influence of phytoplankton on world climate and their use as indicators of climatic change.

The role of algae and other marine plants is vital to studies of conservation, human impact, environmental change, and management of the marine environment. This is especially the case in relation to the effects of excessive
nutrients, algal blooms, and the effects of red tides on human health. Marine plants also serve as indicators of environmental degradation. Another important focus in marine botany is the use of marine plant communities as a source of food and shelter for commercial fish and prawns. This interest extends to the culture of microalgae as an essential source of animal food in mariculture. Algae are also mass cultured for human consumption, food additives (colouring and gelling compounds), fodder, pharmaceuticals, and other fine chemicals.

Marine botanists are employed in research or management in universities, departments of agriculture and fisheries, museums, maritime services, water boards, sewerage and drainage boards, the CSIRO, institutes of marine science, and environmental agencies. There are also growing private industries in the areas of environmental consultancy services, mariculture and marine chemistry.
Marine chemists and chemical oceanographers study the dissolved and particle-bound materials in marine organisms and the marine environment. An understanding of marine chemistry is essential for pure and applied research across many disciplines, including the biological and physical sciences. Marine chemists measure the amounts of individual elements or compounds in the sea and determine their physical properties and reactions. This often involves the development of analytical procedures that can be used at sea and in the laboratory. Examples include instruments for measuring levels of carbon dioxide (CO2), dissolved organic carbon, and volatile compounds in sea water. The dynamics of some of these compounds is important to understanding climate.

Determining the amounts of compounds in the sea is not always an easy task, even for commonly occurring substances. For example, analysis of iron levels in sea water is difficult because although iron is essential for all forms of life, it is present at concentrations that may be less than one part per hundred billion. Other important elements and compounds such as magnesium, bromine and sodium sulphate are also obtained from the sea. One cubic kilometre of sea water contains five kg of gold and 1.5 tonnes of uranium, but great advances in chemical techniques are required to make commercial use of these relatively small concentrations. Indeed, the future exploitation of minerals from the sea depends on significant advances in technology.

Another important area of chemical research is the production of value-added organic substances such as drugs and oils derived from fish and other organisms.

In recent years much interest has centred on the disposal of radioactive, industrial, and domestic wastes in the ocean. While it might seem very convenient to dump these wastes in the deep ocean, careful chemical analysis has shown that these materials often find their way into surface waters or into living creatures consumed by man. Pollution of beaches by oil wastes, sewage and other materials dumped at sea continues to occur and is a significant problem. It has been suggested that chemical dispersants used
on oil spills may create a worse problem than the one they are intended to alleviate. Also, many pollutants such as metals or hydrocarbons (oil and pesticides) accumulate in plants and animals at levels many times their concentration in sea water. Addressing these problems is a challenge currently facing marine chemists and chemical oceanographers.

Recent advances in technology have increased the amount of data that can be gathered at sea. However, marine chemists spend most of their time in a laboratory conducting chemical analyses and interpreting results. Career opportunities exist mainly in public-funded research and management organisations, although there are some opportunities for applied careers in private enterprise.

Photo: Deploying a CTD (conductivity, temperature, depth) device from a research vessel. Source: Geoscience Australia
Marine conservation involves applying scientific understanding to manage the human use of, and impacts on, marine environments and resources. It is an integral part of the national objective of providing for ecologically sustainable development while protecting biological diversity, heritage and cultural values. Collecting the information needed to establish and implement management of the marine environment and its resources often involves priorities and approaches which differ from those of land-based research programs.

Marine conservation research acts as a link between researchers and managers. It may interpret fundamental studies and devise means whereby relevant findings can be applied to improve management. Alternatively, it may interpret the issues and priorities faced by managers so that they may be taken into account in developing and reporting on special research initiatives and other research programs. Further, since many impacts upon marine environments and resources are the direct consequence of land use and management, marine conservation research provides an important information link between terrestrial and marine programs.

Marine conservation is particularly important in Australia since we have one of the longest coastlines in the world and the great majority of our population lives on or close to the coast. Also, Australia is responsible for the management of the Exclusive Economic Zone (Australian Fishing Zone), which extends up to 200 nautical miles from the coast and islands to cover an area one and one-half times the land mass of the continent.

Marine conservation, both research and management, is multidisciplinary. The importance of the biological, chemical and physical sciences in describing and understanding marine environments and their resources is matched by the importance of the social and economic sciences in understanding how and why impacts occur and how they can be managed to retain or achieve ecological sustainability.

For research careers, tertiary training is essential in at least one of these areas, and is usually followed by additional training through a postgraduate...
course or specialist in-service program, however, there is a variety of careers for research assistants that do not require postgraduate training.

Some universities offer specialist multidisciplinary courses in coastal zone management at the undergraduate level, and courses in marine and coastal conservation are increasingly available as units within other programs.

The largest employers of marine conservation staff are commonwealth and state government bodies, although coastal local authorities are becoming increasingly involved. Several government organisations now have graduate programs in place designed specifically to train newcomers to the field of conservation. In the private sector, fisheries, tourism, and other coastal and marine industries are likely to hire staff or consultants to help meet their responsibilities under coastal and marine management strategies.

Photo: Green Turtle, off the coast of Cairns
ECONOMICS

Economics is concerned with the efficient allocation of resources between the competing demands of different users. An important aspect of economic efficiency is the economic sustainability of resources. Marine resources include stocks of fish, marine mammals, marine flora, mineral stocks, shipping lanes, areas for recreational activities, marine energy sources and the marine environment in general.

Research economists working in the area of marine science attempt to understand and evaluate the behaviour of producers and consumers of marine resources. Predictions about outcomes, such as the equilibrium level of a fish stock, are generally based on models of a competitive market economy. Much work addresses problems, which arise when the market mechanism fails to allocate resources efficiently. Market failure occurs frequently in the allocation of marine resources because of the difficulty of establishing property rights in a marine environment. For example, allowing general access to fish stocks almost always results in economic overfishing so that the stock makes less than its potential contribution to the economy.

Applied economics in marine sciences involves the application of economic principles to the management and utilisation of marine resources. The optimisation of the economic value of a resource, although it may not be the only aim, is an important objective. The application of economic principles requires an understanding of how the market allocates resources between competing users, and of why the market may fail to achieve efficient allocation of marine resources in the absence of full property rights to these resources. Economists need to recognise that government policy in response to market failure may also have its shortcomings.

Applied economists develop and implement policies based on theoretical models of resource use generated and tested in collaboration with researchers from other scientific disciplines. Applied economists are usually part of a multidisciplinary resource management and policy unit and need to
have a good understanding of the political and institutional framework governing resource allocation and use.
A research economist will normally have an honours degree in economics, or a higher degree such as a masters or a doctorate. Preparation for an honours course is usually a three year undergraduate university program in economics. Studies in the areas of natural resource and environmental economics, mathematics and statistics, computing, and the biological and physical sciences are useful in addition to general economics coursework.
An applied economist working in marine science will normally have a pass or honours degree in economics. A higher degree is an advantage but not essential. Courses in resource and environmental economics can usually be taken as part of an undergraduate degree. Familiarity with mathematical, statistical and computing techniques is important, and some knowledge of the biological and physical sciences, law and political science is also advantageous. A postgraduate diploma in fisheries or marine science is a useful supplement to an undergraduate training in economics.

Applied and research economists working on marine resources are employed in universities, international commissions, the CSIRO, commonwealth departments, state departments such as fisheries departments, and in areas of private industry such as the fishing, oil and marine recreational industries.
Photo: Intertidal oyster farm in Tasmania
The growing popularity of Australia as a tourist destination is largely attributable to its remarkable natural environment, particularly its spectacular coastline and coral reefs. Ecotourism encompasses activities such as structured environmental education programs for tourists, ranging from whale-watching excursions to involvement of volunteers in research, and a host of other activities designed to provide visitors with access to, and information about, natural features in a low impact manner. Ecotourism is differentiated from education in that academic credit is not given to programs in ecotourism. With the rapid growth in the ecotourism industry since 1990, a great variety of educational experiences relying on verbal and practical demonstrations await the traveller. While boat skippers and trained guides can provide valuable information about the local environment, there is increasing demand for high quality information, at various levels of sophistication, to be provided by people with a more global understanding of their discipline. This knowledge is usually acquired through degree programs.

Students planning a career in ecotourism should be aware that employment in some areas is seasonal. They should look not only for training that allows them to interpret a particular environment, but should also seek some technical or management training to increase the likelihood of continuity in employment during any seasonal hiatus. This wider training allows workers in ecotourism to further their careers by moving into management. All ecotourism employees require excellent communication skills.

In addition to the large number of private tourist operators that employ 'environmental interpreters', many government agencies also provide interpretive services to the public. These include the Australian Institute of Marine Science, the Great Barrier Reef Marine Park Authority, the Australian Antarctic Division, departments of environment and conservation, and local authorities. An interpretive officer is usually required to hold a bachelors degree and some may also require a Diploma in Education. Employment in a government agency can provide opportunities for involvement in ecotourism at all levels, from the production of published materials, to oral presentations.
and management. A period of employment in this capacity is well regarded in the private sector of the industry. A listing of ecotourism operators may be obtained from the Ecotourism Association of Australia.

The greatest concentrations of potential employers in the private sector are in Queensland's urban centres adjacent to, or on the resort islands of, the Great Barrier Reef. However, equally fascinating coastal and island areas in all other states are now providing a focus for the development of ecotourism, for example in the area of whale watching. In all of these activities, there is a need for environmental educators, researchers and managers to ensure that the impact of tourists is controlled and minimised.
Careers in marine education fall into two main categories: education contributing to an academic award, such as a school grade, diploma or degree, and education of the general community for its intrinsic value. Many education opportunities for the general public regarding the marine environment are made available by not-for-profit organisations such as Marine Discovery Centre’s, Parks and Wildlife Summer Ranger programs and local interest groups, such as the Tasmanian Marine Naturalists.

Marine educators range from professional teachers to marine biologists. Several Marine Discovery Centres employ many staff with marine biology training to deliver education programs to primary and secondary school students. Increasing public awareness of the need for conservation of the marine environment and its valuable resources is reflected in the increased attention given to marine science in academic curricula at all levels of education. Specialist educators may also design a school curriculum, produce support materials and even teach the program.

Marine education in schools is enhanced by the development of field study centres with a partial or total emphasis on marine studies. Many field study Centre’s offer hands-on opportunities with aquaria and touch pools – the responsibility for the development and management of which often falls to the marine educators. As such, there are opportunities to work in hands-on environments in the collection and care of marine species.

Aquariums also offer many opportunities to combine marine science/biology and marine education. Work is available in the development and deliverance of interpretation sessions to all levels of the community, including school students and the general public, and also in the area of animal care and collection. Some aquariums, such as the Melbourne Aquarium, offer the opportunity to work as part of research teams investigating different aspects of animal behaviour.
At tertiary level, the main areas of employment in education are as tutors or lecturers. To be even considered for a lecturing position requires a doctoral degree, but it is possible to work as a tutor with a bachelor’s degree. Recently, the number of international university student groups visiting Australia has increased markedly, and many of these incorporate a marine component into their studies. This activity is providing a welcome source of employment for some graduates, although the work can be seasonal and some groups require tutors to hold a minimum qualification of a master’s degree.

Photo: School students involved in a Marine Education lesson with the Marine Education Society of Australia.
Photo: Students involved in underwater surveys with the University of Sydney
The role played by engineers in marine science and technology may prove to be more significant than their role on land. The particular difficulties associated with engineering in the marine environment call for new materials, new methods of analysis and design, and the most advanced technical skills available.

Coastal and maritime civil engineers have long been involved with the design and construction of seawalls, jetties, harbours and the associated problems of coastal and beach erosion. Modern design methods employ mathematical models that enable computers to simulate the effects of waves and currents on these structures and to predict the extent of undesirable effects such as erosion, flooding and storm surges following large storms and cyclones. Ocean civil engineers can specialise in design and construction of structures, including platforms for oil drilling or deep-water mining operations. An understanding of the wave climate at the construction site, provided by computer studies of wave generation and wave characteristics, is vital for the successful design of such structures. Electrical engineers develop computer-based control systems, which continuously monitor the platform's position and make corrections to compensate for fluctuations in wind, tides and currents. In this way, computers keep the platform located precisely over a predetermined spot on the sea floor, which may be several kilometres below the surface. Mechanical, civil and electronics engineers are developing new instruments for measuring, monitoring and exploring the underwater environment. One-atmosphere pressure suits can allow a diver to move and perform tasks at depths of kilometres and to photograph and sample the abyssal plains. However, manned dives are increasingly giving way to surface-controlled unmanned submersibles, which are now used routinely in jobs as diverse as checking and maintenance of man-made structures such as rig platforms and the exploration of the deepest parts of the ocean to help answer questions about the earth's crust.

The marine environment in Australia is characterised by a very rich interaction between physical, chemical and biological processes. Industry, commerce,
urbanisation and recreational activities in turn interact with the natural system. These interactions are causing a host of problems, including the impact of pollution on coastal ecosystems and over-exploitation of natural resources. An integrated approach to the problems of management of man in nature and development is required, taking into account all relevant processes and interactions within the coastal and marine environment. Coastal engineers are involved in the investigation and assessment of coastal and marine environments, and planning for their use, development and conservation. Systems engineers, as well as civil and environmental engineers, contribute the special skills required for computer-assisted mathematical analysis and the co-ordination of multi-disciplinary studies.
Environmental consultants provide independent services in the collection, interpretation and application of environmental data. They act as an interface between the scientific community and clients, where clients may be private individuals, companies, statutory authorities or government agencies.

Projects in consulting involve a variety of disciplines, including aquatic biology, fisheries, water quality, coastal engineering, marine chemistry, oceanography, hydraulics, pollution control and environmental planning. Each discipline is specific and concerned with defining practical solutions to complex environmental issues. Consultants therefore usually work in a team with specialists from a range of disciplines outside their own area of expertise. They need to be able to liaise effectively and communicate their results to a broad audience, including laypersons, other scientists, engineers, and mediating and decision-making authorities.

Consultants work on a diverse range of projects including the measurement of an environment's physical and biological attributes, design of structures built for the marine environment, environmental management and planning, effluent discharge strategies, environmental impact studies, rehabilitation projects, environmental audits, and resource inventories. Environmental monitoring is becoming mandatory for developments as diverse as construction works and effluent discharges. Consultants are generally required to design and implement monitoring studies and therefore need the skills to design cost-effective and statistically valid programs.

The role of consultants is changing rapidly as government bodies reduce their staffing levels and contract increasing numbers of projects to consultants. Knowledge of law, conventions and liabilities relating to coastal and offshore areas is therefore becoming increasingly important.

There is often considerable repetition in the projects taken on by consulting agencies because of the widespread and frequently occurring nature of the environmental issues that need to be addressed by a variety
of potential clients. Some examples may include hazardous spill assessment and remediation; assessment, removal and remediation of leaking underground storage tanks; and investigations into ground water contamination.

As a potential contractor to private industries and government agencies who require various science- or engineering-related projects, consultants have considerable opportunity to make real improvements in the protection and remediation of the environment.

Environmental consulting is an interesting career that involves a wide variety of work and often requires travel to remote areas. It is a field that is growing rapidly as the community demands that greater emphasis be placed on managing development and minimising its effects on the natural environment.
FISHERIES:
With increasing fishing pressure on wild stocks of fish, crustaceans and molluscs in Australian and international waters, sound fisheries management is vital. Effective management relies on fisheries scientists to collect and analyse accurate data. The fisheries scientist is responsible for collecting and interpreting the data that managers need to make fundamental decisions, such as how many fish of a particular species can be caught, what the minimum size should be, and when and where they can be caught. To address these questions, information is needed about how fast the animal grows, how long it lives, and where and how often it reproduces.

The fisheries scientist is also concerned with factors affecting the marine environment, and particularly with the effects of fishing on a variety of habitats and the species they harbour. Another important area of contemporary fisheries science is the effect of climate on fisheries. It should also be realised that there is always the possibility of discovering new fisheries; it can be an exciting experience setting out on an exploratory cruise. Perhaps one of the most important skills of the fisheries scientist is discerning which questions are the most pressing.

With increasing awareness that particular fisheries are just one component of a much larger ecosystem, fisheries science is linked closely to, and draws on the expertise of, several other disciplines. A typical program could conceivably enlist the services of a biologist, an oceanographer, a meteorologist, a taxonomist and an economist, even before putting to sea.

The working life of a fisheries scientist is varied, but it can be divided broadly into three main areas: collecting data and samples in the field, analysing and interpreting the data (which usually takes place in the laboratory or in front of a computer), and writing up the data into reports or research articles. With continuing emphasis on accountability, these results are generally presented publicly to other researchers or to industry. Collecting information in the field may require donning a SCUBA tank, spending weeks at sea on a research vessel, or camping by a river in some pristine natural environment (or by a foul-smelling swamp next to heavy industry)! Once the collections are made,
the long and sometimes arduous task of data analysis follows. Possibly the most rewarding moment is when the patterns and relationships become clear and the scientist can add something to the intriguing jigsaw puzzle of fisheries science.

Employment has traditionally been with government agencies such as the CSIRO, the various state organisations, and universities; however, with increased interest in mariculture, private enterprise is also a significant employer of graduates.

Photo: Atlantic salmon being transferred into a freshwater bath (photo J.Harris)
Photo: Juvenile kingfish being grown out in tanks on land (photo J.Harris)
Seafood technology involves research to increase the value, storage time or quality of seafood for existing or new markets. Food technologists work in private industry and government institutions in research and advisory roles as full time positions or frequently as independent consultants.

Many technologists enter the seafood industry with university qualifications in food technology, while others have science degrees, usually majoring in microbiology or biochemistry. Graduates are also recruited for production and quality functions.

Working for commercial industry, technologists are concerned with the properties of the product and how systems of processing, packaging and distribution can be applied to particular items. Some develop new products, while others supervise and develop processes to improve efficiency or to produce better goods.

Technologists advise production staff, and are responsible for defining quality specifications and other standards and procedures that ensure that standards are adhered to. They perform quality assurance and quality control functions and are therefore often the contact point between food processing companies and local or overseas regulatory bodies, such as local health surveyors or inspectors of export items. Sound knowledge of the regulations, and what is required to meet them, is essential. Food technologists also fulfil a regulatory and advisory role in formulating and appraising standards and regulations in government.

Research opportunities are usually focussed around state departments and or in universities as part of research projects in honours, masters or doctoral degrees, or commonly joint projects between university’s and the relevant state department. Research into seafood technology is broadly separated into
three areas being; post harvest processes, product safety, and product development.

The post-harvest component is focussed on the quality of live seafood during commercial capture or growing which ultimately impact on the final quality of the product. This research draws successfully on expertise in areas of physiology, biochemistry and aquaculture.

Product safety is focussed on farming and processing practices which impact on the safety of consumers eating farmed or caught and processed product. This work requires a background in microbiology or toxicology.

The area of product development is focussed with developing new products from existing raw resources. Usually this is undertaken by people with food technology degree’s and in close association with marketing professionals. This area is currently a major focus with value-adding initiatives effectively increasing the profit and returns for commercially grown or caught product. With innovations in presentation and shelf life through packaging and portioned sizes new markets have been tapped into which has resulted in higher returns per kg. With wild capture fisheries reaching their maximum output future increases in commercial returns will undoubtedly have to come from this area.

The three areas of research are closely associated and vital in providing top quality and valuable seafood. Although the job market in food technology in Australia is not large, as commercial fisheries and aquaculture focus on this area there will be an ever increasing need for technologists for both research and industry opportunities in the future.
Photo: A food technologist measures the flesh characteristics of Rock Lobster in a South Australian Seafood Factory. (Photo M. Roberts)
Geography is concerned with the nature, causes and spatial organisation of physical and human phenomena on the earth’s surface. It includes the study and interpretation of the natural environment, socio-economic systems and human-environment interactions in both marine and terrestrial ecosystems.

Coastal physical geography or geomorphology deals with the nature, evolution and change of the coastal environment. It includes the study of the physical processes that drive the coastal zone, namely ocean waves, tides and currents, and the atmospheric processes important to both coastal dynamics and ecology. It also includes the study of physical and biological systems that make up the coast, across the full range of coastal systems including estuaries, deltas, beaches and surf zones, barriers and coastal dunes, rocky coast, coral reefs and the inner continental shelf.

Coastal geomorphologists are interested in interactions between physical, biological and chemical processes within coastal ecosystems, and the local and regional controls on variability and change in these systems. They study the dynamics of the coastal ocean and atmosphere using sensors to monitor waves, currents, salinity, temperature, and wind. Digital surveying equipment is used to map the coast and inner shelf, and a variety of seismic and coring techniques are employed to probe the nature of the subsurface. This information is combined with dating techniques to understand the dynamics of the coastal zone at time scales ranging from seconds to millennia. The results of these studies provide information on coastal evolution, contemporary processes including shoreline erosion and are increasingly being used to predict future coastal change in response to climate induced changes in sea level, tide range and wave climate.

Environmental and human geographers are increasingly concerned with the nature and management of human interaction with and impact on the coast.
Short-term impacts include pollution of coastal areas whereas climate change is generating longer term impacts. These geographers study the relationships between people and the coast and how coastal development can proceed sensibly. This requires an understanding of coastal ecosystems and the impact of development on these systems. Environmental geographers also study the impacts of land clearing, urban development and run-off in effecting increased sedimentation and pollution in the marine environment. This requires collection and analysis of coastal water and sediments to assess contaminants and their sources.

The integrative nature of geography has placed it at the forefront in the application of geographic information systems (GIS) and remote sensing to coastal research. This technology facilitates the interaction of physical and human geographers with scientists from other disciplines in research into the complex and dynamic ecosystems of the coastal zone.

Photo: Setting up a GPS base station for a Digital GPS beach survey. (Photo A.Short)
**Applied geographers** and **geomorphologists** are employed in a wide range of applied positions dealing with the coast and ocean. They work at all levels of government dealing with the coastal zone, as environmental officers with local government, as scientific officers with a range of state and commonwealth agencies dealing with the environment, the coast, parks, marine reserves and policy. Their work ranges from developing coastal policy to monitoring water quality and human impacts in coastal systems, including tropical and temperate reefs, mangroves, wetland and marshes. They also work as environmental, coastal and engineering consultants where they provide information to clients about the impact of development in the coastal zone.

In **coastal zone management**, geographers work for local and state planning authorities who plan and oversee the development of the coastal zone, while at a national level they work of national and marine park authorities whose task it is to manage and protect some of the most valuable coastal and marine ecosystems in the world.
Photo: Large-scale human impact in the coastal zone. This Western Australian development has impacted the tidal inlet, wetlands and longshore sand transport, placed a major community in a previous wetland, and generated severe downdrift shoreline erosion. (Photo A. Short)
A pristine section of the southwest Tasmanian coast, managed as part of the Tasmanian Wilderness World Heritage Area. (Photo: A.Short)
Marine Geologists study the seafloor and the earth beneath the seabed to determine the type of rocks and resources present and their geological history. Exploration techniques include collection and analysis of samples and direct probing of the subsurface by drilling and increasingly seabed mapping using high resolution sidescan sonar. Palaeontologists use fossils, especially microfossils, to determine the age of strata. Geochemists use the ratios of various elements' isotopes to determine the origin of certain materials including fossil fuel and the temperature at which they formed.

Sedimentologists interpret the source of ocean floor sediments and the mode of their transport and deposition. Geophysicists use indirect methods such as seismic reflection to investigate subsurface strata and materials. Other routine geophysical techniques utilise variations in magnetic and gravitational fields and heat flow patterns within the earth to interpret the nature of the underlying crust. This is used to recreate the evolution of continents and oceans (plate tectonics), as well as predict contemporary hazards such as volcanic eruptions, earthquakes and tsunami.

Petroleum geologists and geophysicists search for fossil fuels using evidence such as the type, thickness, and organic content of sediments, the structural form of sedimentary basins, and possible migration paths by which oil and gas might reach suitable reservoirs in porous sedimentary beds. Mineral exploration companies also search the sea floor for metal deposits. Sedimentary deposits of gold have been discovered offshore and the feasibility of mining heavy metals, such as nodular concretions of manganese, from the ocean floor is being assessed. Marine geoscientists also study the sea-bed materials of the continental shelf and coastal regions to assist marine engineers design offshore and nearby structures. The movement and distribution of sediment in the coastal zone are important areas of study that are critical to management of the coastal zone.
Mineral exploration companies search the sea for deposits of gold, tin and diamonds. Gravel and sand will soon be extracted from the seabed in preference to mining rivers and coastal dunes. Some companies are assessing the feasibility of mining valuable metals from nodular manganese and iron concretions from the deep ocean floor.

Study of sea-bed materials using corers, side scan sonar, submersibles, remote vehicles and other technology provides vital information to marine engineers for designing offshore or coastal structures, such as harbours, oil platforms, pipelines, and telecommunications cables.

Marine geoscience is a field which is developing rapidly, particularly in response to innovations in technology and equipment and the need to map Australia’s Exclusive Economic Zone and its resources, an area larger than continental Australia. Australia is a participant in the Deep Sea Drilling Project, which is a world-wide program that is yielding new and exciting information, especially from the deep oceans. Relatively recent application of specialised technology has revealed that seabed sediments contain a remarkably complete record of environmental change. Areas of growth include oil and gas exploration, seabed and resource mapping, offshore engineering, marine park management, subsea remote sensing technology and management and use of marine data.

The primary training required is in the physical sciences (geology, chemistry and geography), usually combined with mathematics and physics. An alternative is engineering or training in science-law. Organisations employing marine geoscientists include various commonwealth and state government departments such as Geoscience Australia, government geological surveys and public works departments, defence agencies, industrial corporations including petroleum exploration companies, geological and engineering consultants, and academic institutions.
Environmental law is an area of legal practice, which is increasing in importance both nationally and internationally. This is reflected in the continuing expansion of environmental legislation enacted throughout Australia, as well as in the number of international conventions and treaties to which Australia is a signatory nation. Environmental law is a specialised area of legal practice as it provides the basis for the development, implementation and enforcement of regulatory control of the environment. In practice it encourages balanced and prudent environmental decision making for a wide range of environmental problems. These cover a broad spectrum of concerns such as sustainable use of natural resources, conservation of biodiversity, preservation of natural and cultural heritage, establishment of marine protection areas, management of toxic chemical hazards, environmental planning and management, and multiple use of large marine ecosystems. Issues such as these represent a major contemporary challenge for the management of marine environments, especially environmentally sensitive areas.

Because environmental disputes are founded predominantly on scientific and technical issues rather than questions of law, the law turns to science for answers to factual questions that are beyond the understanding and knowledge of non-scientists. Lawyers, who may not have had any scientific training, are then required to understand the scientific evidence, review it to ensure that it is consistent with the standards and criteria adhered to by scientists, and to apply this evidence to the dispute in question. These features illustrate clearly that environmental law is not the exclusive domain of lawyers or scientists. Rather, there must be integration of law and science to ensure that legal decisions are consistent with established scientific standards. This can be achieved by pursuing academic studies, which focus on an interdisciplinary approach to law and science.

There are now 22 Law Schools in Australian universities, which offer an undergraduate degree program in law. Environmental lawyers need to be familiar with many areas of law, including the traditional fields, for example
torts, property, town planning, constitution and administrative law. However, anyone considering a career in marine resource management law would be well advised to have a bachelors degree in science, majoring in marine science, but including subjects that give them broad expertise across the environmental sciences.

Career opportunities range from professional legal practice, litigation and alternative dispute resolution, crown or corporate law, to careers in government, either in regulatory or non-regulatory roles, and tertiary teaching.

Mariculture is the commercial farming of marine organisms. This can include fish such as tuna, salmon, barramundi and trout, crustaceans such as prawns and molluscs such as oysters, mussels and abalone. This form of farming has a long history in Australia and has made a significant contribution to the nation's marine products ($AUS708 million 2003/2004). The most valuable mariculture products in Australia are cultured pearls, which was also the first sector of the industry to be established; and tuna, which is one of the latest. More recently, Australia has followed a global trend of both increased production and increased numbers of species being cultured on a commercial or experimental scale. These more recent initiatives include the farming of tuna, salmon, abalone, mussels, barramundi, aquarium fish, kingfish, giant clams, and penaeid prawns.

The expanding mariculture industry requires people with formal training in a number of different disciplines, including on-site farm management, specialist production processes and technology, business management, animal health and marketing. The industry also requires expertise in applied and strategic research in all of these disciplines. Farm management involves the implementation of mariculture technology, which includes methods for controlling the grow-out conditions of the targeted species. Post-harvest management or processing involves the preparation and/or preservation of the products, and their delivery in good condition to consumers. Research is needed to refine each step of established production methods and to explore the potential for previously untested species. There is a growing need to develop specialist knowledge in the prevention and cure of diseases that affect marine organisms. In line with other primary industry sectors, there is also a demand for graduates in environmental science to assist with the planning of mariculture developments to ensure that the environmental impact of mariculture facilities is minimised and is acceptable.

When planning a career in mariculture, it is important to recognise the diversity of the industry. The training requirements for salmon farmers in Tasmania are quite different from those of prawn farmers in Queensland, or...
from those of scientists attempting to improve disease resistance of aquarium fish or growth rates of tuna. However, many aspects are easily transferable, and graduates often find work overseas.

Mariculture is an expanding industry in Australia and recent graduates are employed on farms in the areas of operation, management, research and development. State departments of primary industry or agriculture or resource sciences employ officers in the areas of environmental planning, policy development, implementation and biological & ecological monitoring and research. Federal agencies, for example CSIRO and the Australian Institute of Marine Science, and universities are the main employers of researchers, while universities also employ lecturers to teach mariculture. Furthermore, opportunities exist for experienced people to work as consultants to this developing industry.

Photo (1) : Upwelling system for growing juvenile scallops in a commercial shellfish hatchery. (Photo J.Harris)
Photo (2): Land-based abalone farm (Photo J. Harris)
Marine biotechnology is a relatively new enterprise, particularly in Australia, and some of the nations most elite marine science institutes are leading the discovery and applications of marine biotechnology. Australia is surrounded by one of the worlds largest and most biodiverse ocean territories, and offers a wealth of largely untapped raw material for the discovery of pharmaceutical and other biotechnology products.

With development of this industry within Australia, we can satisfy the world's growing need for food, drugs and materials from the ocean without the over-exploitation and destruction of its habitats by applying advanced technologies to the cultivation of marine organisms. Marine biotechnologists work in an array of areas including identifying and testing marine natural products, molecular marine biotechnology and discovery and cultivation of marine natural products.

Several universities now offer marine biotechnology as a combination with a degree in Aquaculture, or as special units to add to a Bachelor of Marine Science. Some courses focus on novel attributes of coral reef environments that are the basis of the expanding industry of biotechnology. Emphasis is given to the abilities of corals and other reef associated organisms (eg. sponges) to protect themselves against the sun, repel and/or destroy non-self cells, and to immunise themselves against some diseases. Aspects covered in such courses include: collection of organisms; field experiments; and, molecular and genetic techniques to separate and identify ‘useful proteins’.

Employment opportunities are growing within the industry, and once qualified, largely depend on your interests. In the commercial division management of fish farms or research is one path while employment as a research scientist with a government or university is another traditional path. Other potential jobs include: Fish Export Inspector, Fish Farm hand, Fisheries Biologist,
Fisheries Officer and Fisheries technical officer. Marine biotechnologists are also employed in a number of capacities through consulting both nationally and internationally.
MATHEMATICS, STATISTICS AND COMPUTING

All marine scientists must have a good knowledge of statistics and be familiar with computers. It is most unusual to see any job advertisement in marine science that does not explicitly request quantitative skills. Marine scientists require these skills to plan their data collection properly and analyse their results. However, specialist mathematicians, statisticians and computer scientists are also required.

Data collection in most areas of marine science is an expensive and difficult process. The advice of expert biometricians and statisticians is essential to ensure that data are gathered in ways that maximise the value of the results. To provide useful advice, the biometrician (biological statistician) needs a good understanding of the biological questions and practical difficulties of data collection as well as familiarity with the latest statistical techniques and methods. A good biometrician is therefore not tied to a computer terminal in an office, but also works in the field to experience the problems first hand. Students interested in a career in this area should take courses in biology (particularly ecology and marine biology), mathematical statistics and computing.

Statisticians are not the only mathematicians who contribute to marine science. As the pressure on fisheries grows, increasingly sophisticated mathematical models are required to ensure that marine resources are managed responsibly. Fisheries modellers require a variety of mathematical skills. First, they must be competent statisticians to extract the relevant biological information from large amounts of ‘noisy’ data. Second, they require mathematical skills in areas such as calculus and probability theory to construct models of the fisheries. Third, they require computing skills to implement the models. Finally, as with biometricians, practical contact with the problems in the field is essential. Natural resource modellers will usually combine ecological courses with statistics, applied mathematics, and computer science.

Mathematicians and computer scientists also play a central role in oceanography. The understanding of current flows, with its implications for
dispersal of marine organisms, sediments and pollutants, requires large-scale computer models. Computing skills of a high order and mathematical skills in areas such as fluid dynamics and numerical methods are essential. Oceanographic modellers usually have an applied mathematics and computer science background, although some may have entered the field from engineering.

Most mathematicians, statisticians or computer scientists working in marine science are employed by government departments and instrumentalities such as the CSIRO Divisions of Fisheries and Oceanography, the Australian Institute of Marine Science, the Antarctic Division, state departments of primary industry, and tertiary institutions. However, increasing numbers are working in environmental impact assessment, either employed by private industry or as self-employed consultants. Demand in this area is expected to increase substantially in the next few years.
Marine microbiology is the study of marine life forms that cannot be seen with the naked eye, including viruses, bacteria, fungi, protozoa and microscopic algae. Representatives of each group have been found in almost every marine habitat examined, from tropical coral reefs to the Antarctic and the greatest depths of the ocean. Microbes occur in the water column and sediments, on the surfaces of marine plants, animals and inanimate objects, in the intestinal tracts of fishes and invertebrates and even within the tissues of other living things. There is a staggering diversity of forms and modes of life among marine microbes. Some require light for growth; many require the saline nature of sea water, while others can survive without oxygen. Because of their small size, the importance of microbes to life in the oceans is often not appreciated. Knowledge of their activities assumes a new importance when one considers that each millilitre of sea water may be the home for millions of individuals, and each gram of sediment may support thousands of millions of microbes. Microbes play a crucial role in ocean food webs, which support the diversity of life in the sea. Scientists therefore study the microscopic plants that fix carbon dioxide, the bacteria which grow on the myriad of organic, inorganic, dissolved and particulate chemicals in the sea, and the protozoa which feed on them. In this way knowledge is gained about how each life form contributes to all levels of the food web. Other microbiologists investigate the unique ways in which microbes change chemicals from one form to another, and the importance of this to the health of the oceans. For example, particular kinds of microbes carry out some steps in the cycling of nitrogen from a dissolved gas in the sea to proteins in plants, animals and microbes, to inorganic forms and finally back to a gas. Maintenance of this cycle is essential for life in the oceans. Many aspects of marine microbiological research have the potential to provide practical information and to form the basis of new biotechnological developments. Microbiologists studying diseases of marine organisms are providing disease diagnosis and control strategies to those attempting to grow marine animals such as prawns, molluscs and fish. New chemicals with
potential industrial applications, such as friction-reducing lubricants on the surfaces of some fish, have been found to be produced by marine microbes. Major efforts are also being put into the search for new pharmaceuticals from marine microbes, such as antibiotics and anti-cancer agents.

The incredible diversity of microbes, their wide distribution in marine habitats, metabolic capabilities and intimate involvement in processes occurring in the oceans ensures lifetimes of discovery for scientists. Research into the activities of microbes involves opportunities for collaboration with scientists from disparate disciplines such as botany, geology, zoology, chemistry and marine biology. Field work and laboratory analysis using traditional microbiological methods as well as sophisticated techniques such as DNA technology are all tools of trade for the marine microbiologist. Marine microbiologists require tertiary qualifications and are employed by universities, a variety of state and federal departments and instrumentalities, and by private industry.

Photo: Processing marine bacteria in the laboratory. Source: Australian Institute of Marine Science
Almost all marine animals have other animals living on or inside them. Some form loose associations, like cleaner fishes and coral trout, while others are more intimately connected, such as the algal cells that live within corals and giant clams. Many parasites, for example the protozoon that causes 'white spot' disease in fish, are often clearly pathogenic to the host. The feeding mechanisms of these organisms, their methods of transfer between different host species, and their effect on the hosts have fascinated biologists for many years.

With the development of mariculture, study of marine diseases and parasites has become particularly important. Diseases and parasites flourish in the intensive culture of single species of fish and shellfish, especially if water exchange in the culture system is limited. The skin and gills of fish raised in sea cages can be attacked by bacteria, amoebae and small crustaceans, while prawns in hatcheries are weakened by viruses and killed by bacteria. Oysters die in thousands each year from the protozoans that cause 'winter mortality' and 'QX disease'.

Marine biologists with skills in microbiology and parasitology determine the sources of infection and explore methods of control. Veterinarians with an interest in marine pathology play a valuable role in diagnosing infection, prescribing the necessary antibiotics to control bacterial disease, and helping to develop vaccines. Microbiologists and parasitologists detect and describe the new diseases that arise as mariculture develops and also investigate the diseases of marine fish in aquaria and oceanaria. Real and imaginary diseases sometimes delay or prevent sale of Australian seafood products overseas. Understanding the diseases which exist in Australia circumvents potential problems quickly and helps boost our exports.

Marine biologists and veterinarians investigate marine parasites and diseases for other reasons. Their work helps to determine the cause of strandings of turtles and whales, unravels links between skin diseases in fish and water quality, clarifies migrations of fish and prawns when conventional tagging methods are not feasible, and seeks biological control agents for pests.
The more we manage marine organisms, the more we will be able to manage their diseases. A career in this area has several possible starting points: as a veterinarian, microbiologist, parasitologist, or marine biologist. For many, it provides the opportunity to combine a scientific career with recreational interests such as fishing or diving. Several universities offer courses and specialist workshops to allow scientists to become proficient in the identification and control of parasites and diseases in marine organisms.
Pharmacology is the science of the nature and properties of substances used for treating diseases (it is distinct from pharmacy which is the preparing and dispensing of prescription drugs). Pharmacology is a comparatively modern science that has developed enormously this century and is still expanding rapidly.

Marine pharmacologists work with extracts or substances isolated from marine organisms. Many exciting biologically active substances such as antibacterial, anti-viral, anti-tumour, and biologically toxic compounds have been discovered in, and isolated from, marine plants and from marine animals as diverse as sponges, fish, sea squirts and echinoderms. The yield of such substances from marine species has been greater than that obtained from terrestrial species.

The whole pathway of discovery of pharmacological activity, isolation, purification, and characterisation of a unique active substance requires close interaction between pharmacologists and chemists. Once biologically active substances have been characterised, the marine pharmacologist will continue to work closely with a chemist to develop methods of synthesising the substance or an active analogue of it. There are many benefits of developing synthetic means of production, such as reducing costs of commercial production, the ability to obtain pure substances, and minimising impact on the marine species in which useful substances were first found.

Marine pharmacology continues to benefit from close interdisciplinary interaction with marine biologists and chemists, and from an increased understanding of the mechanisms of action of existing drugs, metabolism, drug specificity for action at particular 'receptor sites', the development of alternative tests to those requiring live animals, and improvements in synthetic chemistry technology.

Marine research into pharmaceutical compounds found naturally in Australia’s oceans is a new and growing area of expertise. Another area of marine pharmacology expected to require increased attention in the future as high density farming of marine animal and seaweed species increases in Australia.
is in disease control and ensuring the well-being of animals grown for production.
Physical oceanography is the study of the physical processes, which occur in the ocean. Physical oceanographers study the currents, tides, waves, temperature, salinity and density of our oceans, and determine the influence of these processes on the physical environment. Examples include the study of ocean-atmosphere interactions that influence weather and climate, the transmission of light and sound through water, the ocean’s interactions with its boundaries at the sea floor and the coast, and the transport of pollutants and nutrients, which may impact on the marine ecology.

Physical oceanographers use observations from ship-deployed instruments, computer or physical models, remote observations from satellites or airplanes, theoretical studies, and/or combinations of these methods for studying the ocean. Some key research programs in which Australian physical oceanographers are involved include: (i) the ARGO program, an international long-term program which comprises a global array of floating buoys which measure temperature and salinity of the upper 2000 m of the ocean; (ii) the “Blue-Link” ocean forecast model, which makes use of the countries largest supercomputers, and aims to supply day-to-day forecasts of changes in ocean currents and temperature to marine and coastal industries; and (iii) constant monitoring of ocean temperature from satellite images. The information obtained is useful for the fishing industry locating oceanic frontal systems where fish feed, marine transport industries and sailors looking to follow ocean currents to get the quickest ride or conserve fuel, or climatologists assessing ocean conditions which lead to cloud formation and rain. These projects all require significant international interaction and enable ample opportunity to travel, work at sea, and attend scientific meetings.

In addition to the deep-water oceanography programs listed above, oceanic processes on the continental shelf and in the coastal zone are also studied. On the continental shelf, wind-driven currents act to draw deep, nutrient rich
water up into the coastal zone. Upwelled water fertilises microscopic marine plants, which can bloom in great abundance and provide an important food source for fisheries (e.g., the pilchard fishery in the Great Australian Bight).

The effects of waves and currents determine the shape of beaches, the distribution of pollutants on the coastline, and the flushing and environmental health of bays and estuaries. Current research programs are investigating the impact of waves, tides and wind-driven currents on the movement of sub-tidal sand-waves in the shallow waters of Torres Strait, and the impact these may have on seagrass distribution and related fisheries (Prawn and Dugong). Such programs require significant collaboration between the physical oceanographer, marine biologists, geologists, chemists, and engineers to describe and predict the nature of our environment.

A strong background in mathematics, physics or engineering is required for oceanography. Given the enormous scope of the subject, the skills learned in basic training can be adapted to specialised fields. An undergraduate degree (preferably to honours level) can lead to employment as a scientist or research assistant in universities, government laboratories, environmental agencies, or other private industry. Postgraduate study provides opportunities to become leaders in research and in the management and monitoring of our marine environment.
Photo Deployment of an oceanographic mooring from a research vessel to measure waves, currents, salinity and temperature on the continental shelf. Source: Geoscience Australia.
Photo: Satellite image of Sea Surface Temperature (Source: CSIRO)
Remote sensing is a rapidly evolving technology, which uses aerial photography and satellite imagery to provide information on the distribution of a variety of physical and biological parameters in the ocean. The ocean is a complex and dynamic system, which displays variability over a range of time and space scales. Marine remote sensing, or satellite oceanography, provides data that are an invaluable complement to information collected from ships, such as information on current patterns and ocean surface characteristics, including surface temperature and amounts of phytoplankton. It can provide synoptic coverage, which cannot be achieved using other methods.

Many oceanic parameters can be measured by remotely-based sensors. They include sea-surface temperature, sea-ice distribution, turbidity and ocean colour, which may be related to biological productivity. Active sensors such as the radar altimeter and microwave scatterometer on board the European Space Agency Satellite ERS-1 can provide information on ocean currents, ocean fronts, eddy structures and wave statistics.

Two recently-launched sensors are now playing an important role in showing the distribution of small plankton that are the basis to oceanic food webs and productivity worldwide. They include the Sea-viewing Wide-Field-of-View Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectrometer (MODIS). The continuing international commitment to the collection of remotely sensed data should ensure growing opportunities for careers in this field.

Most job opportunities in this field are with universities and commonwealth agencies, for example CSIRO, the Australian Institute of Marine Sciences, the Australian Antarctic Division, and the Australian Centre for Remote Sensing. Increasingly however, coastal engineers and other professionals, particularly those concerned with monitoring and managing coastal environments, are making use of remote sensing to detect changes in shoreline morphology, the
extent of shallow reef systems, or the extent and distribution of coastal vegetation such as mangroves and seagrasses.

PHOTO: Satellite sea-surface temperature image of the Leeuwin current off Western Australia, August 2004.
Taxonomy is the study of the classification and identification of animals and plants. Correct identification of organisms is the basis for all other biological studies. The determination of taxonomic relationships is critical to an understanding of evolutionary history, biodiversity, biogeography, comparative biology and community ecology. However, a substantial fraction of Australia's marine invertebrate fauna, and many of its fishes and marine algae remain undescribed.

Traditionally, taxonomic methods of classification have used a wide range of morphological characters, but biochemical, genetical (for example, RNA and DNA sequences), ecological, physiological and behavioural characteristics of organisms are contributing increasingly to taxonomic and phylogenetic analyses.

Not all universities offer specific courses in taxonomy, but courses in evolutionary biology may cover the principles, if not the practice, of the field. A student typically becomes involved in taxonomic research by undertaking a masters degree or doctorate in the discipline. Research projects may describe previously unrecognised species, investigate the taxonomic relationships between species, and perhaps generate hypotheses to explain their evolutionary history. Taxonomists require good powers of observation and usually have skills in computing.

Students of taxonomy are often co-supervised by practicing taxonomists employed in museums or herbariums where the necessary collections of research material are housed. However, taxonomists must also work in the field and many have active research programs in coastal and offshore environments investigating the composition and diversity of biotic communities. Many modern biochemical and molecular techniques require fresh material, and extensive field work may be necessary to collect material for study.

Marine taxonomists are employed by state museums and herbaria, and by the CSIRO, but lecturers and other researchers in universities also undertake taxonomic research. State and federal national parks or fisheries agencies
employ people with an understanding of taxonomy and biodiversity to identify and manage representative marine and estuarine habitats. Similarly, people with a good grounding in taxonomy will be valuable assets to teams undertaking marine ecological studies and may be employed at technical or scientific levels depending on the skills, qualifications and duties required for the position. These teams may work in government or operate privately as consultants for other groups undertaking biological surveys or environmental impact assessments.

Photo: Juvenile sea urchins at 3 days old. The primary spines of the urchin are already forming, as seen under a microscope. (Photo B. Hammond)
ZOOLOGY

Zoologists study animal life in all its diversity, including the interactions of animals with other organisms and with the physical and chemical components of the environment. Free-swimming, large and active life forms such as fish, corals and other attached organisms, burrowing animals, parasites, and microscopic animals are all of interest to the marine zoologist. Animals are found in a stunning variety of physical conditions everywhere in the sea, from above the high tide mark to the abyssal depths. Zoologists study animals at all depths, but given the enormous difficulty and expense of studying abyssal life, have concentrated their efforts close to the sea surface and the coast. Zoologists may study the biochemistry or physiology of animals in the laboratory or, with the advent of automatic data loggers and transmitters carried by the animals, in their natural habitat. Other zoologists study animal behaviour, genetics or ecology.

Ecologists study the numbers of and interactions between organisms at several levels. They may concentrate on the dynamics of populations of particular species or communities of interacting species. An understanding of community dynamics and how species interact is vital in fisheries and in the management of marine ecosystems. Some marine ecologists investigate the movement of energy and molecules through ecosystems. Most marine ecologists work extensively in the field, which often involves SCUBA diving. They may work from major cities or from remote field stations in studying animals on coral reefs, rocky shores, sandy beaches, mudflats, and in mangrove forests or in seagrass beds. They also work in the laboratory sorting and processing samples, which usually requires identifying, counting and measuring animals, and analysing and interpreting data with the aid of a computer. Mathematics, statistics and computer modelling continue to increase in importance as basic tools of the modern zoologist.

The identification, classification, evolutionary relationships and geographic distributions of animals are important areas of zoological research often pursued in museums and universities. This can be challenging work both intellectually and technically. The effects of pollution on organisms and
ecosystems have also become a major research area for zoologists. Industrial effluents, sewage outfalls, runoff from agricultural areas, and stormwater from urban areas can all contain substances with far-reaching and complex effects. It is possible that these pollutants contribute to problems such as outbreaks of crown-of-thorns starfish on the Great Barrier Reef. In dealing with these problems, zoologists must collaborate with other marine scientists including botanists, mathematicians, physical oceanographers, organic chemists and biochemists.

Marine zoologists are employed in a great diversity of areas at all levels of government including federal marine agencies (CSIRO and the Australian Institute of Marine Science), by universities and museums, and in a variety of endeavours in private industry, such as environmental consulting, ecotourism, and pharmaceutical research.

Photo: A zoologist works on spawning sea urchins to examine the effects of water temperature on reproductive success.
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