Technical Annex 3

State of the Marine Environment Report for Australia

State and Territory Issues

Edited by
Leon P. Zann
David Sutton

Department of the Environment, Sport and Territories

Ocean Rescue 2000 Program


AUSTRALIA'S 200 MILE
EXCLUSIVE ECONOMIC ZONE
(excluding Macquarie, Heard, and Macdonald islands)
SYDNEY Capital city
Access port for foreign fishing
Limit of the Australian 200 nautical mile EEZ
State boundary
Perennial river
Intermittent river
Major ocean currents
DEPTH IN METRES
0
200
1000
2000
4000
Scale 1 : 25 000 000
0 200 400 600 800 1000 km
Map projection Mercator
Original map by CANDATA reproduced from Australian Fisheries Resources, Bureau of Resource Sciences, 1993.
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA
DARWIN
PERTH
ADELAIDE
CANBERRA
MELBOURNE
SYDNEY
BRISBANE
HOBART
INDIAN OCEAN
SOUTHERN OCEAN
PACIFIC OCEAN
CORAL SEA
TASMAN SEA
Timor Sea
Arafura Sea
INDONESIA
PAPUA NEW GUINEA
SOLOMON ISLANDS
VANUATU
New Caledonia
NEW ZEALAND
Sumatra
Borneo
Java
Sulawesi
Moluccas
Timor
Irian Jaya
Christmas Island
Cocos (Keeling) Islands
Norfolk Island
Lord Howe Island
PACIFIC INDIAN OCEAN THROUGHFLOW
EQUATORIAL
SOUTH CURRENT
WEST AUSTRALIAN CURRENT
LEEUWIN CURRENT
FLINDERS CURRENT (SUMMER)
ANTARCTIC CIRCUMPOLAR CURRENT
EAST AUSTRALIAN CURRENT
TASMAN CURRENT
SOUTH SUBTROPICAL CURRENT
CORAL SEA CURRENT
Great Australian Bight
Gulf of Carpentaria
Great Barrier Reef
North West Shelf
Bass Strait
Torres Strait
Cape York
Port Hedland
Broome
Karumba
Cooktown
Townsville
Mackay
Rockhampton
Gladstone
Mooloolaba
Moreton Bay
Tweed Heads
Coffs Harbour
Newcastle
Ulladulla
Eden
Port Lincoln
Kangaroo Island
Port MacDonnell
Portland
Devonport
Triabunna
Fremantle
Bunbury
Albany
Esperance
Geraldton
Carnarvon
Ceduna
INSET
ANTARCTICA
Scale 1 : 87 700 000
Lambert Azimuthal Equal Area projection
AUSTRALIAN ANTARCTIC TERRITORY
Mawson
Davis
Casey
Amery Ice Shelf
Ross Ice Shelf
Ronne Ice Shelf

The State of the Marine Environment Report for Australia Technical Annex: 3

State and Territory Issues

Edited by
Leon P. Zann
David C. Sutton

Great Barrier Reef Marine Park Authority
Townsville, Queensland, Australia

Ocean Rescue 2000
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Department of the
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Disclaimer:
These papers are independent scientific contributions and have been subject to an open peer review process. The views contained are not necessarily those of the Department of the Environment, Sport and Territories, the State or Northern Territory Governments, or the Great Barrier Reef Marine Park Authority.

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Introduction

Australia is an island continent and the sea is very important to Australians. A quarter of the population lives within three kilometres of the coast, some 86% live in the coastal catchments, and two-thirds reside in coastal towns and cities.

Australia's coastline, including that of Tasmania, is almost 70 000 kilometres in length. Australia's seas are vast in size and have a rich and unique marine biota. Australia's newly proclaimed 200 mile Exclusive Economic Zone (EEZ) is over 11 million square kilometres in area, and is one of the largest in the world. It spans 33° of latitude (58° including the Antarctic Territory), and encompasses all five ocean climate zones.

The sea has great economic value to Australia. Coastal and marine tourism, fisheries, marine transport, and offshore petroleum are estimated to be worth around $17 billion per year.

Our view of the sea has changed greatly over the past 40 years. In the 1950s the sea was regarded as the last frontier. In the 1960s it was seen as the solution to the increasing resource depletion on land. By the 1970s there were early concerns about the vulnerability of coastal waters. During the 1980s these deepened as some fisheries and marine ecosystems began to decline.

In 1990 the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), reporting to the United Nations on the health of the world's oceans, concluded that 'chemical contamination and litter can be observed from the poles to the tropics and from beaches to abyssal depths', and if allowed to go unchecked, this would lead to 'global deterioration in the quality and productivity of the marine environment. We fear, especially in view of the continuing growth of human populations, that the marine environment could deteriorate significantly in the next decade unless strong, coordinated national and international action is taken'.*

Ocean Rescue 2000 program

Because of growing concerns in Australia on the state of Australia's marine environment, the Commonwealth Department of Environment, Sport and Territories established the Ocean Rescue 2000 program in 1991 to promote the conservation and sustainable use of the marine and coastal environment. Ocean Rescue 2000 builds on existing marine conservation and management programs and is part of the national strategy for Ecologically Sustainable Development.

*GESAMP: (IMO/FAO/UNESCO/EMO/WHO/IAEA/UN/UNEP) 1990, The state of the marine environment, UN Regional Seas Reports and Studies No. 115, UNEP.

The principal objective of the program is to develop and implement the Australian Marine Conservation Plan which is to guide the use and management of Australia's marine resources. Other objectives include ensuring adequate baseline and monitoring information on the marine environment, activities and management, and ensuring its accessibility to decision-makers and managers; fostering an educated, informed and involved community; and developing and implementing a national representative system of marine protected areas.

The program consists of the following elements:

- National Representative System of Marine Protected Areas;
- Australian Marine Conservation Plan;
- State of the Marine Environment Report for Australia (SOMER);
- National Marine Education Program;
- National Marine Information System; and
- Marine and Coastal Community Network.

The State of the Marine Environment Report

The State of the Marine Environment Report (SOMER) is the first comprehensive, scientific description of Australia's marine environment. It was undertaken primarily to provide baseline information for the proposed Australian Marine Conservation Plan. It has also provided information for the Commonwealth government's new national State of the Environment reporting program which will report in 1996.

The Commonwealth Department of the Environment, Sport and Territories commissioned the Great Barrier Reef Marine Park Authority (GBRMPA) to prepare SOMER. The Authority has 20 years experience in research and management of the Great Barrier Reef, the world's largest multi-use marine protected area, and its expertise is being increasingly sought for marine environmental management, both nationally and internationally.

SOMER describes in detail the major marine ecosystems and their states; the major uses of the marine environment and their effects; the general issues and threats affecting the marine environment; the condition or health of the marine environment; and marine environmental management and conservation. SOMER examines habitats and communities from the shore to the ocean depths.

The SOMER Process

The production of SOMER was a great challenge. Australia's marine environment is vast and covers a great range of climates, ecosystems, habitats and human influences. More significantly, it is very incompletely known. Long-term scientific information on the marine environment, essential to accurately assess its condition, is very scattered, or lacking altogether in many areas.

The topics covered in SOMER were initially identified by a workshop of experts from marine science, resource management and industry. The GBRMPA appointed a senior marine scientist to coordinate the project and produce the reports. An expert Advisory Committee assisted and advised the coordinator in the identification of expert authors and reviewed the technical papers and reports produced. These commissioned technical reviews were also subject to a process of open scientific peer review. The 83 technical papers thus produced provided the source material for the main reports, the *State of the Marine Environment Report for Australia: Technical Summary* and the non-technical overview *Our Sea, Our Future.*

Much of the information collected for SOMER is unpublished. Because of the scientific value of this information, a range of papers is being published. This volume contains seven technical papers reviewing the state of the marine environments of the six Australian States and the Northern Territory. While each paper was subject to peer review by the relevant government departments, it should be noted that they do not necessarily reflect the views of State and Territory governments.

Leon P. Zann
SOMER Coordinator

SOMER process

topics identified by workshop

expert scientists commissioned to produce **technical papers**

papers peer reviewed

Selected papers published: **SOMER Technical Annexes 1 & 2**

technical papers, condensed & management implications identified

reviewed by authors, SOMER Advisory Committee and relevant govt agencies

combined to produce technical report: **SOMER Technical Summary**

major findings and issues identified & collated

reviewed by SOMER Advisory Committee and relevant govt agencies

published as non-technical report: **Our Sea, Our Future. Major findings of SOMER**

major findings summarised in brochure: **Our Sea, Our Future. Summary of SOMER**

→ *applications of SOMER:*

- ***Australian Marine Conservation Plan***
- ***National Marine Education Program***
- ***Marine Environment Conference (Uni Queensland, 1995)***
- ***National State of the Environment Report (1995)***

Acknowledgments:
SOMER is the result of the efforts of 134 scientists and technical experts, 14 members of the Advisory Committee, and around 160 external reviewers. Production of this volume: D.C. Sutton and Jim Campbell.

SOMER Advisory Committee:
Dr Don Kinsey (Committee Chair), former Executive Officer of the Great Barrier Reef Marine Park Authority, Townsville, Qld; Associate Professor Paul Adam, School of Biological Science, University of New South Wales, Sydney, NSW; Dr Joe Baker, Senior AIMS Fellow, Australian Institute of Marine Science, Townsville, Qld; Dr Eric Bird, Geostudies, Black Rock, Vic; Professor Ben Boer, Law Faculty, University of Sydney, NSW; Dr Des Connell, Director, Government Chemical Laboratory, Brisbane, Qld; Dr Pam Eiser, Australian Committee IUCN, Sydney, NSW; Dr Laurie Hammond, CEO Foundation for Research, Science and Technology, Wellington NZ (retired); Dr Tor Hundloe, Industry Commission, Canberra, ACT; Professor Arthur McComb, Environmental Science, Murdoch University, Murdoch, WA (retired); Professor Jason Middleton, Chairman, Centre for Marine Science, University of New South Wales, Sydney, NSW; Dr Russell Reichelt, Director, Fisheries Resources Branch, Bureau of Resource Sciences, Canberra, ACT; Dr Graham Ross, Series Manager, Fauna of Australia, ABRS, Canberra, ACT; Professor Graeme Kelleher (Ex-officio), former Chairman, Great Barrier Reef Marine Park Authority, Canberra, ACT.

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Issues in the New South Wales marine environment

Robin Macdonald

Australian Defence Industries Limited
(Formerly of the Environment Protection Authority
New South Wales)

Introduction

History

European settlement of the New South Wales (NSW) coastline commenced in 1788 when Captain Arthur Phillip established the penal colony of Sydney. He was conscious of the need for planning to prevent pollution and issued orders to control domestic animals and the indiscriminate clearing of trees near the Tank Stream, which served as the colony's water supply. Despite his efforts, by 1795 pollution of the stream had worsened due to people building too close to, and taking water direct from, the stream and raising pigs behind their homes. By 1810 tanneries, dyeing works, breweries, distilleries and slaughterhouses had also been built around the stream further increasing pollution problems. Expansion of the colony to the Parramatta area was accompanied by clearing of mangroves, clearing of bush for agricultural purposes, infilling of bays, expansion of urban areas and new industries, all of which contributed to pollution of the upper stretches of the Parramatta River. (Similar activities and effects had already occurred in the Sydney area). The necessity for a safe water supply for the settlers and a reduction in the pollution of local waterways finally led to the commencement of sewerage and water supply schemes in the latter part of the 19th century.

European settlement along the coastline progressively occurred to take advantage of abundant timber and coal resources and the productive farmlands along the many river valleys. The largest population centres outside Sydney developed at Newcastle (Hunter region) and Wollongong (Illawarra region) because of suitable port sites and abundant coal resources, both of which facilitated the establishment of iron, steel and associated industries. Expansion of the settlements and development till present times has led to progressive losses of habitat.

On the basis of population growth and building approvals, Department of Planning data have shown that the Hunter and Illawarra regions were amongst the top ten growth centres in Australia in the period 1971-1991. Gosford-Wyong (between Sydney and the Hunter regions) was also in the top ten together with the Richmond-Tweed region (located in the northern portion of the State). Neither of these regions is highly industrialised; both appear to be chosen as desirable regions to live in because of perceived better lifestyles. Nevertheless, this growth is bringing with it the earlier problems of the colony, namely rapid changes in land use and increased needs for water supplies and sewerage services.

More than 80% of the State's population now live in the coastal area with the bulk of the population and industry being concentrated in the Newcastle/Sydney/Wollongong area (these and other locations mentioned in the text are shown in Figure 1). Thus, it is not surprising that the largest pollution problems, and those attracting the most media attention, have been associated with this region.

The major coastal marine issues over the past 10 years have been associated with sewage and its disposal, in particular eutrophication of the Hawkesbury/Nepean River system (the catchment where the bulk of the growth in Sydney's population is occurring) and pollution of Sydney's beaches, adjacent coastal waters and associated fauna (in particular fish). Sewage effluent disposal has been a sensitive issue along the coast, with many communities concerned to avoid disposal strategies which they perceive could lead to similar problems to those identified in Sydney. Coastal development has been controversial and has been discussed at a number of inquiries (see later section).

Coastal waters (estuarine and marine) are extensively used for recreational purposes (swimming, diving, surfing, sailing, boating, fishing) as well as for commerce (shipping and

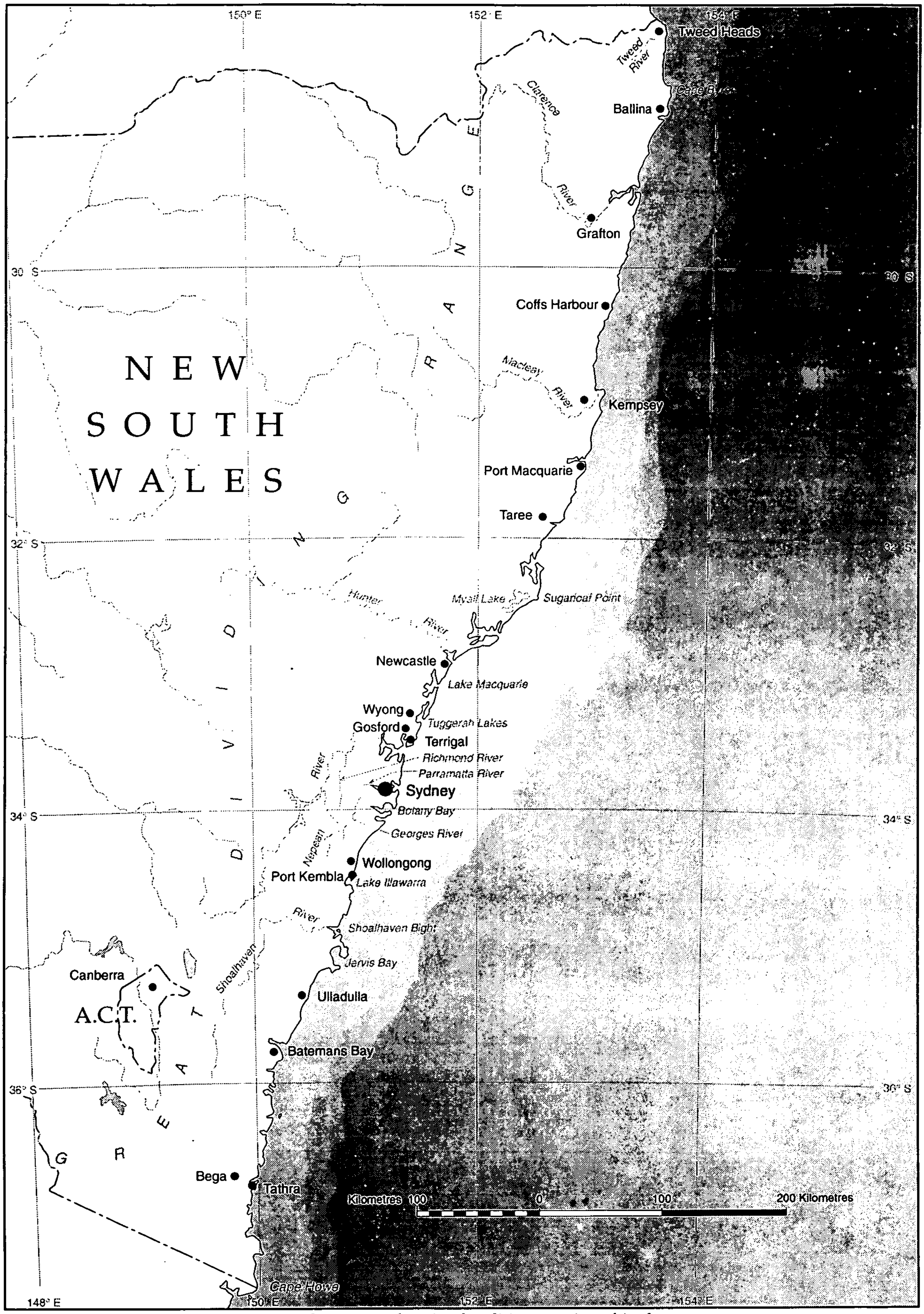

Figure 1: State map showing localities mentioned in the text.

fisheries, including oyster cultivation). Recreational activities in particular have increased over the years as a result of increased leisure time, greater access to transport to coastal areas and waterways, a desire for water (particularly coastal) based holidays, greater ownership of watercraft and an increasing aged (retired) but active group in the coastal community.

There are competitive pressures between commercial and recreational fishers; the fisheries resource in many species and areas is unable to satisfy the needs of an increasing number of amateur fishers and an increasingly efficient commercial fleet.

The bulk of the State's exports and imports are handled through port facilities at Sydney, Newcastle and Wollongong. Port development in the northern section of Botany Bay (Sydney) has caused concern to environmentalists because of beach erosion and changes in seagrass distribution due to the changed wave energy distribution that occurred during and after dredging. The current extension of Kingsford Smith airport runway into Botany Bay (the third runway) is an incremental development changing the nature of the bay; it will result in removal of seagrass habitat during the dredging and reclamation activities. (However the Federal Airports Corporation is proposing to re-establish some seagrass beds as partial compensation). Other developments, affecting habitats and thus marine communities, are occurring at a smaller (but cumulative) scale in many coastal areas as a result of activities such as the construction of marinas, residents cutting down mangroves or reeds to gain views or access for their boats, infilling (or reclamation) for construction or spoil disposal purposes and extractive industries (to obtain sand and gravel). Although any development by itself may have little effect, the long-term effect of many such incremental changes may be detrimental.

Coastal water characteristics

For the purposes of this chapter, the marine environment has been interpreted as including estuaries and coastal lakes. Such waters are often tidal, which may help flush pollutants or diluted effluents to the ocean where dilutions are greater.

NSW coastal waters are affected by interactions between the southward flowing East Australian Current (EAC) and cooler Tasman Sea water intruding from the south. The EAC is a southerly jet of warm Coral Sea water which may separate from the coast as far south as Ulladulla (400 km south of Sydney) but more typically would separate from the coast at Sugarloaf Point (about 300 km north of Sydney), forming turbulent warm (anticlockwise and often 150 km in diameter) and cold (clockwise and about 30 km in diameter) water eddies. These eddies may affect coastal (shelf) water movements further to the south by encroaching on the shelf as they travel south and dissipate into the surrounding Tasman Sea, a process that can take up to six months. This EAC influence typically causes higher temperatures in shelf waters and a strong flow to the south that is uniform throughout the water column. Recent analysis of offshore current data has shown that the EAC directly influences Sydney's coastal waters about 75% of the time (Lee & Pritchard 1993). In general, the effect of the EAC on shelf waters decreases south of the separation zone whereas strong southern flows and associated warm waters are consistently found further north.

Other influences on coastal water movements are coastally trapped waves, tides and wind. Coastal trapped waves originate in Bass Strait and southern NSW and travel north along the continental shelf past Newcastle with a periodicity of typically 7-20 days. They may cause current reversals and either downwelling (during northward flows) or upwellings (during southward flows) in Sydney inner-shelf coastal waters. Such (natural) upwellings may be associated with increased nutrient concentrations in surface waters which may lead to enhanced algal blooms in coastal waters. The influence of such phenomena is more marked during quiescent periods of EAC activity. Tides tend to have small effects in offshore waters except where ebb jets from bays or large rivers occur. In the Sydney region, winds, particularly those associated with storms from the south-east, may break up thermal stratification in the offshore waters and enable normally submerged sewage plumes to surface.

Northern rivers tend to be broad slow-flowing rivers with well developed coastal flood plains, extensive associated coastal wetlands and coastal towns at the river mouths. High rainfalls in the catchments can lead to high flows and flushing of the estuary and, at times, extensive flooding. Pollution problems have tended to be related to agriculture and agricultural industries, forestry operations, sand mining, urbanisation, flood mitigation works and water supply dams; these have led to concerns about increased erosion and sediment loads, pesticides, nutrients (from sewage, agriculture, piggeries etc.) and changes in flow regimes. Development of drainage channels in some areas has resulted in 'acid drainage' problems that have caused massive fish and benthic kills. (Acid drainage results from the oxidation of sulphide minerals in certain soils to acids during dry periods and their subsequent leaching into drains following rain. The acid also dissolves aluminium; both are toxic to aquatic life.) Infilling of wetlands and increased incidence of fish diseases, such as 'Red Spot', possibly related to flood mitigation works, have also caused concern.

The catchments of many coastal lagoons (Lake Macquarie, Tuggerah Lakes and Lake Illawarra) are progressively becoming urbanised. Both Lake Macquarie and Tuggerah Lakes are used for cooling of power station generating units. (Lake Illawarra is no longer used for this purpose as a result of rationalisation of electricity generating facilities.) Tidal flushing of all these waters is limited.

Southern rivers tend to be shorter in length and have poorly developed coastal flood plains (with the exception of the Shoalhaven and Bega valleys); often the rivers or lakes may be separated from the ocean by permanent or semisubmerged sandbars. Thus, they have less flushing and are less able to tolerate stresses. Tourism and urbanisation tend to be the major developments although agriculture, fisheries and production and transport of woodchip exports are important local industries. Water quality problems tend to be localised and are associated with nutrient enrichment and erosion and sedimentation.

Major environmental issues and disturbances

Recent inquiries into the coastal zone have addressed planning matters and other environmental issues on both a state and federal basis. A summary of concerns expressed in recent reports is as follows.

The House of Representatives Standing Committee on Environment and the Arts (1991) documented concerns with respect to:

- ocean disposal of sewage and the lack of suitable alternatives;
- impacts of bio-accumulation of toxic substances;
- the need for national water quality guidelines to be finalised;
- the need for national standards for waste discharges;
- the need for a national database inventory for the coast;
- introduction of exotic micro-organisms from ballast waters;
- disposal of wastes and rubbish at sea.

The Resource Assessment Commission (RAC) has published a background paper (1992a) and a draft summary and interim conclusions report (1992b). The latter expresses concerns about the continuing rapid urbanisation of coastal areas and identified likely impacts as:

- further losses of fish stocks, natural habitats and wetlands;
- further deterioration of water quality in many locations.

They felt that the latter would threaten the amenity of many beaches which were considered to be one of Australia's major tourist attractions.

The Parliament of New South Wales Legislative Council's Standing Committee on State Development (1992) has also reported on coastal planning and management in NSW; their recommendations include:

- development of national ambient standards and guidelines for environment protection and pollution control, taking into account carrying capacities;
- development of catchment environment protection plans;
- establishment of environmental monitoring programs;
- attention to cumulative impacts (including those from nonpoint sources such as urban stormwater run-off, watershed management, farm practices etc.).

Currently, the Coastal Committee of NSW is carrying out a review of 'The New South Wales Coast Government Policy'. This policy is applicable to the coast outside the Newcastle-Sydney-Wollongong region. The Committee has an independent chairman and includes representatives from local government and shires, a delegate from the Nature Conservation Council and government departments.

Some of the above concerns have already been addressed; for example the Australian and New Zealand Environment and Conservation Council (ANZECC 1992) has recently published national water quality guidelines and, together with the

Australian Water Resources Council, is working towards national standards for waste discharges. There is a strong commitment to total catchment management (TCM) by the New South Wales Government and TCM committees, involving both government authorities and local representatives, have been formed in many areas. (Under the TCM umbrella, the NSW Government, through the Public Works Department, is developing a State Estuaries Policy). The other environmental issues, which are commonly identified by the community, are reviewed below. Sewage disposal is treated as two segments since ocean or lake/river disposal may lead to different impacts on the environment.

Sewage

Historically, sewerage systems and sewage treatment works have been constructed after urbanisation has occurred. This often led to the installation of inadequate septic disposal systems and resultant illegal disposal of effluents to local waterways. In New South Wales, major construction activities by local authorities in the 1970s and 1980s have resulted in a situation where most coastal urban communities with a population greater than 700 are connected to a sewerage system. Developments in existing or new urban areas are usually connected to sewerage systems before premises are occupied. Thus, the effects of septic systems on waters are not an issue in most areas. Emergency sewer overflows have been installed throughout sewerage systems to ensure that any excess flows in sewers, particularly during and after storms, do not result in sewage overflows in people's homes. Some overflows near urban areas have led to much complaint because of the frequency of overflow and degraded receiving water quality. Illegal connection of storm waters to sewers increases the frequency and extent of such problems. Many authorities are now actively testing areas for such illegal connections; they have been greater than 50% in some older urban areas.

Sewage treatment works effluents in NSW are usually irrigated onto land (including being sprayed on areas such as golf courses) or discharged to local creeks, rivers, lakes or the ocean. The percentage utilised on land has been small to date (less than 5%) and there are several (small) examples of disposal to sand dunes. All discharges have to meet specified licence (i.e. effluent quality) conditions which are set on an annual basis by the Environment Protection Authority (EPA). Licence limits take into account the treatment efficiencies of installed facilities, the type and location of the discharge, possible effects of the effluent on the receiving environment and relevant standards and guideline documents. The effects of effluents discharged to waters can be summarised as follows.

Disposal to ocean

During dry weather, effluent discharges to ocean waters from individual outfalls vary from less than 0.5 to approximately 500 ML/d. With the exception of discharges in the Newcastle-Sydney-Wollongong region, sewage is treated to a secondary standard before discharge from isolated rocky shoreline locations (eg headlands) where dilutions and mixing processes are greater. Environmental monitoring near these latter outfalls has not been extensive and has shown only slight, if any, impacts; there have been few complaints concerning either effluent quality or impacts. (In the Newcastle region all discharges will be to a secondary standard by 1996). Traditionally, sewage sludge disposal from major treatment plants has been mostly to ocean; this no longer occurs in Sydney and will be discontinued in the Hunter region soon. (Higher treatment of sewage results in increasing quantities of sludge to be disposed of; as ocean disposal and incineration are not favoured by the public, disposal strategies will increasingly tend to be to land, as a fertiliser or component of compost, or to landfill).

Public perceptions of the effects of ocean outfalls have been strongly influenced by the impacts observed at Sydney when effluents, which had received only partial primary treatment, were discharged at shoreline sites i.e. prior to September 1990. Then, beaches often had high faecal coliform densities (greater than Health Department guidelines), sewage-derived materials and plastics were often present on beaches (Heggie & Nelson 1992) and some species of fish caught near the shoreline discharges had elevated organochlorine concentrations (Mann & Ajani 1991). Although faecal coliform densities are commonly measured in bathing waters and used as an indicator of the presence or absence of sewage, their densities cannot be directly related to the health risk for swimmers. (It should also be noted that faecal coliforms in receiving waters may also arise from other sources; however their ease of measurement and low cost makes them an extremely useful indicator bacteria).

An Environmental Monitoring Program (EMP) was developed and initiated by the Sydney Water Board (SWB) as a requirement of the State

Pollution Control Commission's (SPCC) approvals in the early 1980s to construct three deepwater (60-80 m) outfalls; since 1990 the EMP has been carried out by the EPA. The program measures the environmental changes following diversion of sewage discharges to deep water and includes oceanographic studies (examining and predicting plume behaviour), chemical studies (water quality and contaminants in fish, sediments and moored oysters) and biological studies (fish population and abundance).

EMP studies have shown that since the commissioning of the three deepwater outfalls (August 1991), beach water quality has markedly improved with faecal coliform densities at Sydney's previously dirtiest beaches meeting Health Department guidelines more than 90% of the time in the summer of 1991/92 (Figure 2) as compared with 10% previously. Many of the instances when beaches do not meet criteria occur during or after storms when run-off (including that transported by stormwater drains) and sewer overflows (at coastal locations or to drains) can affect beach water quality. The incidence of sewage-derived grease on beaches has been reduced but not eliminated; its presence appears to be strongly correlated to weather conditions with south-easterly (onshore) winds resulting in a greater occurrence of grease. (Storms often occur during these conditions; these can result in increased sewage flows and bypasses of excess sewage flow to the shoreline outfalls as well as input of pollutants from storm waters.) Progressive installation of finer screens at sewage treatment works has resulted in most large materials (condoms etc.) being removed at the treatment works. Whilst Sydney outfalls carry the largest flows and trade waste component, increasingly stringent controls by the SWB have meant that the pollutant loads carried by these systems are being progressively reduced.

Disposal to rivers and lakes

Discharges to coastal rivers have undergone secondary treatment, often combined with a

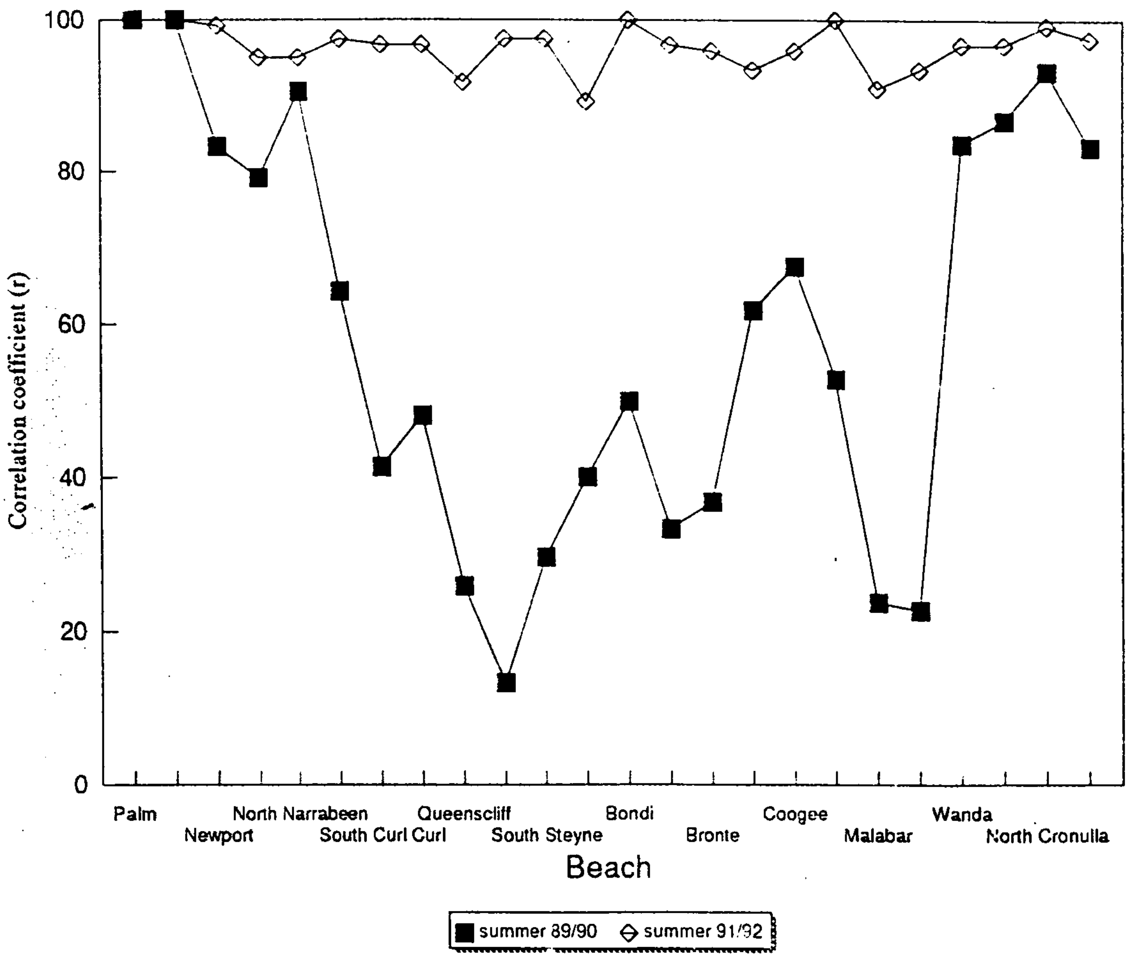

Figure 2: Percentage of time faecal coliform densities at Sydney beaches met health guidelines during the summer seasons of 1989/90 (prior to deepwater outfall commissioning) and 1991/92 (post deepwater outfall commissioning)

tertiary stage for disinfection. Localised eutrophication has occurred when discharges have been to low flow or poorly flushed creeks or rivers. As a result of environmental concerns, extensive studies took place in the late 1970s concerning Georges River and the Hawkesbury/Nepean River system, both rivers occurring in the Sydney region. As a consequence, sewage effluent discharges were diverted from the Georges River to the ocean outfall system to decrease eutrophication and thus improve river water quality.

The Hawkesbury/Nepean River system (to the north and west of Sydney) is more complex and the bulk of the expansion of Sydney's population is occurring in this catchment. The river is used for many purposes ranging from recreation, commercial fishing and as a source of potable and agricultural waters, to receiving and transporting treated effluents and urban and agricultural run-off. Although local sewage treatment works have been expanded to cater for the population growth, there has been increasing concern about river water quality.

The State Pollution Control Commission published two reports concerning this river system (SPCC 1985, 1983a). They concluded that water quality would continue to deteriorate unless ammonia was oxidised at treatment works to a greater extent and total nitrogen and total phosphorus concentrations in effluents were reduced. Since this time, some gains in effluent and river water quality have been made; ammonia and total phosphorus (TP) concentrations in effluents and the river have significantly decreased but total nitrogen (TN) has remained relatively unchanged. This is in agreement with the changes in total nitrogen and phosphorus loads discharged from sewage treatment works above the Colo River confluence between 1979-81 and 1990-91. (TN loads have changed from 1767 to 1868 kg/d whilst TP load have changed from 406 to 151 kg/d.) The result has been that algal growths have decreased but not to target levels in all river sections (less than 20 μg/L chlorophyll a, see Figure 3) (EPA 1992). Further reductions in nutrient concentrations in effluents will be required as catchment populations, and thus nutrient loads from sewage works, continue to increase.

Studies of the major northern rivers were published by the SPCC in the mid 1980s and options for sewage disposal were discussed. Impacts of treated sewage effluent disposal to other coastal rivers have been studied to lesser extents. The rate of installation of phosphorus removal facilities at coastal sewage treatment works has been slow; for some river systems, this may not have large impacts because of the small size of the treatment works, the dilution available or the magnitude of other catchment nutrient sources. However, as populations increase, problems may arise.

Lake Macquarie has traditionally received discharges of treated effluents; however, as a result of an environmental audit (SPCC 1983b) which identified concerns about eutrophication of the northern sections of the lake, it was decided to remove these effluents from the lake by a combination of reuse options and diversion of treated effluents for discharge through an offshore ocean outfall. These strategies should be completed in 1996. Other major coastal lakes do not receive discharges of treated sewage effluents although sewer overflows could possibly impact some areas during wet weather.

Bio-accumulation of contaminants

Large numbers of fish have been analysed as part of the Sydney EMP (Mann & Ajani 1991). This report records that morwong, blue groper and snapper accumulated the highest concentrations of contaminants such as organochlorines and mercury. Red morwong caught near previous cliff-face outfall sites have shown decreased concentrations of organochlorines such as chlordane and dieldrin (Philip 1995) since the deepwater outfalls were commissioned, which is consistent with data showing decreased chlordane levels in oysters moored near such sites (Philip 1995; EPA unpublished data). By contrast, at the deepwater outfall sites, chlordane in moored oysters has only been detected at trace concentrations both before and after the outfalls were commissioned. Chlordane and dieldrin concentrations in rubberlip morwong and snapper have decreased during this period (EPA unpublished data). These preliminary data indicate that the increased dilution of the sewage (now averaging about 500-2000 times) may reduce the availability of such contaminants to fauna. Contaminant concentrations in several fish species caught near Sydney and at more distant control sites since the commissioning of the outfalls will be reported in 1994.

EPA data concerning organochlorines in red morwong caught in both the Sydney and Illawarra areas have shown that the latter contain far lower levels. This is consistent with Water Board (Andrijanic 1991) studies which also found

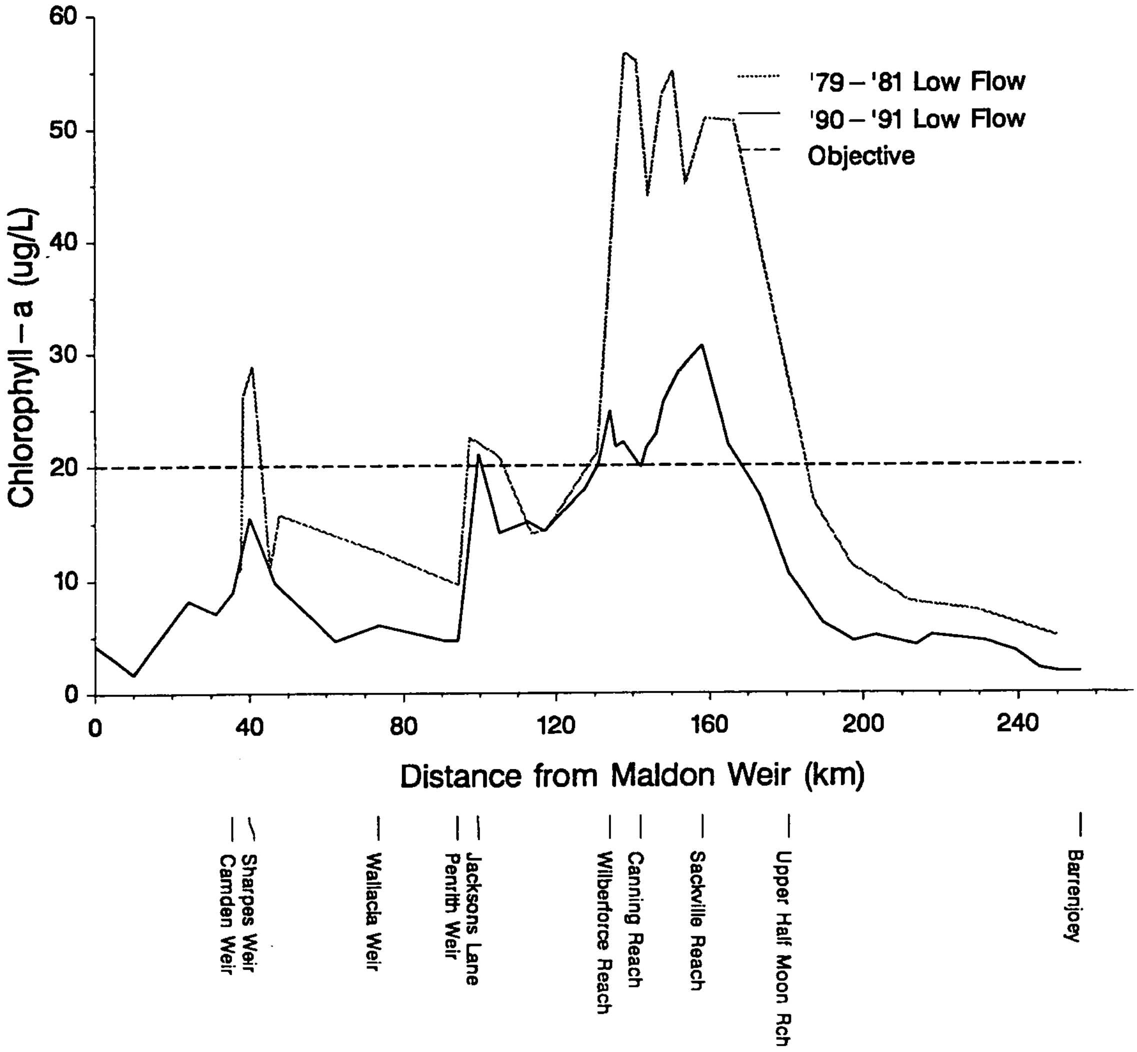

Figure 3: Geometric mean chlorophyll a in Hawkesbury/Nepean main stream in 1979-81 and 1990-91

contamination decreasing with increasing distance from Sydney.

Contaminant data for four species of fish collected by NSW Fisheries in 1991/92 from ten estuaries along the NSW coast have shown that organochlorine concentrations are low in most areas, with highest levels being observed in fish collected from the Parramatta and Georges Rivers (NSW Fisheries pers. comm.).

Fishing closures (or bans) apply at a small number of locations, namely near the three major (old) Sydney shoreline sewage outfall sites, in the upper sections of Parramatta River, Cooks River, Throsby Creek and to the mouth of the Hunter River (Newcastle), South Channel of the Hunter River and Port Kembla Inner Harbour and its tributaries. (Bans at nonoutfall sites have often been gazetted because of concerns about possible contamination arising from effluent discharges or contaminated sediments). The bans around the Sydney outfall sites are under review as more recent data for fish and oysters, showing decreased organochlorine contamination since the deepwater outfalls were commissioned, are becoming available.

Water quality

Water quality has already been covered to some extent in the previous section. However, it is recognised that there are other inputs to waters besides sewage and that alterations to physical features of systems can cause changes in water quality.

As the degree of urbanisation of coastal areas increases, urban run-off impacts may become greater There have been several studies in Australia of the composition of urban run-off, one of which (Rowlands et al. 1992) is of direct relevance to coastal areas. Here, the quality of urban stormwater run-off, under varying flows, from five coastal catchments in the Sydney region was measured and the relationship to local bathing water quality examined. No significant correlation was found between the concentrations of faecal bacteria, nutrients and suspended solids in the drain discharge and in nearby bathing waters during dry weather. Wet weather discharges tended to have equal or higher pollutant concentrations than dry weather flows.

Stormwater run-off from developed rural and urban areas may cause increased rates of erosion and adversely affect waters because the run-off may result in increased rates of erosion and sedimentation and may contain nutrients, oil and grease, trace metals, faecal material (from sewer overflows and pets) and refuse (plastics, cans etc.). There are few documented measurements of the scope of resultant problems; erosion of tributaries, sedimentation of bays and lakes, changing sediment type (sand to mud), together with changes in weed growth and distribution are the problems commonly identified (for example in Lake Illawarra, Lake Macquarie and Tuggerah Lakes). Sediment may smother bottom habitats, decrease water depths or provide a source of fine material which can be readily stirred up by wind waves etc., thus decreasing water clarity and making areas unsuitable for primary recreation (e.g. swimming). As a result of these concerns, increasing attention is being given in new urban developments to the installation of stormwater detention ponds. (Guidelines to improve stormwater quality have been published (SPCC 1989a)). For example, in the Lake Macquarie catchment, developers have been requested to formulate erosion control plans which will be used in conjunction with silt traps, trash racks and floating booms.

Algal blooms, including red tides, commonly occur along the coast, particularly during summer. Their incidence and frequency has not been widely studied. Causes of at least some of these blooms are most likely to be ocean upwellings which bring nutrient rich waters to the surface.

Petroleum spills

Spills of crude oil or refined products have tended to occur frequently but have involved low volumes; thus, in the last two years, 330 spills have been reported to the EPA or Maritime Services Board. The median size of a spill has been less than ten litres and the maximum size 3000 L. The small spills have generally been associated with fuelling of small boats whilst the larger have been associated with pipeline incidents. Most have tended to be of nuisance value rather than of ecological significance, although possible long-term cumulative effects may be significant in some areas. Nevertheless, the large quantity of oil transported and refined in the NSW coastal region has resulted in the precautionary development of oil spill response committees and plans to handle spills of varying magnitude. A series of coastal resource atlases is being produced by the EPA which document environmentally sensitive coastal areas and complement existing manuals and plans for dealing with oil spills. (Funding for this work is provided by the Australian Maritime Safety Authority). (This section does not include the quantities of petroleum products transported to coastal waters by stormwater run-off or arising from road accidents).

Spoil dumping

Sea dumping of dredge spoil regularly occurs although it is generally restricted to those cases where alternative reuse or disposal (of spoil) has been investigated and found to be impractical or exceedingly costly. Spoil is analysed for contaminants before any permission to dump is given. The bulk of the spoil arises from maintenance dredging of Newcastle, Sydney and Port Kembla harbours; this has averaged about one million tonnes per annum over the period 1989-1992. The Sydney harbour tunnel project accounted for approximately half the material dumped during this period.

Habitat losses

Drainage, reclamation, sedimentation, changed energy environment or decreased water quality (due to increased turbidity or eutrophication) are all factors that may result in loss of suitable habitats for fish and other biota, thus raising concerns for the long-term management of marine fisheries resources and ecosystems. Weirs on rivers may restrict and change water flows, thus causing major habitat changes as well as preventing fish migration for breeding purposes. Recent mapping of estuarine wetlands on the NSW north coast has shown that there have been changes over the last 40-50 years (see Table 1, R.J. West, Fisheries Research Institute, NSW, unpubl.). Most habitat categories have declined with the exception of seagrasses in the Macleay River, which have increased in area due to construction of a new river entrance which resulted in a protected tidal inlet being formed. A State Environmental Planning Policy (No. 14 - Coastal Wetlands) was gazetted in 1985; this policy restricts developments of lands and aims

Table 1: Changes in seagrass, mangrove and saltmarsh areas (km^2) in three northern rivers

River	Year	Seagrass Area	Mangrove Area	Saltmarsh Area
Tweed River	1947	1.41	2.89	0.70
	1962	0.87	2.91	0.38
	1981	0.40	3.09	0.20
	1986	0.39	2.76	0.20
Clarence River	1942	5.28	5.13	2.41
	1966	2.76	5.07	2.34
	1971	1.58	5.20	2.41
	1981	1.54	4.89	2.14
	1986	0.83	4.79	2.05
Macleay River	1956	0.88	5.38	6.09
	1976	1.32	5.42	4.17
	1981	1.29	5.70	3.97
	1986	1.31	5.70	3.97

to ensure designated wetlands are preserved and protected. (This policy restricts development only to the extent that it makes certain forms of development 'designated', and thus requiring the production of an EIS; the Director of the Department of Planning has a concurrence role in any consents). The SPCC (1989b) published an Environment Protection Policy which restricts the use of natural wetlands for effluent disposal purposes. West (pers. comm.) believes that government legislation, such as the Environmental Planning and Assessment Act and the Clean Waters Act together with greater public awareness of the value of wetlands, have helped arrest declines in wetland areas, particularly of mangrove communities.

Data covering the changes in wetland areas for the whole of the State are not readily available, although similar losses have been reported for other coastal lakes and rivers; for example seagrasses decreased by 44% in the Georges River between 1951 and 1979, possibly due to increased turbidity and siltation (Shepherd et al. 1989).

Fish stocks

Estimates of fish stocks, which are necessary to manage a resource, are difficult to determine. They are often derived from short-term monitoring of stock size and age structure and commercial fish catch data of limited accuracy. For most species, a detailed knowledge of population dynamics, ecology and the effect of environmental stresses is not available. The ESD Working Group on Fisheries (1991) listed species in New South Wales which were regarded as overfished or fully fished; of 41 estuarine and marine species of importance to commercial and recreational interests, there was inadequate knowledge available to satisfy either management or ecologically sustainable development purposes for any of the species. Recreational pressures on some fish stocks in certain areas may be significant and need to be evaluated when management plans for particular species are being formulated. Thus, the potential yield from many fisheries remains uncertain due to lack of information on aspects such as fish stock, fishing effort, catch rates, biology and environmental pollution interactions.

The eastern rock lobster is a documented example (NSW Fisheries 1992) of a species whose NSW catch has fallen dramatically from about 400 tonnes per annum in 1947 to 100 tonnes/annum in 1991. Reductions in some areas of the State have been proportionally greater. During the period 1970 - 1991, the catch per unit effort has declined by two thirds. These two declines led the committee to conclude that rock lobster stocks were unable to sustain the current fishing efforts and that a new management strategy was required. This species is caught in both inshore and offshore waters by both commercial and recreational fishers. Although there is a legal size limit which is attained at approximately 3-4 years of age, maturity and hence breeding does not occur until approximately 6-7 years. The result is that harvesting of immature adults commonly occurs. A management plan has been proposed which includes recommendations that a limit be placed on the number of animals allowed to be taken each year for commercial purposes and proposes protection for large female mature animals. Only time will show whether the management plan will be successful in preventing a continual decline in the resource.

Monitoring of the marine environment

All wastewater discharges to the marine environment are required to meet licence conditions set, on an annual basis, by the EPA. Pollution reduction programs may be required to be developed for progressive implementation where it is believed that the discharge quality needs to be improved. Generally, environmental monitoring is not required to be carried out by the discharger. However, major discharges, such as Sydney's ocean outfalls do have such conditions; these data, together with results being obtained by the EPA from the EMP, are providing an extensive picture of the Sydney marine environment. The data collection phase of most EMP monitoring studies was due to be completed by the end of 1993 and reported in 1994.

In the Newcastle region, the Hunter Water Corporation and the Hunter Port Authority are funding a four year study by the EPA into the presence of contaminants in coastal waters and sediments. As in the Sydney EMP, oysters are being used to monitor contaminant concentrations in the waters. (Initial results have shown that the level of contaminants in the coastal waters are very low). Oysters have also been deployed in the Illawarra region for comparison with Sydney EMP data. Oysters have also been collected from estuaries along the whole coast and contaminant concentrations will be used to indicate the relative status of the different estuaries.

Currently, as part of the Sydney EMP, fish are sampled from the Sydney region, central coast (at Terrigal, 50 km north of Sydney) and at Jervis Bay (140 km south). This sampling was due to be completed in 1993 and decisions will be made as to whether the sampling should continue. NSW Fisheries data for contaminants in four fish species from various estuaries along the coast will complement these data.

The Sydney Water Board is carrying out a variety of marine studies in the Sydney and Illawarra regions in connection with its needs to have information for future planning purposes for its existing shoreline outfalls and stormwater discharges. These studies, when published, will complement other data being collected.

Discussion

Population increases in coastal areas contribute to many coastal problems. Such increases result in augmentation of existing sewage treatment works and/or construction of new facilities. Higher rainfall along the coast tends to reduce the opportunities for reuse of treated effluent and thus effluents are discharged to coastal waters. The location of the sewage discharge sites has tended to cause public concern when coastal locations have been suggested, even though data showing significant adverse impacts (outside the Newcastle-Sydney-Wollongong area) are lacking. The public, in several locations, has preferred discharges to creeks, rivers and wetlands rather than to ocean even though the former routes inevitably result in the same flows reaching the ocean. (This situation has arisen because communities wish to avoid similar problems to those in Sydney before commissioning of the deepwater outfalls.) The result is that a high degree of nutrient removal (to minimise eutrophication of receiving waters) and disinfection (as dilutions of the effluent may be small) are required to minimise impacts. Disposal of effluent to artificial wetlands is often proposed; this has potential but also drawbacks because of land requirements, a lack of long-term experience with such systems and their limited capacity for phosphorus removal.

Increasing urbanisation, together with road construction, farming, flood mitigation and drainage works, may all lead to increased erosion and sedimentation, thus reducing water quality and adversely affecting aquatic habitats. Often coastal urbanisation leads to local pressure for insect control; there is little information on the ecological effects of resultant control programs. The progressive changes in wetlands need assessment and monitoring whilst the importance of different habitat types and the effects of incremental losses are not well understood and require further study. At this stage, contaminant problems have generally been associated with the major urban areas; longer-term monitoring will establish whether the expanding country towns and cities will experience similar problems or whether trade waste controls (on discharges to sewers), controls on usage of chemicals and/or high dilutions of sewage will prevent such problems.

Acid drainage in some northern rivers can decimate all fish and benthic life; although only an intermittent problem in some areas, cooperative research between developers, agriculturalists and fisheries personnel is required to develop management options to prevent such occurrences. The possible relationship of acid drainage to 'red spot' disease need to be investigated. Some fish species appear to have declining stocks because of overfishing; a solution to this problem should involve recreational fishers, commercial operators and state and federal authorities.

Whilst there are already some monitoring programs, particularly around Sydney and Newcastle, there is a need to establish longer-term programs on a statewide basis. A better understanding of the influence of oceanic currents along the whole coast and the flushing characteristics of estuaries are prerequisites for effective programs.

The coastal marine environment, which includes associated rivers and tributaries, is sensitive and important and is expected to come under increasing pressures in future years. Its flora and fauna will only be protected for a variety of users if issues and problems are approached on a catchment, and, in many cases, a State basis. This will require cooperation and understanding and a willingness to negotiate solutions which may involve concessions by all parties. For example, sustainable and equitable harvesting of fish by both commercial and recreational interests will require such an approach. Agreed sets of data and guidelines, which can be used by all parties involved in future decision making, will be needed. It is proposed that priority should be give to monitoring the changes in coastal resources (such as wetlands), implementing a coastal monitoring network, evaluating contaminant patterns along the coast, ascertaining fishery stocks and developing guideline documents for nonpoint sources of pollution (e.g. farming, drainage, forestry etc.).

In summary, provision of sewerage services, deepwater outfalls for major Sydney sewage discharges, trade waste controls (by sewerage authorities), nutrient removal and pollution controls are limiting further marine environmental degradation near major urban centres. Sustainable management of fisheries resources and control of diffuse sources are not as well advanced. Further study and monitoring of both water quality and coastal resources, particularly outside the major urban areas, will be required to ensure that the coast and its resources remain available for all to use and enjoy in a sustainable and equitable fashion.

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Issues in the Victorian marine environment

Ross Winstanley

Marine Resources Branch
Department of Conservation and Natural Resources
Victoria

Introduction

Victoria has an area of 227 600 km^2, a 2000 km coastline and a population of 3.7 million, giving it the highest population density and population-to-coastline ratio of all states and territories. The coast features two major embayments, Port Phillip Bay and Westernport Bay; the largest estuarine lakes system in the southern hemisphere, the Gippsland Lakes; the large shallow coastal lagoon system Corner Inlet/Nooramunga; and numerous smaller inlets and coastal streams.

By world standards, no major rivers drain to the Victorian coast; the largest is the Snowy River which has an average annual discharge of 1 790 000 megalitres. Of the State's total annual rainfall, 14% (21 000 000 ML) eventually flows to the sea (Vic. Govt 1982). The Great Dividing Range extends through north eastern to central Victoria, feeding major rivers northwards into the Murray River and southwards into the estuaries and coast of eastern Victoria.

The Victorian coast forms the northern boundary of Bass Strait, a shallow basin whose waters are influenced by the Tasman Sea and the East Australian current to the east, and the colder and more fertile subantarctic waters of the Southern Ocean to the south and west. While seasonal upwellings occur off western and eastern Victoria, the coastal and offshore waters are characterised by low nutrient concentrations. The water temperature range is from about 12°C to 18°C (Gibbs et al. 1986a).

The state's major industrial centres are concentrated around Port Phillip Bay's 264 km shoreline, and 70 % (3.2 million) of the State's population live in the expanding Bay-side cities of Melbourne and Geelong.

Port Phillip Bay's marine environment is of special interest and concern. The main body of the 1950 km^2 Bay is a shallow basin, 24 m deep at its deepest point, with predominantly sand, silt and clay substrates. The average tidal exchange with Bass Strait, through the 3 km wide Rip, is about 1 km^3 or 4% of the Bay's volume (Vic. Govt 1992c). The water temperature range is from about 10°C to 21°C.

Each year, the Bay's volume of 25 km^3 receives 1.4 km^3 of fresh water from the rivers which drain its 9790 km^2 catchment, plus 1.2 km^3 of rainwater, 0.2 km^3 of treated sewage effluent and 40 000 tonnes of sediment from the Yarra River. Melbourne has about one third of Australia's manufacturing industry, disposing of 35 million tonnes of industrial wastes to sewers each year (Vic. Govt 1989a). The range of chemicals and materials manufactured and used, with potential for environmental damage, is increasing.

Coastal, bay and inlet waters support a variety of commercial activities: shipping, oil and natural gas fields, fishing and aquaculture. The infrastructure (e.g. harbours, wharves) and industrial complexes (e.g. refineries, chemical storages, superphosphate plants, aluminium smelters, fish processors) which support or depend upon these maritime activities are concentrated in particular areas on the fringes of these waters. The Port of Melbourne is Australia's largest general cargo port and, in 1987-88, handled merchandise worth over $23 billion, representing 27% of the total value of the country's international trade (Vic. Govt 1989a). Submarine pipelines bring oil and natural gas ashore from the Bass Strait oilfields to the Ninety Mile Beach and carry natural gas across the floor of Port Phillip Bay.

Several important recreational activities also focus on these coastal waters: recreational fishing, boating, sightseeing and related tourism - all of which are of great significance to coastal economies. Each year the Bay receives around 30 million recreational visits, including two million boat trips by Victoria's 65 000 recreational boats (Vic. Govt 1992c). Careful impact monitoring, assessment and planning are essential to ensure.

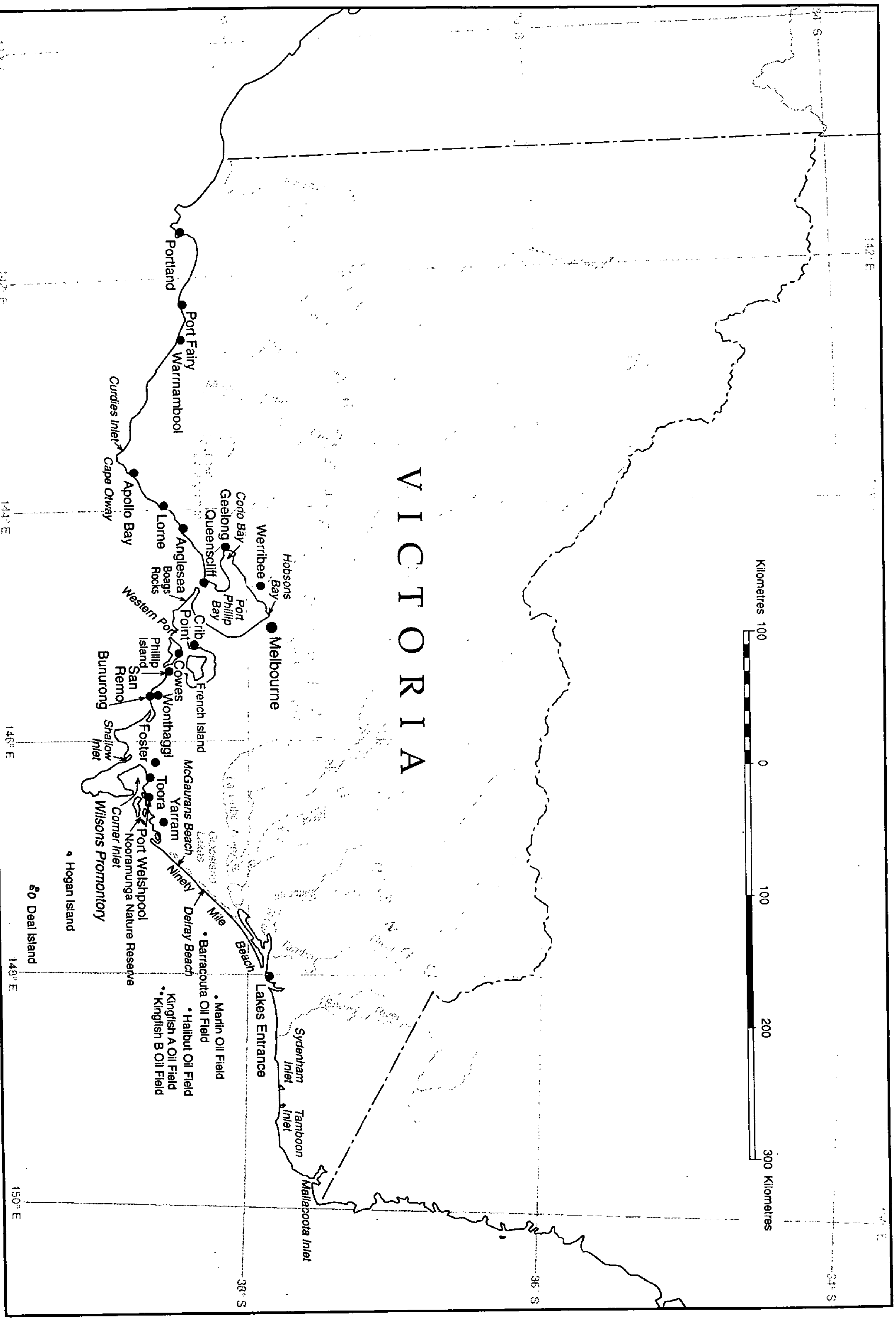

Figure 1: State map showing localities mentioned in the text.

that the benefits derived from these recreational activities do not occur at the cost of the marine resources and environments on which they depend.

Coastal waters also play a vital role in receiving point and non point source discharges of domestic and industrial origins, requiring strict licensing and monitoring programs. Population growth, industrial development and consequent increases in the environmental pressures on coastal waters, require careful long-term planning and capital works programs. At the same time, there is a need to improve the quality of coastal discharges and to mitigate the effects of past pollution, adding to the complexity and costs of these tasks.

Most major problems arise from the concentration of population and industry around Victoria's two bays and the advanced state of development of the catchments to the bays and inlets. These problems take the form of discharges (both point source and diffuse) with their consequent inputs of nutrients, toxicants, silt and debris and their short-term (e.g. occasional algal blooms and bacterial contamination) and longer-term environmental impacts (e.g. seagrass loss and seafood contamination).

These problems are aggravated by physical disturbances to marine environments from shipping and related works, coastal development and fishing, and by the introduction of exotic species.

This section of the report focuses on chronically and acutely disturbed and contaminated waters, and the factors producing these impacts, in: Victoria's bays, inlets and estuaries; its Territorial waters (total area about 8 000 km^2); and contiguous offshore waters. The emphasis is on factors that limit options for the future, by causing profound or enduring habitat changes. Locations mentioned in the text are shown in Figure 1.

Major issues

Nutrients

Point source and diffuse inputs of nutrients continue to be the most pressing marine pollution issue in Victoria. Elevated nutrient levels can cause eutrophication and may increase the frequency of algal blooms, which may in turn cause major ecological problems, significant human health problems, and mortality and contamination of fishery and aquaculture stocks.

In Port Phillip Bay, while the annual nutrient load comes from a number of areas, the largest is the Werribee Treatment Complex where 65% of Melbourne's domestic sewage and 80% of its industrial wastes are treated through an extensive lagoon and land filtration system (Vic. Govt 1992c). Treated wastewater, containing nutrients and trace levels of toxicants are discharged into the western side of the Bay. The measurable impacts include more prolific growth of reduced numbers of seaweed species within 4 km of the outfalls, and seagrass declines resulting from enhanced epiphyte growth.

Phytoplankton biomass is generally higher in Port Phillip Bay than in the open waters of Bass Strait (Longmore et al. 1990; Gibbs et al. 1986a), and is often highest near major nutrient discharges in Hobsons Bay and off Werribee (Longmore 1992). Chlorophyll concentration varies over time within the Bay, and concentrations are generally higher in winter than in summer. This pattern is a response to nutrients carried in freshwater discharges, rather than a typical seasonal pattern related to temperature and/or light. Two analyses of chlorophyll data collected in the Bay during 1970-1986 indicated a three-fold increase off Werribee, a decrease in Corio Bay, and no trend in the centre of the Bay (Brown 1990; Saunders & Goudey 1990).

The commissioning of the South Eastern Purification Treatment Plant at Carrum, south-east of Melbourne, has helped to accelerate the rate of connection of unsewered properties. This has resulted in a reduction in the amount of nitrogen compounds entering the Bay by 700 tonnes annually; average bacterial levels at beaches have also decreased (Vic. Govt 1992c).

Nutrient enrichment from catchments is implicated in algal blooms which are occasionally severe in the Gippsland Lakes (see below). Recent anthropogenic sources supplement nutrients stored in sediments as a result of accession over thousands of years when the Lakes were terminal wetlands with limited and intermittent connection with the ocean.

In areas where discharges occur to the open waters of Bass Strait, the effects of nutrient addition appear limited to the vicinity of the discharge point. While these inputs may be of local significance, they are unlikely to cause nutrient enrichment of open ocean waters.

Toxicants

Trace levels of toxicants are released in treated sewage and other effluents which are discharged directly into bays and coastal waters. The EPA licences discharges of effluents.

During the last 20 years, almost all industrial discharges to the Bay and its tributaries have been diverted to the sewerage system. This, together with the EPA's licensing and monitoring of discharges has been very successful in reducing the inputs of many toxicants into Port Phillip Bay. Mean concentrations of heavy metals (particularly mercury and cadmium) in fish, shellfish, sediments and water in Port Phillip Bay have decreased since analyses started in the 1960s. For example, the mean mercury concentration in sand flathead flesh has fallen from 0.5 ppm (the food health standard) in 1975-1978 to 0.24 ppm in 1990 (Fabris et al. 1992b).

The presence of mercury in the edible flesh of many shark and dogfish species found off Victoria led to the banning of landing and possession for sale or consumption of all species other than school shark, gummy shark, southern and common sawshark, angel shark and elephant fish (Fishing(Shark Amendment) Regulations 1990).

Tributyltin (TBT) based antifouling paints are particularly potent toxicants which gained widespread usage during the 1980s. TBT is so toxic in the marine environment (producing imposex or shell thickening in gastropods) that the use of TBT-based paints on vessels smaller than 25 m long was banned in Victoria in 1989. However, the residual levels in the waters and sediments in Port Phillip Bay, and the TBT present on larger ships that ply the Bay mean that environmental impacts can be expected to continue for some time. Recent EPA work found low levels of TBT in water, sediments and biota; the biological effects appear to originate prior to the 1989 ban on TBT (Foale 1993).

PCBs and chlorinated pesticides such as DDT and dieldrin are persistent compounds which show high degrees of bio-accumulation in marine food chains. Both of these classes of organic toxicants are present (at levels below the maximum permitted concentrations) in flathead flesh from all sites sampled in Port Phillip Bay (Nicholson et al. 1991). Flathead livers showed elevated levels of heptachlor in the Geelong Arm and PCB in Corio Bay and the Geelong Arm. An unpublished 1990 report indicated that levels of PCDD and PCDF (toxic equivalents) in mussels and fish represented only a low human health risk, on the basis of international standards. Congener profiles show a different pattern on each side of the Bay, suggesting different processes affecting contamination; the Werribee Treatment Complex is important to the western side, and diffuse run-off to the eastern side of the Bay.

The lethal and sublethal effects of toxicants on marine species and communities present in Victoria's bays, inlets and coastal waters are completely unknown.

Stormwater, silt and debris

The run-off of stormwater, silt and debris from rural and suburban areas is a major pollution issue in Victorian bays and inlets. In Westernport Bay, accelerated sedimentation due to catchment erosion and stream channelisation is believed to have been a major factor contributing to the loss of about 70% of the seagrass beds during the 1980s. In this instance, there are thought to have been two harmful effects of silt: elevation and shallowing of the banks where seagrass grows, and increased turbidity and reduced light penetration necessary for bottom plant growth.

Plastic litter such as bags, package strapping material and fishing tackle maim and kill marine birds, mammals and fishes, as well as reducing the aesthetic values of Victoria's waters and shores. This litter originates from stormwater, beachgoers, fishers and shipping.

Over 300 drains enter Port Phillip Bay, carrying untreated stormwater, oils, grease, wastes and litter from roads and gutters, and part of the estimated 90 tonnes of dog faeces produced each day (Vic. Govt 1992c).

The increase in sediment inputs to rivers and streams due to human activities has been proposed for listing as a Potentially Threatening Process (under the Flora and Fauna Guarantee Act) which ultimately impacts on Victorian estuaries and inlets (DCNR 1991). The Victorian Flora and Fauna Guarantee provides both the power and active programs to protect threatened species and biological communities through a process that provides for full public participation.

Algal blooms and marine biotoxins

Given the right combination of nutrients, temperature and salinity, the periodic blooming of marine algae is a natural phenomenon. The frequency and extent of such blooms appear to have increased as the result of increased nutrients and altered stream flows. These effects have been particularly marked in the Gippsland Lakes where severe blooms have caused major environmental damage over wide areas, reducing dissolved oxygen levels to the point of killing fish and other aquatic life. In turn these effects flow on to fish stocks and the commercial and recreational fisheries that depend upon them, as well as the associated tourism on which much of the regional economy depends.

Although infrequent in Port Phillip Bay, algal blooms have been observed to have severe direct and indirect impacts on fish and shellfish. For instance, in 1950, large numbers of fish and invertebrates died in Port Phillip Bay at the time of a bloom, believed to have been a 'red tide' dinoflagellate species *Gymnodinium mikimotoi* (Callan et al. 1993).

Early in 1984, large numbers of flathead (two species), flounders (two species), spikey globefish and smaller numbers of several other species in the northern part of the Bay were recorded suffering from severe lesions on their heads, bodies and fins, and high external parasite loads (Gibbs et al. 1986b). In some cases, eyes were absent and fins completely eroded. Close examination showed the presence of extensive degeneration and deposits of iron compounds in the livers and, in some cases, the kidneys. Analyses of affected fish failed to find elevated levels of heavy metals or a range of organic toxins. Biotoxins resulting from a large phytoplankton bloom in the northern part of the Bay late in 1983 (following heavy drought-breaking rains), or polynuclear aromatic hydrocarbons were regarded as the most likely primary causes of this event.

In the spring of 1987, the bloom of a diatom *Rhizosolenia chunii* (normally present in the Bay in smaller numbers) resulted in a bitter taste in shellfish and, later, a high incidence of shellfish mortality (Parry et al. 1989). Harvesting and marketing by mussel farmers was suspended during most of the 1987-88 season, resulting in the loss of mussels worth $1 million. In August 1993, when the compilation of this report was completed, a bloom of *R. chunii* extended through most of the Geelong Arm affecting mussels off Clifton Springs and Portarlington.

Blooms of the toxic dinoflagellate *Alexandrium catenella* in January 1988, April 1991 and January 1992, resulted in the issuing of public health warnings against eating shellfish from the northern areas of the Bay. This exotic species, capable of causing paralytic shellfish poisoning (PSP), was first recorded from the Bay in 1986, but there has been no report of PSP resulting from shellfish consumption, despite high PSP toxin concentrations being recorded in mussels off Williamstown during the 1992 bloom (Callan et al. 1993). These blooms have been observed to follow heavy rainfalls in summer or autumn.

A widespread bloom of the diatom *Nitzschia pseudodelicatissima*, capable of producing domoic acid which causes amnesic shellfish poisoning (ASP), was first recorded from Port Phillip Bay in November 1991 (Callan et al. 1993). All mussel harvesting was suspended temporarily, although extensive analyses showed that the Bay strain was nontoxic. In August 1992, domoic acid levels detected in the viscera of scallops off Lakes Entrance caused a ban on the distribution and marketing of unprocessed scallops; *N. pseudodelicatissima* was not detected in the region.

Although *Dinophysis acuminata*, which can produce diarrhetic shellfish poisoning (DSP), has been identified as common in Port Phillip Bay, no shellfish from the Bay have been reported to have caused DSP (Callan et al. 1993).

During the winter of 1993, *Alexandrium tamarense* was reported from Port Phillip Bay for the first time. Levels were highest in the Geelong Arm in the vicinity of mussel farms where PSP toxins were detected in mussels.

Pathogens

The current ban on harvesting of shellfish for consumption from Hobsons Bay was introduced following frequent occurrences of high levels of *Escherichia coli* and other bacteria. In 1956, three cases of typhoid fever diagnosed in Melbourne, were attributed to consumption of shellfish from Hobsons Bay.

During the last five years, Port Phillip Bay shellfish aquaculture areas have been studied and ranked according to strict environmental standards, and are monitored to ensure that the marketed products are free of contamination by pathogens such as *Escherichia coli* and toxic algae (Arnott 1990).

The EPA monitors Port Phillip Bay waters during the summer swimming season to ensure that people engaging in swimming and other primary contact activities are not exposed to unacceptable risks from exposure to pathogens.

Monitoring of coastal sewage discharges is also required; for example, the Geelong and District Water Board regularly publishes the results of its monitoring of *Escherichia coli* on the coast either side of its offshore discharge at Black Rock, south of Geelong.

Heavy mortalities of native flat oysters *Ostrea angasi* were reported in Port Phillip Bay and some other Victorian waters in 1991. Investigations showed the presence of a haplosporidian parasite believed to be *Bonamia* sp. (Hine et al. in press).

Heat

Large volumes of seawater are used for industrial cooling purposes, resulting in significant though localised heating of receiving waters. The Newport D Power Station on Port Phillip Bay discharges the largest volume of heated effluent into Victoria's coastal waters. This effluent is also licensed to contain chlorine, ammonia and iron. In the early 1970s, predischarge studies concluded that the effluent may increase the likelihood and duration of algal blooms in Hobsons Bay. However, there has been no subsequent assessment of the actual impacts on blooms or other aspects of the ecology and fisheries resources in the area.

The Shell refinery in Corio Bay daily discharges 250 000 m^3 of heated seawater which may contain traces of hydrocarbons. This effluent is also treated with chlorine to prevent settling of fouling organisms in the pipelines and heat exchanges.

The Alcoa aluminium smelter and Pivot Phosphate Cooperative are also licensed to discharge cooling water into Corio Bay.

Petroleum

The petroleum industry in and offshore from Victoria affects coastal and offshore marine environments in a number of ways.

Most exploration and all current oil production (and the associated environmental risks) off Victoria takes place outside Territorial waters. The eastern Bass Strait oilfield contains 12 platforms, a number of well heads and a system of connected pipelines which carry oil and natural gas to the shore at several points on the Ninety Mile Beach. Development of this field continues, accompanied by large quantities of cuttings and drilling muds. These platforms, well heads, pipelines and drilling wastes constitute a significant alteration to the marine environment. Exclusion zones around these fixtures encroach on several commercial fisheries and minor spillages and blowouts have occurred, but there is no evidence of contamination of fish arising from the drilling and extraction operations.

During the 1970s, the Danish seine fishery based at Lakes Entrance drew public attention to the incidence of marine debris resulting from the exploration, construction and operations of the oilfields. In 1983, their subsequent Supreme Court action and compensation highlighted the damage to fishing gear caused by this debris and resulted in a major clean-up of the area.

During 1992 and 1993, BHP Petroleum's survey and exploration program in the Otway Basin, off western Victoria, resulted in a number of exploratory drilling operations and raised well heads. This raised a number of concerns about physical disturbances to the bottom, impacts of drilling muds, possibilities of blowouts and spills, with consequent damage to marine communities. Particular concerns were focused on the rock lobster fishery, calving whales and marine birds. Prior to this, acoustic survey work had attracted opposition by conservation groups and commercial fishers concerned about the possible impacts on marine ecosystems and resources, particularly whales and fish populations.

Spillages associated with loading and unloading crude oil and petroleum products at the refineries in Port Phillip Bay, Corio Bay and Westernport Bay result in localised contamination by both hydrocarbons and dispersants. In Corio Bay, for instance, fish tainted with hydrocarbons are reported periodically by anglers and fish consumers. Analyses of petroleum hydrocarbons in the flesh of sand flathead from 10 sites in Port Phillip Bay showed the highest level (46 ppm) 8 km east of Corio Bay; the highest level in flathead livers (641 ppm) was from Corio Bay (Nicholson et al. 1991). Although there is no maximum permitted concentration for petroleum hydrocarbons, taint in fish has been detected at 10 ppm (Connell & Miller 1981). Hydrocarbons of pyrogenic origin enter Port Phillip Bay through the atmosphere and stormwater run-off and from vessels operating on the Bay (Vic. Govt 1992c).

Minor oil spills are regular events in Victorian bays. In Port Phillip Bay, spills of less than five litres occur almost daily while spills greater than 100 litres occur less than once per month (Vic. Govt 1992c). Larger spills occur offshore occasionally, affecting penguins and other marine life. In 1988, a spill of 180 l in Portland Harbour resulted in the deaths of seabirds and the issuing of a warning to local fishers about the possible contamination of fish (LCC 1993).

Seepage of petroleum products from storage sites close to Port Phillip Bay causes localised contamination. For example, in 1993 it was discovered that a Bayside petrol station had for years been losing petrol through a broken pipe, into the soil 50 m from the shore at Hampton. The possible impacts of seepage from larger current and past storage areas in Hobsons Bay, Corio Bay and Westernport Bay are unknown. During the 1980s, a much larger and very expensive clean-up was required at a former oil storage site, adjacent to Hobsons Bay, before a major residential development could proceed.

Oil pollution events in Victorian territorial waters are dealt with under the Victorian supplement (or State Plan) to the National Plan for combating such pollution at sea. The Port of Melbourne Authority is responsible for coordinating State and Commonwealth agencies and industry bodies in these operations. The occasional incidence of ships running aground in the lower end of Port Phillip Bay, in clear conditions and well marked channels, are a reminder of the potential for major oil spills in coastal waters and embayments.

Coastal development

In Victoria, the public ownership of nearly all coastal foreshores has helped to buffer the marine environmental impacts of nearby land use and has also limited development on coastal land. This affect is greatest where the public reserve is at least several hundred metres wide.

Some coastal developments have become widely accepted, particularly where they are perceived to provide useful and accessible public amenities, for example public boating and lifesaving club facilities. Others are perceived to enhance the marine environment by adding to the diversity of habitats for shellfish (e.g. seawalls and breakwaters), fish (e.g. artificial reefs, shellfish farms and piers), penguins (e.g. St Kilda harbour) and seals (e.g. channel markers and Bass Strait oil rig buoys).

Many coastal developments, while providing a number of benefits, entail significant ongoing environmental costs to the community. For example, the establishment of Portland Harbour has altered coastal processes in the area, changing the reef and seagrass habitats and eroding public and private land to the north. Major protective works have been necessary to prevent further property losses, but nothing can be done to mitigate the marine habitat impacts. Furthermore, dredging and dumping of sand from the harbour is a continuing, costly and controversial issue that causes further disturbance to marine habitats.

In the Gippsland Lakes, the proliferation of public and private jetties, marinas and related boating facilities has grossly altered the nature of the shoreline and inshore habitats and restricted general access to those areas.

Still other coastal developments are less well accepted because community perception of their benefits is outweighed by concern over their potential for adverse marine environmental impacts. Examples include coastal sewage treatment plants and discharges, and oil terminals and refineries. In August 1991, a massive fire at the bulk liquid chemicals storage facility at Coode Island drew public attention to the hazards associated with the increasing usage and resultant maritime transport, handling and storage of a wide range of hazardous chemicals at shore-based facilities. In this case the solution chosen - a proposal to relocate the storage facility from one Bayside site to another more remote one west of Pt Wilson (either on land or on a man-made island) - has also aroused wide public concern.

Ballast waters and exotic species

Exotic species may be introduced into Victorian waters through the discharge of ballast waters, from growths on the hulls of ships or - possibly - through translocations of fish and shellfish for aquaculture and fisheries purposes (DCNR 1993). That most introduced species have been reported from major port areas like Hobsons Bay and Corio Bay, suggests that shipping is the main source.

Millions of tonnes of ballast water from foreign ports have been discharged annually into Victorian ports. In 1986-87, about two million tonnes were discharged in the ports of Melbourne and Geelong, and a further 0.5 million tonnes in Westernport Bay (NREC 1991). Australian Quarantine Inspection Service guidelines for ballast water movement and discharge, introduced in 1990, are intended to reduce the risk of further introductions of exotic species from ballast water.

Already, a number of exotic species have become established in Victorian waters. Little is known about the timing of the introductions, their range and rate of spread or their ecological impacts.

The following exotic macroflora and fauna species have been identified in Victoria:

blue spot goby	*Pseudogobius olorum*
striped goby	*Tridentiger trigonocephalus*
yellow-fin goby	*Acanthogobius flavimanus*
crab	*Carcinus maenus*
crab	*Cancer novaezealandiae*

Pacific oyster	*Crassostrea gigas*
mussel	*Theora lubrica*
Asian mussel	*Musculista senhousia*
polychaete	*Mercieralla enigmatica*
polychaete	*Boccordia proboscidea*
polychaete	*Pseudopolydora paucibranchiata*
polychaete	*Sabella spallanzanii*
ascidian	*Styela plicata*
alga	*Stictyosiphon soriferus.*

Of these species, only the Pacific oyster was deliberately introduced into Victorian waters, decades ago.

The colonial polychaete *Sabella spallanzanii* has recently been reported to be the visually dominant organism in the Geelong Arm (Carey & Watson 1992).

The alga *Polysiphonia brodiaei*, first recorded around ports and subsequently found at a number of more exposed locations, may also be an exotic.

Rice grass *Spartina townsendii* was deliberately introduced and planted for land reclamation and bank stabilisation in inlets and estuaries, and has significantly altered the nature and ecology of areas where it is now established, such as Anderson Inlet.

The toxic phytoplankton species *Alexandrium catenella*, capable of causing PSP, has been identified in Port Phillip Bay since 1986, including major blooms in 1988, 1991 and 1992. There is a slight possibility that this species may be endemic to Australian water, but only discovered by recent monitoring programs.

Some additional species have recently been introduced into Tasmanian waters from Japan, and may reach Victoria. These include the kelp *Undaria pinnatifida*, the toxic alga *Gymnodinium catenatum* and the predatory starfish *Asterias amurensis*. All three species have the potential to cause ecologically and economically important changes and it is difficult to see how they can be kept out of Victorian waters in the long-term.

Recognising their potential ecological significance, the introduction of exotic species into Victorian marine waters has been formally listed as a Potentially Threatening Process (DCNR 1993).

Habitat modification or loss

Marine habitat modifications have occurred in Victoria as the result of a variety of human activities: coastal development and reclamation; land clearance, agriculture, forestry and water management in the catchments; coastal discharges; disposal of junk; port maintenance and development; fishing; and the introduction of exotic species. These result in effects such as: shallowing and infilling; seagrass loss; increased turbidity; altered temperature and salinity; burying or removal of benthos; eutrophication and chemical contamination.

While some of these, such as reclamations for the development of recreational boating facilities or container terminals, clearly destroy marine habitats entirely, others such as the establishment of marinas may replace a natural habitat with highly modified habitats which may support marine communities. In the latter example, leaching and discharges of hydrocarbons, antifouling paints and other pollutants must be controlled if these communities are to remain healthy.

Until about 20 years ago, Port Phillip Bay and coastal waters were frequently made the final resting place for unwanted ships, munitions and other items. The 'ships graveyard' immediately west of Pt Nepean features a number of First World War submarines. This form of disposal of unwanted hardware is no longer practised.

During the 1970s, artificial reefs were established at several sites in Port Phillip Bay and off Phillip Island. Other reefs have since been built off Portland and at the southern end of the Bay. However, there has been no attempt to monitor the ecological and fishery impacts of any of these reefs, hence their real benefit is uncertain.

The blasting of sand barriers at the mouths of inlets such as the Tamboon, Sydenham and Curdies Inlets is undertaken primarily to protect private property and land use from high water levels. However, it clearly represents a significant interference with natural coastal processes and the condition of aquatic environments in these inlets.

Human activities that alter rivers and streams have substantial effects on estuaries and inlets. In Victoria, this has been recognised formally in the listing of alteration to flow regimes (resulting mainly from diversions and storages) as a Potentially Threatening Process under the Flora and Fauna Guarantee Act (DCNR 1992a).

The establishment of mussel farms in Port Phillip Bay has added a new three dimensional form of marine habitat characterised by diverse and abundant assemblages of fish species targeted by commercial and recreational fishers.

Public health

A number of marine environmental issues have serious public health implications: phytoplankton blooms, toxicants and bacteria.

Human health may be threatened by primary contact with contaminated water (e.g. swimming) or by eating contaminated seafood. Because of the potential seriousness of these risks, programs are in place to monitor coastal discharges, toxicant levels in fish and shellfish, and the presence of potentially toxic plankton species, particularly in commercial shellfish and aquaculture production areas.

The harvesting of shellfish for human consumption is prohibited in Hobsons and Corio Bays and off the Werribee Treatment Complex, and public health messages and signs warn against collecting shellfish near a number of drains around Port Phillip Bay. However, shellfish from most areas of the Bay pose no human health problems.

In the latter part of 1992 and early 1993, the collapse of large sewerage pipes in Melbourne lead to the discharge of large volumes of raw sewage via the Maribyrnong River into Port Phillip Bay. This resulted in public health warnings about the private collection and consumption of fish and shellfish, and in the suspension of commercial fishing in the northern waters of the Bay. The high levels of bacterial contamination associated with this event also restricted swimming and related activities on northern and eastern beaches.

This was a particularly dramatic example of the raw sewage discharges which occur quite regularly when Melbourne's sewerage system is unable to cope with breakdowns or overloads.

It must be emphasised that conditions posing risks to human health are extremely limited in their geographic and temporal occurrence in Victorian waters.

Marine parks and reserves

Several marine and/or estuarine areas containing features of high conservation value have been proclaimed as Marine Parks or Marine Reserves in recent years.

The Harold Holt Marine Reserves (Victoria's first marine protected areas, proclaimed in 1979), comprise five areas at the southern end of Port Phillip Bay: Point Nepean, Point Lonsdale, Popes Eye, Mud Island and Swan Bay. A further reservation, Point Cook Marine Reserve on the western shoreline of Port Phillip Bay, was proclaimed in 1982.

Subsequently, the Wilsons Promontory Marine Park and Reserve, and the Corner Inlet, Nooramunga and Shallow Inlet Marine Parks in South Gippsland were proclaimed in 1986. The Bunurong Marine Park, near Inverloch, is Victoria's most recent reservation, being proclaimed in 1992.

These areas have been reserved to protect their special conservation, recreation, education and scientific values. Only the Wilsons Promontory and Bunurong marine communities were surveyed in any detail prior to their proclamation (Wilson et al. 1990). Otherwise, there has been a distinct lack of detailed research on the communities in marine protected areas and of effective programs to monitor the response of communities in recently proclaimed areas.

The 1987 State Conservation Strategy and the 1988 Coastal Policy for Victoria outlined proposals for a systematic ecological survey of Victoria's marine ecosystems: to provide an inventory of species, communities and habitats; to determine their conservation status; and to provide the basis for protecting representative examples of ecosystems of special significance. This work has not proceeded and there is no systematic basis for assessing conservation values or the need for further reservations or other special protective measures. This situation has also made it extremely difficult to judge the potential impact of major developments and of discharges.

Competing uses and conflicting interests

Victorians want to make use of their common property bays, inlets and coastal marine waters in a variety of ways, including:

- commercial harvesting of living and nonliving natural resources (e.g. fisheries, aquaculture, sand/mineral extraction);
- recreational harvesting of living resources (e.g. angling, spear fishing, intertidal food gathering);
- nonexploitative use/appreciation of aquatic species, habitats and environments (e.g. for conservation, recreation, education and scientific purposes);
- various types of urban, industrial and tourism development (e.g. canal estates, marinas, shipping ports, tourist resorts);

- disposal of a variety of urban, industrial and agricultural wastes and effluents.

Many of these uses are, or are perceived to be, incompatible with each other if applied to the same area or to the same stock of natural resources. Such situations usually lead to competition and conflict of interest between different user groups. Types of conflict which commonly occur include:

- conflicts between commercial and recreational fishers when competing for the same fish stocks;
- conflicts between conservationists and fishers (commercial and recreational) over the impacts of fishing methods and the restriction of fishing activities in areas of high conservation value;
- conflicts between the proponents of development projects and both fishing and conservation interests over the possible adverse environmental effects of such proposals;
- conflicts between public authorities and various sectors of the community over the most appropriate methods for transporting, storing, treating and/or disposing of effluents, wastes and toxic or hazardous substances.

Three recent reviews or planning processes emphasise the complexity and intensity of natural resource management issues when it comes to marine and estuarine areas. These were the proclamation of the South Gippsland Marine Parks, the development of the Port Phillip Bay Management Plan, and the Parliamentary Natural Resources and Environment Committee's (NREC) review of Victoria's bay and inlet commercial and recreational fisheries.

In the first case, the special conservation values of the shallow mangrove-fringed waters of Corner Inlet, Nooramunga and Shallow Inlet and the granite reefs at Wilsons Promontory, were recognised and protected by proclamations under the Crown Lands Reserves Act. The proclamations were strongly opposed by some commercial and recreational fishing interests concerned by the possible loss of access to fishing opportunities. The proposal to phase out commercial abalone and rock lobster fishing in the Wilsons Promontory Marine Reserve in particular, was strongly opposed and led to a successful Supreme Court challenge. Research conducted by the Department of Conservation and Natural Resources established the suitability of waters in the Corner Inlet and Nooramunga Marine Parks for commercial aquaculture of native flat oysters. However, development of the aquaculture potential of the area has not progressed, largely because of some concerns over the compatibility of commercial aquaculture with the protection objectives of the Corner Inlet and Nooramunga Marine Parks.

The Port Phillip Bay Management Plan (Vic. Govt 1992a) highlights the difficulty of avoiding conflicts between activities and values that are basically incompatible. In this instance, the protection of marine habitats in the Bay for effective marine conservation and to maintain fish stocks for commercial and recreational fishing and aquaculture, is at odds with plans for significant further development around the Bay, including expanding shipping and port facilities.

In the late 1980s, a small increase in commercial gill netting for snapper in Port Phillip Bay lead to a successful campaign by some anglers and commercial longline fishers to have all target gill netting for snapper banned during the October-December period each year. Within 12 months, bag limits were also introduced for recreational snapper catches. In neither instance was the decision based on an assessment that the snapper stocks required greater levels of protection, or that the measures taken would achieve increased protection if such were needed.

Responses to the NREC's enquiry emphasised the ongoing conflict over fisheries resource allocation between commercial and recreational fishers in Victoria's bays and inlets. Predictably, strong arguments were put by both groups. Tourism and local government submissions generally favoured giving preference to recreational fishing, particularly in the smaller inlets, because of its increasing importance to coastal economies.

Policy dilemmas

Living marine resource conservation and environment protection has been characterised by fragmentation of policy development, administration, information-gathering programs and recognition of the needs of client groups. At the heart of this issue has been the absence of a clear overriding aquatic conservation policy framework (ARSFC 1992).

This means that, while some sectors of government agencies and the community are now more aware than ever of the fundamental importance of protecting marine habitat to assure the future of marine resources and the resulting community benefits, the separation of responsibilities for fisheries management, environment protection, ecological diversity, water resource management and catchment/coastal management, inevitably leads to inconsistency or incompatibility of agency objectives and programs. Attempts to have sister agencies develop a team approach to issues of mutual concern often failed because of the absence of an overall guiding policy framework, the basic incompatibility of their separate objectives and the incompleteness of their combined objectives and responsibilities.

The need for an integrated approach in the conservation of marine (and other) natural resources in Victoria has been recognised in bringing these agencies together in one ministry, and commencing a thorough marine and coastal planning process (see below).

Many human activities in and around Victoria's coastal waters have the potential to modify aquatic habitats and fish stocks and are therefore, in the long-term, incompatible with the maintenance of such natural resources. The Government is therefore faced with two policy options which are mutually exclusive in any one area (ARSFC 1992). These are to:

(a) give priority to development activities at the expense of degraded marine habitats and resources; or
(b) protect marine habitats and conserve fish stocks at the expense of restricting further development activities.

Failure to recognise and to make a clear choice between these options, or failure to implement option (b) if chosen, is effectively a decision against the maintenance of habitats and living resources. Irrespective of the choice made, continued population growth close to Victoria's public waters will inevitably cause further losses or degradation of marine habitat and fish resources.

The Victorian Government's most recent response to this issue has been the establishment of the Marine and Coastal Study being conducted by the Land Conservation Council. The scope of this strategic marine planning effort extends to Victorian coastal public land and waters, including bays, inlets and estuaries. The LCC is scheduled to make its recommendations to the Minister for Planning and Development in December 1994.

A major contributor to this dilemma is the lack of credible information to demonstrate the likely impacts of proposed developments. In the absence of this information and in the face of demonstrable economic benefits, development usually proceeds.

Overfishing

The cumulative effects of years of commercial and recreational fishing are demonstrable for many fish and shellfish stocks in Victorian waters. However, the judgement of where the impacts of fishing on stocks reach the point of being described as 'overfishing' can be rather arbitrary and ill-defined.

Evidence of overfishing of fish stocks in Victorian waters is available for at least two important fisheries. The clearest evidence is for school sharks *Galeorhinus australis* and gummy sharks *Mustelus antarcticus* in Victorian, Bass Strait and other southern Australian waters. Current estimates suggest that the biomass of school sharks has been reduced to about 20% of the virgin biomass, and the biomass of gummy sharks has been reduced to 40-50 % of the virgin biomass (T.I. Walker DCNR, unpublished). While limited entry, tough gear restrictions and licence consolidations with gear forfeits have significantly reduced fishing capacity, further substantial reductions in catch must be achieved to enable the decline to be halted and the school shark stocks to be rehabilitated. State and Commonwealth agencies are working with industry to develop a long-term management strategy and a structural adjustment process for the fishery.

In the case of rock lobster (*Jasus edwardsii*) stocks, the mean catch rate of the commercial fishery is taken to be an index of stock abundance; this rate is expressed as kg/potlift or kilograms of rock lobster taken for sale each time a pot is lifted. Since 1950, the mean catch rate has declined from about 2.5 to 0.5 kg/potlift and is still falling. This has occurred despite technological advances that enable more precise navigation and position fixing and better discrimination of bottom features, all of which make rock lobster stocks easier to target.

The public perception that scallop stocks, particularly in Port Phillip bay, have been severely overfished, is really a result of the extreme variability of annual recruitment to scallop stocks and the fact that the Bay fishery is largely based on 1+ year old scallops. This means that the potentially harvestable stock each year can vary from 20 million to 2700 million in the space of two years, as happened between 1990 and 1992.

Although not based on any quantitative assessments or surveys, the Shellfish Protection Regulations (1983) were introduced in recognition of a general view that uncontrolled gathering of molluscs and crustaceans (for food and fishing bait) from some intertidal and shallow subtidal shores in the bays and the central Victorian coast have an unacceptable impact on marine communities and habitats. Impacts on intertidal molluscs, resulting from noncompliance with these regulations, has been demonstrated near Williamstown (Keough & Quinn 1991).

The earliest major commercial fishing requiring legislative control in Victoria was dredging and raking for native oysters (*Crassostrea angasi*) in several bays and inlets. The fishery in Westernport Bay supported 21 boats at one stage and the fishery at Port Albert shipped oysters to Melbourne as early as 1843 (K.J. Street DCNR, unpublished). As a fishery resource, these stocks were extinguished by the 1920s. However, it remains unclear whether stocks crashed because of overfishing, impacts of dredging or habitat changes caused by clearance in catchments of those bays and inlets.

Overexploitation of whales and seals during the early settlement of Victoria caused the elimination of the New Zealand fur seal, Australian sea lion and the Southern Right whale from the region and the elimination of Australian fur seal colonies from a number of Bass Strait islands. The numbers of sightings of Southern Right whales in western Bass Strait is increasing, suggesting that, while the more accessible sub-population that was hunted off Tasmania was extinguished, the subpopulation whose range extended into the Great Australian Bight survived and is recovering (Warneke 1989).

Ecological impacts of fishing

Between 1963 when the scallop fishery commenced in Port Phillip Bay, and 1968 when the fishery collapsed, catch rates progressively decreased as the virgin stock was caught. Subsequently, the fishery has experienced wide variations in annual catches, reflecting the variability of annual recruitment. Public concern over perceived ecological damage from the use of scallop dredges increased during the 1980s. In 1984, this lead to the banning on commercial scallop and mussel fishing in depths less than 10 m in Port Phillip Bay (5 m in the Geelong Arm) to protect seagrass and shallow reefs and shellfish beds.

Brief studies carried out in 1984 (Anon. 1981) showed no impacts on benthos or mobilisation of toxicants in sediments, but indicated that scallop fishing damaged seagrass beds in shallow waters. As a result, scallop fishing was prohibited in the shallows where seagrass occurs.

In 1991, following a resurgence of scallop fishing in the Bay, public concern prompted the commencement of the first detailed studies of the short, medium and long-term impacts of scallop fishing on benthic communities, associated fishes and sediment disturbance (Parry & Currie 1992). These studies continued into 1993, with early results indicating that scallop fishing causes changes to animal communities in the sediments. The extent of these changes and their persistence are still under investigation.

For decades, commercial mussel dredging in Port Phillip Bay produced most of the mussels (*Mytilus galloprovincialis*) sold in Australia, with an annual production of up to 1600 tonnes. However, in 1986 the Victorian Government closed this fishery because of concerns about its ecological impacts and because the emerging mussel aquaculture industry provided an alternative source of mussels.

The possibility that poor breeding seasons of little penguins (*Eudyptula minor*) may be related to the availability of pilchards (*Sardinops neopilchardus*) and anchovies (*Engraulis australis*) was first raised during the 1970s. Commercial catches of pilchards in Port Phillip Bay increased from about 200 tonnes per annum in the late 1970s to a peak of about 1400 tonnes in 1988-89 (DCNR, unpublished data). In some years during this period, exceptionally poor penguin breeding success and high juvenile and adult mortality were observed among the Phillip Island birds, many of which overwinter in the Bay.

Community concern about the ecological impacts of large annual catches of pilchards, anchovies and related species was recognised as a major issue in a Parliamentary review of commercial and recreational fisheries in bays and inlets (NREC 1991). Stock assessments of Port Phillip Bay pilchard and anchovy stocks and studies of the relationship between these stocks with those in nearby open waters were identified as important areas for future research (Vic. Govt 1992b).

The same review identified the possible ecological impacts of commercial haul seine netting in Corner Inlet, Westernport Bay and Port

Phillip Bay as an issue of great concern to many anglers, commercial fishers and conservation groups (NREC 1991). Aspects of this method that were of particular concern were the impacts on seagrass, nontarget species and undersized target species.

Conservation status of species and communities

Extremely little is known of the structure and diversity of marine communities or the conservation of marine flora and fauna on the open coast. This deficiency severely impedes considered decision making where marine conservation issues are important (Vic. Govt 1989a). Proper consideration of ecological issues usually requires large-scale investigations which may take several years.

A study of possible future pulp and paper mill effluent discharge sites off East Gippsland, between Lakes Entrance and Bemm River, revealed benthic communities of extraordinary diversity on substrates of coarse and medium sands and low-relief limestone reefs (Parry et al. 1990). Most notable was the infauna: a total of 353 species were identified from only four sites at each of which three 0.1 m^2 grab samples were taken. Further sampling in the area (L. Avery & N. Coleman DCNR unpublished data) has expanded the list of species known to occur to over 750. This diversity is considerably higher than has been found in similar surveys elsewhere in the world. Further consideration of a new pulp and paper mill will require additional marine investigations.

Detailed studies, over many years, of a shallow reef community close to San Remo identified a species-rich community, characterised by an unusually large number of species of opisthobranchs and bryozoans, including several species currently not known from elsewhere (DCNR 1992b). The uniqueness of this community resulted in its listing under Victoria's Flora and Fauna Guarantee Act, and caused the relocation of a marina development proposal. More importantly, an Action Statement (DCNR 1992b) specified the monitoring, survey and works control actions to be implemented to protect this community. To the extent that the special significance of this area may be partly attributable to the intensity of the studies there, the lack of baseline studies of the Victorian coast is again emphasised.

Although the marine communities of Port Phillip Bay have been studied several times over the years (Anon. 1973, 1971, 1966), there has been insufficient intensity and consistency between these studies to identify changes in the conservation status of these communities.

Baseline studies of Westernport Bay biota were carried out in 1973 and 1974. The highest number of crustacean species found during the survey of the benthic fauna (Coleman et al. 1978) led to the description of Westernport Bay as 'species packed' (Barnard & Drummond 1978). Another unusual feature of the benthic fauna was the relatively high abundance of the trigonid bivalve *Neotrigonia margaritacea* (Coleman & Cuff 1980). Bivalves of the family Trigoniidae occur as fossils throughout the world, but living species occur only in Australia. The Westernport Bay study is the only one to have provided quantitative data on the distribution of *Neotrigonia* and shown it to be a dominant member of the fauna.

Despite the significant ecological changes that are likely to have resulted from the extensive loss of seagrass in Westernport Bay, and despite the potential effects of proposed industrial development, there have been no follow-up studies or attempts to assess the current ecological status of benthic the Bay since the baseline studies noted above.

Effects of mining and dredging

Dredging of shipping channels and port facilities, and the subsequent dumping of spoil, are important environmental issues, particularly in Port Phillip Bay and Westernport Bay. In the past, tens of millions of tonnes of sediments, some from contaminated port areas, have been dredged and dumped in hundreds of operations in Port Phillip Bay. Because of exemptions from, or limited application of, the requirements of the Environmental Effects Act, it is still not possible to describe the short-, medium- or long-term ecological impacts of this form of dredging and spoil disposal.

For many years, most of the 40 000 m^3 per annum of material dredged from the lower Yarra River and dumped in Port Phillip Bay was silt which originated in the Yarra catchment. This dredging work was suspended in 1989, pending an evaluation of future desilting needs.

In 1992, a major Port of Geelong Authority channel dredging program was scheduled to dump 14 million m^3 of spoil in the Geelong Arm. That longstanding spoil dumping grounds in the area could not accommodate this material indicates that previous dumping has significantly altered the hydrographic (and presumably the ecological) character of these grounds. During the previous 140 years, about 20 million m^3 of spoil has been dredged and dumped in the Corio Bay/Geelong Arm area.

Dredging programs of different magnitudes and frequencies are conducted elsewhere in Port Phillip Bay, in other bays and inlets and coastal waters - all with little knowledge of their ecological impacts. Most are small scale operations or are repeated at intervals of several years. However, at Lakes Entrance, 500 000 tonnes of sand per annum are dredged from the inshore sandbar to maintain safe access to port. At the other end of the scale, the disposal of even small volumes of spoil can cause localised concern.

This issue has concerned fishers for decades. Early this century, commercial and recreational fishers banded together in a united campaign opposed to the dumping of dredged silt in Port Phillip Bay (K.J. Street DCNR, unpublished).

Sand removal from the shoreline occurs to a limited extent, with localised effects. At Sand Island, Queenscliff, sand is removed for purposes which include beach renourishment in Geelong and on the Bellarine Peninsula. Much of the Queenscliff coastline, including Sand Island itself, is an artifact resulting from continual dredging of the entrance to the boat harbour, and associated seawalls. The overall effects of these works include the progressive accretion to the shoreline and shallowing of waters immediately south of the harbour, accretion to Sand Island, and erosion of the shore of Swan Island further north.

In the past decade, approaches for permits to mine sands off Point Cook, in Port Phillip Bay, and to explore Corner Inlet for minerals such as tin and zircon have not progressed to the Environmental Effects Statement stage.

The practice of beach renourishment by the transfer of sand dredged from offshore is largely confined to Port Phillip Bay, although some work has also been done in the Gippsland Lakes. While the primary purpose is usually the improvement or restoration of swimming beaches, some projects are primarily intended to prevent coastal erosion. During the 1970s and 1980s, hundreds of thousands of cubic metres of sand were dredged offshore, dumped close to shore, then suction-pumped ashore to beaches at Mentone and Parkdale. Since 1975, a total of 20 km of beaches have been enhanced around the Bay. In recent years, the high costs and reduced funding available for these works have reduced their frequency and extent. Their ecological impacts on the borrow areas, inshore dumping areas and the nearshore habitats have not been assessed.

Shipping

Discharges of sewage and other wastes (illegally or by accident), ballast water, spillages (while loading and unloading) and contamination from hull maintenance may have significant localised effects in areas such as Corio Bay, Hobsons Bay, Crib Point and Portland Harbour.

Disturbed areas

Under Victoria's Environment Protection Act 1970, three State Environment Protection Policies (SEPPs) have been proclaimed to protect coastal waters; the 1975 SEPP Waters of Port Phillip Bay, the 1979 SEPP Waters of Westernport and the 1988 SEPP Waters of Victoria. These SEPPs set out the basis for maintaining environmental quality sufficient to protect existing and anticipated beneficial uses of these waters and their natural living resources (EPA 1991). A guide for the future use and protection of the coastline, including nearshore waters, has been produced (Vic. Govt 1988), and the environment, history, commercial and recreational uses, and a management and planning framework has been developed for Port Phillip Bay (Vic. Govt 1990). In addition, during the last decade, there has been a great deal achieved in the area of management plan development for specific coastal areas and inlets, such as the Gippsland Lakes Management Plan.

These policies and plans, together with the legislation relating to marine and coastal environment protection, conservation and development, form the current framework for dealing with marine environment protection and management in Victoria.

Port Phillip Bay

A recent environmental health report for the Bay (Vic. Govt 1992c), rated the condition of the majority of the 1 km coastal margin as excellent and the offshore 90% of the Bay as good, measured in terms of compliance with environmental standards. Hobsons Bay, Corio Bay and the Werribee segment (immediately adjacent to the Werribee Treatment Complex) rated fair to poor in relation to shellfish quality, nutrients, toxicants and, in the case of the two bays, the general state of marine habitats.
It is estimated that 1000 tonnes of nitrogen and 30 tonnes of lead (as well as pyrogenic

hydrocarbons) from motor vehicles enter the Bay, via the atmosphere, each year. These and other contaminants enter via dust fallout and rainfall (Vic. Govt 1992c).

Recent studies have shown that nutrient concentrations are highest in Hobsons Bay, off the Werribee coast and in Corio Bay. Phytoplankton growth has increased near Altona, in Hobsons Bay and on the east coast of the Bay (Vic. Govt 1992c). During 1987-89, bottom waters in the centre of the Bay had high dissolved oxygen concentrations for 76% of the time. However, during spring and summer, oxygen levels were lower than the current environmental objective (90% saturation) 40% of the time. The lowest levels recorded approached the level at which some organisms may experience sublethal stresses (Mickelson 1990).

Sediment oxygen demand is low in comparison with values published for other coastal waters around the world, supporting the idea that Port Phillip Bay is relatively unproductive (Newell 1990).

The concentrations of some toxicants are decreasing in sediments and fish tissues, for instance cadmium, lead and PCB in Corio Bay, and mercury in fish Bay-wide (Nicholson 1992). In 1990, the mean concentrations of mercury in the axial muscle of sand flathead (*Platycephalus bassensis*) from 37 sites in Port Phillip Bay were less than half those reported for this species during 1975-78 (Fabris et al. 1992b). The 1990 study showed that concentrations were significantly higher in flathead sampled from deeper waters than in those from shallow waters, suggesting that heavy metal concentrations may be greater in the fine clay sediments present in the deeper central region of the Bay than in the coarser silts and sands in shallower regions.

Petroleum hydrocarbons and organochlorines have been detected in flathead and sediments collected throughout the Bay, with particularly high levels in the Geelong Arm and Corio Bay (Nicholson et al. 1991). Concentrations have not changed much since the 1970s (Vic. Govt 1992c).

The concentrations of metals in mussels in Port Phillip Bay have not changed significantly in the last decade. Mean cadmium levels in mussels in Corio Bay have fallen from the high levels recorded in the 1970s to below the maximum permissible concentrations, although high levels persist at some locations (Nicholson et al. 1992d). Three years after the 1989 ban on the use of TBT on boats less than 25 m long, all indicators pointed to low levels in the Bay (Foale 1993). The highest severities of imposex (a reproductive impairment caused by TBT) in the whelk (*Thais orbita*) continued to be observed close to marinas and harbours.

While the concentrations of dioxins in Bay sediments are low by world standards, their impacts on marine communities there are unknown (Vic. Govt 1992c).

Published and unpublished information on the environment of the Bay has recently been summarised in a number of reports and reviews, as the initial phase of the Port Phillip Bay Environmental Study (Beer et al. 1992; Black & Mourtikas 1992; CSIRO 1992b).

Hobsons Bay

During the spring and summer of 1992-93, broken sewer pipes in inner Melbourne suburbs resulted in large overflows of raw sewage through the Maribyrnong River and into Hobsons Bay. In one incident, untreated sewage flowed into the estuarine section of the river at a rate of 3.1 ML/hr (equivalent to less than 1% of the river flow). Combined with high rainfall and the consequent high outflow rates of the Maribyrnong and Yarra Rivers, this produced high *Escherichia coli* levels over a wide area of northern and eastern Port Phillip Bay for several weeks. Warnings were issued to avoid swimming and collecting of fish and shellfish in the area. Localised outbreaks of illnesses among beachgoers at Williamstown were linked to this episode.

Three large blooms of the toxic dinoflagellate, *Alexandrium catenella*, have occurred mainly in Hobsons Bay; in January 1988, April 1991 and January 1992.

Corio Bay

Corio Bay is extremely vulnerable to environmental damage because it is shallow, has a low rate of exchange with Port Phillip Bay and a high concentration of industrial and shipping activities.

Cadmium contamination of Corio Bay is the most notable of all pollution events in Victoria. During the 1960s, effluent from a paint pigments factory discharged through the stormwater system into this bay. Since this discharge was stopped, cadmium concentrations in mussels have decreased and are now below the maximum permitted concentration (Nicholson 1992). However, the wider impact of this contamination has extended out into the Geelong Arm where the farming of native oysters off Clifton Springs was prohibited because of the combination of the trace levels of cadmium and the oyster's ability to concentrate this metal.

In the period between studies conducted from 1976 to 1978, and 1987 to 1988, concentrations of cadmium, copper, iron, lead, manganese and zinc in tissues of mussels decreased at most sites (Nicholson et al. 1992d). In all cases in the latter study, concentrations of these metal toxicants were well below the maximum permissible concentrations for public health. Concentrations remained highest in mussels from the sites off the industrialised region in the north-western part of Corio Bay. Concentrations of cadmium and other metal toxicants in sediments were also found to have generally deceased, although high cadmium levels persist in the inner Rippleside region (Nicholson et al. 1992c).

A comprehensive study of mercury concentrations in sediments in Corio Bay (Nicholson et al. 1992b), showed that high concentrations remain associated with two historical sources (the former Corio Shire tip and the Phosphate Cooperative plant) and the Shell Oil Refinery. In general, concentrations were greatest 20-30 cm below the surface. While the concentrations reported were considered to pose little danger to aquatic organisms, the ecological implications of channel dredging and spoil disposal warrant careful examination in Corio Bay. Of 13 species of fish studied in Corio Bay, only yank flathead (*Platycephalus caeruleopunctatus*) and snapper (*Pagrus auratus*), had mercury concentrations above the National Food Authority health standard (Nicholson et al. 1992a). Concentrations in sand flathead (*Platycephalus bassensis*) were found to have decreased since the mid-1970s. Mercury concentrations in flathead species have decreased during the 1980s (Nicholson 1992).

Between 1987 and 1990, studies of petroleum hydrocarbons and pesticides in sediments in Corio Bay found that, while concentrations in some areas were lower than in the late 1970s, they were still high enough to be toxic to some benthic species (Fabris et al. 1992a); organochlorine pesticide concentrations were low. Studies of mussels showed that, while inputs of PCBs decreased during the 1980s, Corio Bay continued to be chronically contaminated with petroleum hydrocarbons from oil refining, shipping and recreational boating (Fabris et al. 1992a).

The highest levels of petroleum hydrocarbons and PCBs found in flathead tissues from Port Phillip Bay came from sites in and close to Corio Bay (Nicholson 1992).

The Geelong Shell refinery daily releases large volumes of heated seawater which has been treated with chlorine to prevent settlement of fouling organisms in the cooling system. The quality of the discharge has been improved by the separation of process water (which now goes to sewer) from cooling water.

In 1987, studies of the benthic communities in Corio Bay found them to be typical of those which are to be expected in shallow, muddy environments. Comparison of these communities with those from similar habitats elsewhere in Port Phillip Bay showed that the species diversity in Corio Bay was typical, but the number of animals present was lower (Coleman 1993).

Westernport Bay

Major human environmental impacts on this Bay began in the 1890s with the commencement of large-scale drainage of the surrounding swamplands. The input of sediments is substantially less now and most of the earlier material appears to have become sorted and stabilised, although it is thought to have smothered large areas of former seagrass beds (NREC 1991). Intertidal banks make up about 35% of the Bay area. Of this, about 260 km^2 were covered by seagrass of which some 70% has disappeared in the last two decades. While the causes are not known, accelerated sediment deposition from catchment erosion and swamp drainage, as well as port development, shipping and boating activities, and associated pollutants have all been suggested. The impacts on seagrass-dependent fish species, notably King George whiting (*Sillaginodes punctatus*), and the consequent impacts on commercial and recreational fisheries, have been significant.

BHP's industrial cold steel rolling works are licensed to discharge effluent containing phosphorus compounds, zinc, and surfactants. Esso Australia Pty Ltd at Long Island Point is licensed to discharge effluent containing sulphides, phosphorus compounds, surfactants and other pollutants.

The biological and chemical thresholds set in the SEPP are exceeded at times, probably as the result of phosphorus and suspended solids from agricultural run-off (LCC 1993).

Gippsland Lakes

Since the construction of the permanent opening to the ocean in 1889, the Lakes have undergone a number of major ecological changes, some of which have occurred over periods of decades. Increased salinity in the Lakes has led to the establishment of seagrass beds which now cover about 12% of the Lakes area and dieback of former fringing vegetation from much of the shore.

Lake Wellington has high turbidity (the result of loss of bottom vegetation) and extreme variability in salinity levels, presenting a hostile environment which is reflected by poorer flora and fauna than the lakes further east (NREC 1991).

The presence of the salt-water wedge under brackish outflows and the resultant stratification is thought to be connected to the incidence of algal blooms, particularly of the blue-green alga (*Nodularia spumigena*) (NREC 1991). There are reports of blooms in the Lakes in the 19th century and well documented major blooms in 1971, 1974 and 1987-88 (Chessman 1988). Following the last of these (which lasted for five months), a seminar examined in detail the condition of the Lakes and the range of possible factors which may influence the occurrence of algal blooms. The general consensus was that the major cause was nutrient release from sediments, caused by high oxygen demand in sediments isolated by stratification linked to the inflow of ocean water through the artificial entrance (Bremner 1988).

Since 1986, monthly monitoring of compliance with SEPP water quality objectives has been conducted in Lakes King, Victoria and Wellington. A more intensive program to monitor algal blooms started after the major bloom of 1987-88, but was discontinued in 1991. In the three years since a contingency plan for algal bloom occurrences in the Gippsland Lakes was prepared, there has been no bloom large enough to warrant its implementation.

One significant pollution input into the Lakes system was eliminated in 1992 with the commissioning of the Delray Beach Ocean Outfall. Previously, the Maryvale APM pulp and paper mill's treated wastewater was discharged into Lake Coleman, an enclosed wetland adjacent to Lake Wellington. In addition, the major lakeside towns of Lakes Entrance, Metung and Paynesville have been sewered in recent years.

Coastal waters - general

Victoria periodically experiences minor oil spills along the open coast. For instance, a spill from a passing ship in 1990 resulted in the deaths of hundreds of little penguins off the Otway Peninsula. In the major bays and in harbours such as Portland, minor spills occur frequently.

The main point source discharges to coastal waters are from sewage treatment plants of which nine are treated to a secondary level. The 17 licensed discharges to Victoria's open coastal waters are, from west to east: Portland, Port Fairy, Warrnambool, Apollo Bay, Lorne, Anglesea, Black Rock, Boags Rocks, Cowes, Wonthaggi, Leongatha, Foster, Toora, Port Welshpool, Yarram, McGaurans Beach and Delray Beach.

A descriptive study of these discharges and their impacts (McKenzie & Goudey 1991) showed that some of the sewage discharges (e.g. Warrnambool) have a significant localised effect on marine communities through nutrient enrichment, and all contain low levels of persistent toxicants. Two outfalls, Toora and Foster, discharge into marine parks and are to be phased out. Only two discharges are mainly from industrial sources: the Leongatha outfall discharges milk wastes into the surf zone at Venus Bay, and the Saline Waste Outfall Pipeline at McGaurans Beach discharges saline wastewater containing metals from the Loy Yang power station.

The Boags Rock outfall discharges the highest volume (200 000 megalitres per annum), being 35% of Melbourne's sewage treated to secondary stage at the South Eastern Treatment Plant.

The second largest volume comes from Black Rock where 20 300 megalitres per annum of domestic and industrial waste from the Geelong region is screened before discharging through a submerged pipeline, 1.2 km offshore. Prior to 1989, this discharge was unscreened and occurred at the shore. Acute toxicity tests show that the Black Rock effluent is acutely toxic requiring considerable dilution to satisfy the SEPP Waters of Victoria standards. Anionic and nonionic surfactants, and phenols were determined as the main contributors to this toxicity (McKenzie & Goudey 1991).

During 1992, potentially toxic algae were first reported from Lorne (*Gymnodinium catenatum*) and at several locations from Portland to Lorne (*Alexandrium tamarense*) (S. Conron DCNR, pers. comm.).

Victorian estuaries - general

In virtually every inlet and estuary from Mallacoota Inlet to the Glenelg River, upstream land use practices associated with farming and forestry, plus reduced flow rates resulting from water management, have resulted in significant shallowing and alteration of aquatic habitats. In some instances, this effect has been magnified by other factors. For instance, in Anderson Inlet the introduction of *Spartina* to stabilise banks has accelerated the shallowing and modification of habitats, to the detriment of fish and birds.

Catchment land degradation has caused siltation and high total dissolved solid levels in the estuarine reaches of a number of coastal rivers and streams, notably Glenelg River, Hopkins River, Curdies Inlet, Lake Connewarre and Barwon River, Werribee River, Anderson Inlet, Shallow Inlet, Corner Inlet and Nooramunga, Sydenham Inlet, Snowy River and Mallacoota Inlet. Other consequences include brackish groundwater and severe dry land salting which affect rivers such as the Glenelg, Hopkins and Barwon.

Other common indicators of degraded systems include elevated nutrient concentrations (Hopkins, Curdies, Barwon, Little, Yarra, Bunyip and Thompson), colour (Gellibrand, Barwon, Little, Maribyrnong, Bunyip, Thompson, Tambo and Snowy), bacterial contamination (Barham, Yarra, Bunyip, Tambo and Snowy) and low dissolved levels (Hopkins, Yarra, Bunyip and Thompson).

In several instances, grazing and land clearance has resulted in damage to fringing vegetation and the introduction of weeds.

The damming of many small coastal streams (e.g. Spring Creek and Anglesea River) has greatly modified the physical and biotic nature of their estuaries.

Monitoring

Since 1984, the EPA and the Department of Conservation and Natural Resources have sampled fixed sites, fortnightly, as part of a Fixed Sites Monitoring Program, aimed primarily at assessing compliance with SEPP standards for Port Phillip Bay (Colman et al. 1991). In 1988, the number of sites was increased to six. From 1987 to 1989, routine monitoring of salinity, temperature, nutrient and chlorophyll levels was supplemented by a study of the frequency, duration and severity of depressed dissolved oxygen levels in the centre of the Bay (Mickelson 1990).

Since 1990, in a separate but related program, the Department of Conservation and Natural Resources has conducted a Water Quality Monitoring Program in Port Phillip Bay to provide continuous assessment of water quality to ensure the quality of harvested fish and shellfish and to protect flora and fauna. At two sites, automated data loggers continuously monitor salinity and temperature. At six sites, fortnightly depth-integrated samples are analysed for inorganic nitrogen; phosphate; silicate; particulate phosphorus, nitrogen and carbon; total phosphorus and nitrogen; total organic carbon, suspended solids and chlorophyll pigments. Vertical profiles of temperature, salinity, dissolved oxygen, chlorophyll fluorescence and photosynthetically active radiation are also recorded fortnightly. Time series analysis will be applied to the data to detect temporal trends and to relate trends to possible causal factors.

The Fixed Sites Monitoring Program also covers Westernport Bay (3 sites) and the Gippsland Lakes (5 sites). Water samples are taken at the surface in Westernport Bay and Gippsland Lakes, and near-bottom waters are also sampled in the Lakes to look for conditions that may lead to algal blooms. The following parameters are measured at each site: nutrients, chlorophyll and suspended solids in waters; trace metal concentrations in waters and sediments; petroleum hydrocarbons in sediments.

Since 1989, an annual trawl survey has been conducted each autumn to detect any changes to the abundance and species composition of fish communities in Port Phillip Bay. A total of 22 depth-stratified stations are sampled.

The draft revision of the Port Phillip Bay State Environment Protection Policy (EPA 1991) proposes that the annual load of nitrogen discharged into Port Phillip Bay from the Werribee Treatment Complex must not exceed 4300 tonnes. The draft proposes that the EPA will continue monitoring chlorophyll a, nitrogen and phosphorus, and that it will establish an algal monitoring program. It also proposes that the EPA and the Department of Conservation and Natural Resources will jointly develop a Port Phillip Bay Management Plan (in consultation with other government and nongovernment organisations). Initially, this should address the nutrient sources, loads and status of the Bay; the sources, fate, impact and management of toxicants in Bay waters, sediments and biota; and the strategy necessary for management of environmental quality in the inshore segment of the Bay. The revised SEPP will address all aspects of physical and chemical pollution and disturbance to the Bay.

In September 1987, due to the presence of the toxic dinoflagellate, *Alexandrium catenella*, a marine biotoxin monitoring program was established to protect the health of human consumers of Port Phillip Bay shellfish and to assist with the management of the aquaculture industry (Arnott 1990). The program entails routine phytoplankton monitoring, bioassays and an early warning network.

The value of monitoring of contaminant levels in waters, sediments and biota has been proven repeatedly in Victoria. For instance in Corio Bay, monitoring of heavy metals in sediments has shown general decreases which are at least partly attributable to stricter regulatory measures by the EPA (Nicholson et al. 1992c).

Other recent initiatives include:

- review of liquid waste agreements to reduce the amount of contaminants generated and the quantity of wastewater discharged into sewers; and
- monitoring of stormwater drains entering the Bay;
- installation of litter traps in drains and the Yarra River;
- review of methods used to determine bacterial levels at bayside beaches;
- increased land disposal of dredge spoil, e.g. the 1990 excavation of the Holden Oil Dock.

During the last decade, a number of programs have commenced to address the complex environmental issues facing the Gippsland Lakes. The Gippsland Lakes Strategy focuses on key issues such as catchments, water quality, planning, management and tourism, to provide broad policy directions. Among the more specific programs are the Gippsland Lakes Management Plan, South East Water Management Strategy and algal bloom initiatives (Smith 1988), and the Gippsland Regional Landcare Plan (Regional Landcare Community Reference Group 1993). By early 1993, about 30% of the actions proposed in the Gippsland Lakes Management Plan had been implemented.

Over and above the continuation of current programs, the following initiatives are being planned or implemented to further improve Victoria's marine environment:

- reduced overflows from the sewer system and illegal sewer connections;
- continuation of the accelerated connection of unsewered areas;
- diversion of sewage from the Dandenong Valley from Mordialloc Creek to the South Eastern Purification Plant;
- study of the Bay's capacity to absorb increased inputs of nutrients and toxicants;
- increased public awareness and education to reduce litter;
- coordinated improvements to Kororoit, Mordialloc and Kananook Creeks, including monitoring and phasing out of harmful discharges;
- improved catchment management to reduce siltation of the lower Yarra River and Port of Melbourne area;
- increased penalties for major oil spills.

In addition, industry and the community are being urged to act to improve their respective voluntary contributions to improvement in the quality of the marine environment (Vic. Govt 1992c).

Coastal discharges

Water authorities with ocean outfalls not meeting the requirements of the SEPP Waters of Victoria are required to upgrade their treatment works to produce effluent of secondary treatment quality or discharge their wastes to land (the preferred option) by 1997. Several authorities are already taking steps to upgrade the quality of their coastal discharges. For instance, the Geelong and District Water Board's Black Rock plant and the Warrnambool system are both at advanced stages of planning and upgrading to comply with the SEPP. The Alberton Water Board (Yarram) expects to cease discharging to the ocean by mid-1993.

Authorities responsible for the smaller discharges are at various stages of planning or upgrading their treatment and discharge facilities.

Marine waters - general

Under recent policy statements for Victoria, representative habitats and marine and estuarine areas of high conservation value or importance as habitats for production of fisheries resources are to be identified and, if necessary, set aside as protected areas.

Discussion

The Land Conservation Council (LCC) is conducting a major statewide planning and assessment task upon which much of the future security of Victoria's marine environments rest. This includes an investigation of marine, coastal and estuarine resources; their status and use, and strategic planning advice on the protection of significant environmental values and the sustainable use of these resources. The first stage of this investigation has been the production of a comprehensive report which 'describes the physical, biological and cultural values of the study area, identifies current and potential uses and outlines the broad social, economic, legislative, and conservation context for planning (LCC 1993). The LCC is scheduled to report to the Government at the end of 1994, following public input on the information base, issues and a draft report.

Another significant recent contribution to planning and assessment of the marine environment has been the first stage of a review of conditions and trends in marine and coastal environments, initiated by the former Office of the Commissioner for the Environment (Colman et al. 1991).

The first output of this task was a report outlining a comprehensive approach to detecting long term change in the condition of the marine environment. This report sets out key indicators for marine environments with details on recommended monitoring programs for Victorian marine waters, sediments, biota and ecosystems (Colman et al. 1991).

The study found that very little of the extant environmental data would provide for the detection of long term change, often because the sampling regimes of past monitoring programs were designed for other purposes (e.g. regulatory monitoring and impact assessments). The study observed that 'Unless due attention is given to statistical design, there is a risk that substantial monitoring may be undertaken without any resultant ability to draw any significant conclusions about long-term change.'

Major recommendations were made on recommended key indicators for marine environments. In the case of water quality, key indicators were identified for specific areas (e.g. dissolved oxygen in central Port Phillip Bay) and wider areas (e.g. nutrients and chlorophyll a in Bass Strait). Other key indicators were recommended for marine biota (e.g. extent and health of seagrass meadows), sediments (e.g. nutrient, carbon and toxicant concentrations) and estuaries (e.g. salinity regimes and community structure). To distinguish between changes resulting from natural processes and from human activity, the study also proposed an approach to monitoring process and activity indicators for marine environments.

The establishment of the Office of the Commissioner for the Environment in 1986 was a major step towards a systematic approach to overviewing trends and the state of Victoria's marine environment. In October 1992, this position was terminated and the responsibility for continuing work was taken up by the Office of the Environment. The policy of the current Government is to establish a Parliamentary Committee to continue monitoring of Victoria's environment.

Progress continues towards a systematic approach to the assessment and protection of marine (and estuarine) areas of special significance. The development of biogeographic classifications for the description of the distributions of marine flora and fauna, the development of a national approach to the designation of marine protected areas, and the trend towards nominating significant areas to the Register of the National Estate are contributing to this progress. Malcolm (1992) has reviewed the work in this area, listing Victorian areas proposed for listing on the Register.

In practical terms, the Environmental Effects Statements produced for works, developments and discharges affecting Victoria's marine waters generally provide no more than a snapshot of the environments and marine communities involved. For instance, despite the fact that port authorities have dredged and dumped tens of millions of tonnes of sediment, much from contaminated areas, into bays and coastal waters, there is no basis for determining ecological impacts or of predicting the likely impacts of future spoil disposal on marine ecosystems. Some major developments with the potential for significant marine environmental impacts, such as the Shell/Mobil oil storage at Crib Point, proceed without a requirement for Environmental Effects Statements.

A Trial Dredge Protocol (EPA 1992) has been established to provide guidelines for maximum environmental protection from public works dredging associated with ports, shipping and boating facilities in Victoria. Referring to the relevant SEPP standards, the trial protocol sets out: the protocol objectives; the planning, evaluation procedures; the roles of approvals and works agencies; guidelines for dredging and spoil disposal (including preference for land disposal); and procedures for determining the contaminant status of dredged material. Thus while recognising the importance of shipping, this initiative attempts to control an environmentally damaging activity in a way that previous coastal planning and permitting processes were unable to do.

The protocol perpetuates the provision for exemption of dredging operations 'which are considered essential for the operation of normal port activities'. Such operations usually involve the removal and dumping of large volumes of spoil (particularly in Port Phillip Bay), both in maintenance and development projects. In many instances, the spoil contains low levels of contaminants. The rationale offered is that, provided 'the possible environmental costs associated with legitimate port activities' and other details of these operations are made public, they may proceed.

The implementation of the Gippsland Lakes Management Plan and Strategy Plan, developed during the late 1980s, and the completion and implementation of the revised Port Phillip Bay State Environment Protection Policy are other specific actions that will play important parts in the protection of coastal waters and resources and the improvement of land use management in the catchment and land adjacent to the Lakes.

Monitoring of contaminant concentrations in water, sediments and biota has proven the effectiveness of the EPA's discharge licensing and alternative waste treatment and disposal programs (and the value of environmental monitoring). This has provided a confident basis for a range of current measures designed to achieve further improvements in Victorian marine environments.

Further significant improvements to the quality of coastal waters can be expected under the Coastal Discharges Strategy which requires that all discharges to these waters meet secondary treatment standards, or that disposal occurs on land, by 1977.

In recent years, the Victorian Government has recognised the need for an integrated approach to the planning and management of public waters and their catchments (Vic. Govt 1989a). This has resulted in a shift from river to catchment management boards, and in the establishment of Catchment Coordinating Groups to link agencies and community groups as part of the implementation of integrated catchment principles. The future environmental condition of Victoria's inlets and estuaries will largely depend on how effectively this approach proves to be in reversing river and catchment degradation.

In 1991, for the first time since commercial scallop fishing began in Port Phillip Bay in 1963, detailed investigations were started into the fisheries and ecological impacts of the use of scallop dredges. It is intended that long-term impacts will be studied after the completion of short to medium-term impact studies in 1993. The ecological impacts of other commercial fishing activities are also being proposed, for instance pilchard and anchovy fishing in Port Phillip Bay and the use of haul seine nets in bays and inlets.

Because blooms of potentially-toxic algae such as *Alexandrium catenella* are occurring regularly in Port Phillip Bay, continuation of the Shellfish Quality Assurance Program, begun in 1987, will be necessary to safeguard public health of local and export market consumers of shellfish farmed or taken by fisheries, and to indicate changes to the environmental status of Victorian waters (Callan et al. 1993). National proposals to apply the same monitoring, certification and labelling standards to locally-marketed shellfish as currently apply to exports offer improved product quality, protection of public health and improved cost-effectiveness of management programs.

In 1992, the Victorian Government's unequivocal endorsement of the principles of Ecological Sustainable Development (ESD) in fisheries gave hope that protection of the marine environment, particularly that of fish habitats, will be given greater prominence in future. Already, fishery management plans are being produced on an ESD framework which emphasises the importance of factors including habitat protection and water quality, from the points of view of maintaining exploited fish stocks and ensuring seafood quality.

The Government outlined its commitment (Vic. Govt 1992b) to the 51 recommendations made by a parliamentary review of bay and inlet commercial and recreational fisheries, and emphasising the importance of fish habitat protection. Those recommendations feature expressions of concern and actions to be taken to deal with:

- introduction of exotic species via ballast water;
- maintenance of biological diversity in bays and inlets;
- monitoring of fish habitat and actions to halt deterioration;
- conserving the whole ecosystem in each bay and inlet;
- specific studies of fishing impacts on bay and inlet ecosystems.

During 1992, a major study of the Bay was commenced by Melbourne Water, the Environment Protection Authority, the Port of Melbourne Authority and the Department of

Conservation and Natural Resources (CSIRO 1992a). The main aim of the three year study is to determine the environmental status of the Bay and its capacity to absorb future increases in nutrients (and trace levels of toxicants), principally from the Werribee Treatment Complex. This information is essential as the basis for the environmental management of the Bay for at least the next 20 years (CSIRO 1992a).

The key scientific information to be sought includes a comprehensive understanding of the physical processes which influence transport, distribution and mixing of discharged materials; knowledge of the status of inputs, water and biota and certain transformation processes for nutrients and toxicants; and the role of sediments as storage reservoirs and as sites for transformation processes.

Future concerns

The major challenges lie with protecting and restoring marine environments in the face of further population growth, water usage and intensification of urbanisation and land use. The population of Melbourne is forecast to grow from 3.02 million in 1991, to more than 3.3 million in 2001 and to 3.6 million in 2015 - an increase of 580 000 people in 24 years. Victoria's population will rise to about 5.7 million in that period, increasing by 1.3 million people.

To service the projected growth of Melbourne, upgrading of the sewerage system will be required, plus a reassessment of the environmental impact of point-source and diffuse load to waterways and coastal waters receiving effluent discharges (Vic. Govt 1989a). With major urban growth extending east, particularly into the Westernport catchment, a major additional treatment plant with capacity to service 100 000 people will be needed before the year 2015. Following the trend in environmental policy, land disposal of sewage effluent must be properly evaluated.

The combination of expanded water storages and improved demand management have improved the medium-term outlook for water usage in Victoria. Reduced domestic consumption rates, improved sewage treatment, stricter industrial wastewater management and other related measures will help in the overall effort to reduce the inputs of contaminants to marine waters.

Notwithstanding the previous Government's undertakings given in the state conservation and coastal strategies (Vic. Govt. 1988 & 1987), surveys of Victoria's marine habitats and communities and assessment of their conservation and special protection needs have not proceeded. This will continue to severely hamper the task of marine conservation and promote the continuation of an ad hoc and reactive approach.

Despite the precautionary measures implemented at a national level, a major area of concern for Victoria is the increased incidence and severity of harmful algal blooms in marine waters, apparently resulting from the combination of the global spreading of toxic species and increased nutrient loadings.

Further, it appears to be only a matter of time before the seastar (*Asterias amurensis*) and the Japanese seaweed (*Undaria pinnatifida*) reach Victorian coastal waters. Both are believed to have been introduced in ballast water to the Tasmanian east coast, where they are having significant ecological and fisheries impacts.

In 1989, the Victorian Government prepared a strategy to address the broad implications of the Greenhouse Effect for the State (Vic. Govt 1989a & 1989b). Climate and ocean studies were identified as priority strategic research areas and cooperative research programs commenced with the CSIRO and the Australian Bureau of Meteorology.

Overall, Victorian waters and marine habitats are in reasonably good condition, supporting healthy living resources, supporting a significant fishing industry and water-based recreation and tourism. However, pollution and development have had obvious impacts on water quality and natural resources and there are concerns over their cumulative effects as the population of Melbourne and Victoria grow, accompanied by continuing industrial, coastal infrastructure and residential growth. Even with improved quality of coastal discharges in recent years, the enclosed nature of Port Phillip Bay, Westernport Bay and the Gippsland Lakes, coupled with this continuing growth, mean that there is no room for complacency.

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Issues in the Queensland marine environment

Diane Tarte, Meredith Hall, Karen Stocks

Australian Littoral Society
Moorooka Qld

Introduction

The issues discussed here have been identified through consultation with a variety of people, government agencies and a limited review of the literature. A questionnaire was distributed to 35 government officers, private sector representatives, consultants and community groups seeking their opinions and sources of further information. A summary of the responses to the questionnaire has been forwarded to the SOMER secretariat.

In overviewing the state of the Queensland marine environment, the focus has been primarily on the impacts of land-based activities. There is little documentation of specific subtidal marine areas having been degraded through human activities, although substantial areas of intertidal and near-coastal habitat have been modified for a variety of human uses including urbanisation, agriculture, and industrial port and boating facilities.

The issues discussed are primarily in the context of existing usage patterns and future trends. Elsewhere within the SOMER Report, overview chapters have been prepared describing the specific impacts of present usages of the marine environment. Locations mentioned in the text are shown in Figure 1.

Major issues affecting the Queensland marine environment

Catchment and population issues

Any discussion of present day land uses and population demographics refers to the changes to the land and seascape, occurring over the last two hundred years. For Queensland, the pattern of European settlement is similar to elsewhere within Australia, with most major population and industrial centres located along the coast and substantial areas of the coastal catchments dedicated to agriculture activities.

Of the 32 catchment areas identified by the Queensland Department of Primary Industries, 25 are 'coastal', with the catchments discharging into Queensland coastal waters.

The following is a discussion of the existing patterns and future trends in land use in the coastal catchment areas. This level of detail is included to allow the reader to appreciate the substantial impact that catchment land use and water extraction practices have on the quality of the receiving coastal waters.

Catchment land uses and river impoundments

Table 1 lists the coastal catchment areas and the major river systems in each catchment. Since the 1940s a number of these river systems have been impounded to supply water for agriculture or potable water for urban populations; the rivers with large dams are noted in Table 1. Additionally, weirs or barrages have been built on a number of coastal rivers to reduce the upstream extent of tidal influence and so allow greater access to fresh water in the lower reaches.

The ecological roles of rivers in terms of fresh water flow rates, nutrient cycles and life histories of aquatic species has received scant attention in the placement and management of water storages. Debate about the need to include an 'environmental allocation' when determining water release rates from dams has occurred only in recent years. While some impoundments contain fish ladders, the overall impact of these barriers on the migration of fish and other aquatic species for breeding purposes has not been documented.

Statistics for each catchment area are reproduced in Table 2. Grazing is the major land use, ranging from 96% of the catchment for the Western Gulf to 8% for the Mulgrave-Russell Rivers, and averaging 57% overall. Cropping is a major land use in only a few coastal catchments, in particular the Johnstone and Mulgrave-Russell Rivers; on average only 6% of most catchments is allocated to cropping. These figures are particularly

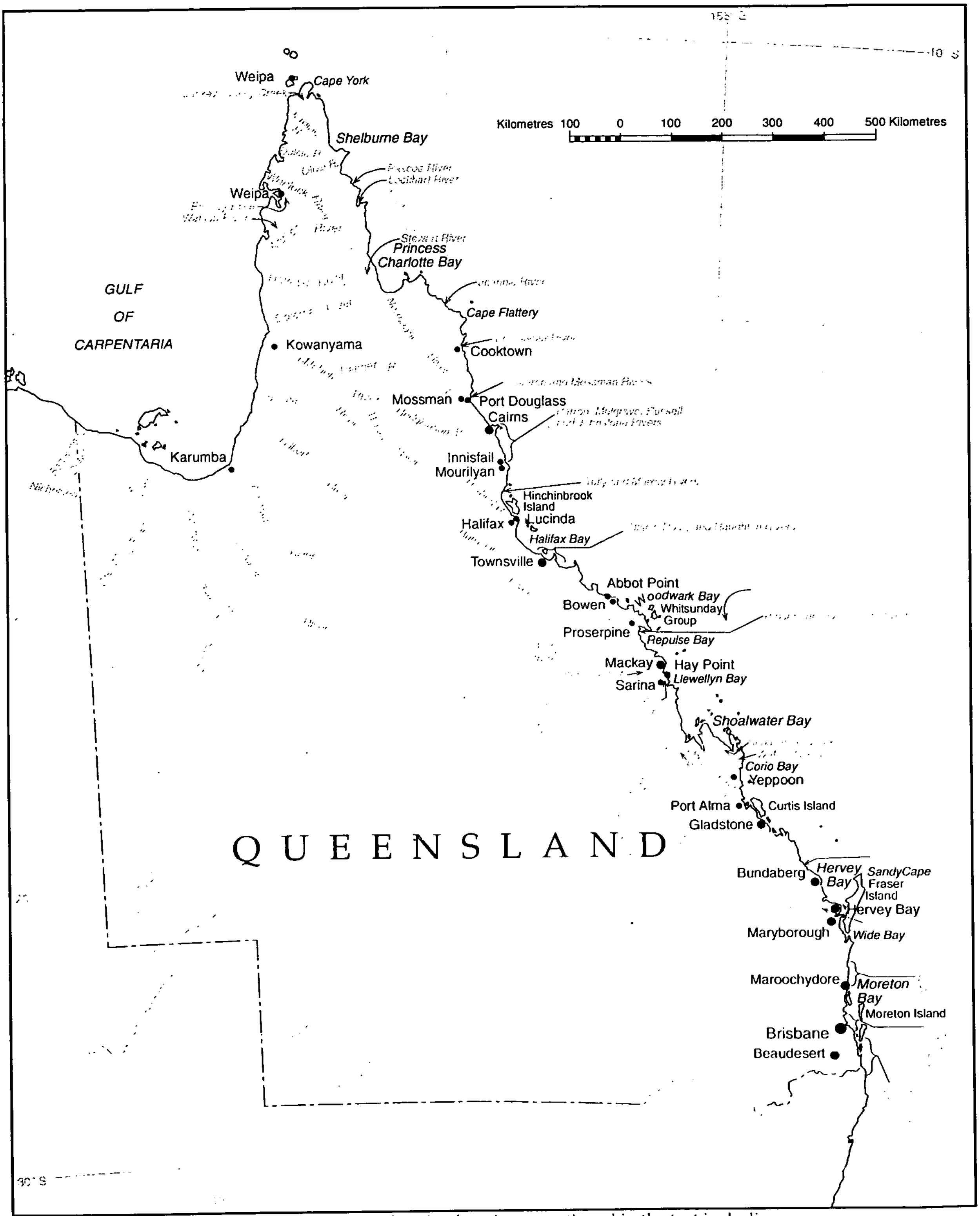

Figure 1: State map showing locations mentioned in the text,including major coastal centres, trading ports and rivers.

Table 1: Major coastal catchment areas in Queensland, including major rivers

Region and Catchment Area	Catchment Area Number	River Basins Included 1	Major Rivers in each Catchment
Carpentaria			
West Cape York	1	920-927	Jardine, Ducie, Wenlock, Embley, Watson, Archer, Holroyd, Colman
Mitchell	2	919	Mitchell, Palmer, Hodgkinson, Walsh
Eastern Gulf	3	916-918	Staaten, Gilbert*, Norman
Flinders	4	915	Flinders, Cloncurry*
Western Gulf	5	910-914	Leichhardt*, Nicholson, Settlement Ck, Gregory
Southern Coastal			
Gold Coast	13	144-146	Tweed, Logan*, Albert, Coomera, Nerang*
Brisbane	14	143	Brisbane*, Bremer*, Stanley*, Lockyer Ck*
Sunshine Coast	15	139-142	Pine*, Maroochy*, Noosa, Mooloolah*
Mary	16	138	Mary*
Burnett-Kolan	17	135-137	Burrum*, Burnett*, Kolan*
Curtis Coast	18	131-134	Baffle Ck, Boyne*, Calliope
Central Coastal			
Fitzroy	19	130	Dawson*, Fitzroy, Isaaca, Mackenzie*, Nogoa*, Comet
Shoalwater Bay-Sarina	20	126-129	Plan Ck, Styx, Shoalwater Ck, Water Park Ck
Pioneer-O'Connell	21	124-125	O'Connell, Pioneer*
Proserpine	22	122	Proserpine
Don	23	121	Don
Burdekin-Haughton	24	119-120	Burdekin*, Haughton, Suttor, Belyando
Ross-Black	25	117-118	Ross*, Black
Northern Coastal			
Herbert	26	116	Herbert
Tully-Murray	27	113-115	Tully*, Murray
Johnstone	28	112	Johnstone
Mulgrave-Russell	29	111	Mulgrave, Russell
Barron	30	110	Barron*
Mossman-Daintree	31	108-109	Mossman, Daintree
North-East Cape York	32	101-107	Jacky Jacky Ck, Olive, Pascoe, Lockhardt, Stewart, Normanby, Jeannie, Endeavour

Key: 1 = River Basin Index as defined by the Australian Water Resources Council
* = Rivers with large dams
Sources: QDPI (1993), Appendices 1 and 2
Water Resources Commission (1989), Appendix: Selected Large Dams

relevant in relation to the export of sediment and nutrients (see Figures 2 & 3).

Table 3, (from QDPI 1993), shows the perceived level of concern rating for 11 key issues considered to be important to the condition of the natural resources in each of the catchment areas, plus the recreational and commercial fishing values for each catchment area. These land management issues will affect the quality of catchment discharges into coastal waters. This assessment is not based on specific research or survey data, but represents the considered opinion of State departmental officers. As such, it provides an indication of the likely physical and ecological condition of each catchment area.

An analysis of Table 3 shows that the issues of most concern are barriers to fish migration, erosion from cropping land, stream channel instability, urban expansion, and in-stream and off-stream water use conflict. Catchment areas in the Southern Coastal region rate the highest levels of concern, with some catchments in the Central Coastal and Northern Coastal regions also showing problems. QDPI (1993) notes that, 'These concerns are generally associated with catchment areas with high and growing populations, and with more intensive land use and high economic productivity.' It is noteworthy that the majority of catchment areas rate highly for recreational and commercial fishing value.

Catchment Discharges

For the marine environment the major impacts of catchment uses are reflected in the changed water quality of rivers discharging into coastal waters. Moss et al. (1992b) have assessed the sediment and nutrient exports of the 20 catchment areas discharging into the northern and eastern coastal waters of Queensland. Their analysis is based on limited existing data and 'best estimates' by the study team, and it utilised an established process modelling approach.

Figure 2 documents the export of sediment from the coastal catchments and indicates contributions from the major land uses of

Table 2: Various catchment characteristics and land uses influencing the quality of discharges from 'coastal' catchments (QDPI (1993), Appendix 3)

Region, Catchment Area and Number	Catchment Area (km2)1	Area Grazing Land (km2)/ % Grazed2	Area Cropping Land (km2)/ % Cropped2	Area Irrigated (km2)2	Area of National Parks/ State Forest - Native/ State Forest - Plantation/ Timber Reserves (km2)3,4	Population / Projected Pop. in 2001 (x 1000)5	Av. Ann. Rainfall (mm)1,A	Av. Ann. Run-off (ML x 1000)1	Volume Major Storages >2500 ML (ML x 1000)1,B
Carpentaria									
West Cape York (1)	64 025	26 770 (42)			6631/ -/ -/ 195.0	6/ 6	800/2 000	28 750	
Mitchell (2)	71 795	67 460 (94)	45 (<0.1)	30.7	494/ 745.6/ -/ 30.1	5/ 6	800/2 000	12 000	
Eastern Gulf (3)	121 290	109 220 (90)			4896/ -/ -/ -	3/ 4	1 000/1 200	12 100	41
Flinders (4)	108 780	103 770 (95)	3 (<0. 1)	1.0	235/ -/ -/ -	8/ 9	400/1 200	3 050	16
Western Gulf (5)	85 960	82 760 (96)			129/ -/ -/ 90.5	26/ 27	400/1 200	9 100	301
Southern Coastal									
Gold Coast (13)	5 995	2 020 (34)	159 (2.7)	69.9	358/ 127.2/ 4.8/ 6.6	381/ 717	1 000/2 000	1 700	235
Brisbane (14)	13 560	6 290 (46)	474 (3.5)	249.8	174/ 1468.6/ 222.6/ 34.6	1104/ 1280	800/1 200	1 350	1 846
Sunshine Coast (15)	6 565	580 (9)	164 (2.5)	44.0	511/ 1793.2/ 414.8/ -	125/ 226	1 200/2 000	2 300	252
Mary (16)	9 595	5 830 (61)	513 (5.4)	251.7	21/ 2669.3/ 669.8/ 43.6	58/ 73	400/1 200	2 300	133
Burnett-Kolan (17)	39 470	26 520 (67)	1 352 (3.4)	348.5	184/ 6178.7/ 211.4/ 123.3	100/ 118	400/1 200	2 900	1 327
Curtis Coast (18)	9 225	6 360 (69)	44 (0.5)	8.6	243/ 708.2/ 5.8/ 251.7	40/ 49	800/1 200	1 500	315
Central Coastal									
Fitzroy (19)	142 645	119 320 (84)	7 065 (5.0)	236.4	3228/ 8472.5/ 14.4/ 1067.1	147/ 187	500/1 800	7 100	1 752
Shoalwater Bay-Sarina (20)	11 270	4 970 (44)	464 (4.1)	140.4	80/ 2233.9/ 48.8/ 96.1	55/ 72	800/2 000	3 700	63
Pioneer-O'Connell (21)	3 925	1 940 (49)	509 (13.0)	136.1	230/ 431.7/ 5.3/ 73.4	19/ 26	1 000/2 000	2 650	10
Proserpine (22)	2 485	1 670 (67)	159 (6.4)	59.0	297/ 252.4/ -/ -	10/ 21	800/2 000	1 400	500
Don (23)	3 985	3 850 (97)	41 (1.0)	33.0	83/ -/ -/ -	10/ 11	400/1 200	700	
Burdekin-Haughton (24)	133 510	118 060 (88)	1 384 (1.0)	401.5	1073/ 1140.6/ 2.5/ 127.9	39/ 41	400/1 200	10 850	2 040
Ross-Black (25)	2 890	850 (29)	10 (0.4)	3.0	307/ 222.1/ 0.4/ -	112/ 159	800/1 200	1 100	420
Northern Coastal									
Herbert (26)	12 130	7 970 (66)	447 (3.7)	19.0	382/ 1094.3/ 34.1/ 73.9	18/ 19	800/2 000	5 000	
Tully-Murray (27)	2 825	530 (19)	151 (5.4)	18.1	166/ 1638.8/ 51.1/ 5.4	22/. 27	800/>2 000	5 300	212
Johnstone (28)	2 330	570 (24)	359 (15.4)	23.0	146/ 765.5/ -/ 4.3	8/ 9	1 200/>2 000	4 700	
Mulgrave-Russell (29)	2 020	160 (8)	313 (15.5)	16.2	420/ 524.4/ 3.5/ 33.6	73/ 115	1 200/>2 000	4 200	45
Barron (30)	2 175	1 200 (55)	116 (5.3)	39.7	50/ 765.3/ 30.0/ 23.5	27/ 37	1 000/>2 000	1 150	407
Mossman-Daintree (31)	2 615	930 (36)	98 (3.8)	1.6	773/ 447.2/ -/ 756.8	7/ 14	1 000/>2 000	4 250	95
North-East Cape York (32)	43 300	26 720 (62)	22 (<0.1)	0.4	7173/ 8.1/ -/ 1861.9	3/ 3	400/2 000	19 100	

(1) Source: Water Resources Commission officers. Several major land uses are shown on the table. Urban land, vacant crown land, aboriginal land, etc are not stated, hence the sum of the land uses shown does not equal the total catchment area
(2) Source: Agricultural Business Units (DPI) officers, current as at June 1991. 'Grazing Land includes some areas in state forests and timber reserves; 'Cropping Land' includes area under irrigation
(3) Source: National Parks data provided by the Dept. of Environment and Heritage, correct to 1992
(4) Source: Queensland Forest Service
(5) Source: Population Projections for the Local Government Areas of Queensland 1986-2001 (James Skinner, Martin Bell, and M. Elizabeth Gilliam), Applied Populations Research Unit, University of Queensland
(A) Range of average rainfall (mm) for the drier sections and the wetter sections of the catchment area
(B) The total storage capacity in the catchment area of artificial storages in excess of 2500 ML

Table 3: Perceived level of concern* of issues plus fisheries values for each 'coastal' catchment (QDPI (1993), Table 1 and Appendix 3)

Region, Catchment Area and Number	Agricultural Land Uses			Water Quality Issues				Water Quantity	Natural Habitat Issues			Fisheries Value 1	
				Surface Water Quality									
	Cropping Land Erosion	Grazing Land Erosion	Urban Expansion	Nutrient Enrichment	Pesticides	Impact on Biota	Ground Water Quality	Instream and Offstream Water Use Conflict	Stream Channel Instability	Loss of Coastal Wetlands	Barriers to Fish Migration	Recreat-ional	Comm-ercial
Carpentaria													
West Cape York (1)	VL	L	VL	VL	L	L	L	L	VL	L	VL	H	H
Mitchell (2)	L	M	VL	VL	VL	L	M	L	L	VL	L	H	VH
Eastern Gulf (3)	VL	H	VL	VL	VL	VL	L	L	L	L	L	H	VH
Flinders (4)	VL	M	VL	VL	VL	VL	L	L	L	VL	L	H	VH
Western Gulf (5)	VL	M	VL	VL	VL	L	VL	L	L	VL	L	H	VH
Southern Coastal													
Gold Coast (13)	M	L	VH	M	L	M	L	VH	M	H	H	M	M
Brisbane (14)	H	M	H	H	M	M	M	M	M	M	VH	M	VH
Sunshine Coast (15)	VH	L	VH	M	L	M	M	M	M	M	VH	VH	M
Mary (16)	H	M	H	M	M	M	H	M	H	L	H	VH	H
Burnett-Kolan (17)	H	M	H	M	L	M	VH	M	VL	L	VH	VH	VH
Curtis Coast (18)	H	M	L	L	VL	M	L	M	L	L	M	VH	VH
Central Coastal													
Fitzroy (19)	M	M	L	M	M	M	M	L	L	M	VH	VH	VH
Shoalwater Bay-Sarina (20)	M	M	L	L	L	L	L	L	VL	L	L	H	VH
Pioneer-O'Connell (21)	H	M	M	L	L	L	M	M	H	L	H	H	H
Proserpine (22)	M	M	L	L	L	L	M	H	L	L	L	H	M
Don (23)	M	M	L	VL	VL	L	H	VL	VH	M	L	L	L
Burdekin-Haughton (24)	M	H	L	M	L	M	H	H	H	L	VH	VH	VH
Ross-Black (25)	VL	L	M	M	L	M	M	M	M	M	L	VH	L
Northern Coastal													
Herbert (26)	L	L	VL	L	L	M	L	L	H	L	H	VH	M
Tully-Murray (27)	L	L	L	L	M	M	VL	H	H	L	H	VH	H
Johnstone (28)	H	L	M	L	L	M	VL	H	M	L	VL	VH	H
Mulgrave-Russell (29)	M	L	M	L	L	H	VL	L	M	H	VL	VH	M
Barron (30)	M	L	M	M	L	M	VL	L	L	M	L	H	H
Mossman-Daintree (31)	L	L	VL	L	L	L	VL	L	L	L	VL	VH	H
North-East Cape York (32)	L	L	VL	VL	VL	VL	VL	L	VL	VL	VL	H	H

1 Information supplied by the Fisheries Division, Qld D.P.I. **Key:** VL = Very Low; L = Low; M = Medium; H = High; VH = Very High

* Definition of Issues

Agricultural Land: Erosion of cropping land - soil loss from cropping land; Erosion of grazing land - soil loss from grazing land; Urban expansion - urban expansion into suitable agricultural land
Water Quality: Surface water nutrient enrichment - increase loading of nitrogen and phosphorous from rural, industrial and urban sources; Pesticides - contamination of water by pesticides from rural, industrial and urban areas; Impact on surface water biota - change in natural water quality sufficient to adversely affect aquatic flora and fauna; Groundwater quality - overall salinity, nutrient enrichment and pesticide levels in groundwater
Water Quantity: Instream and offstream water use conflicts - competing demands between offstream water use (urban, rural, industrial) and instream water use (environmental, recreational)
Natural Habitat: Stream bed and bank instability - changes to the bed and banks of streams that affect existing property, infrastructure and habitat; Coastal wetland habitat loss - loss of natural flora and fauna habitat in estuarine and tidal wetlands; Barriers to fish migration - impact on the up or down stream migration of fish resulting from artificial barriers on watercourses

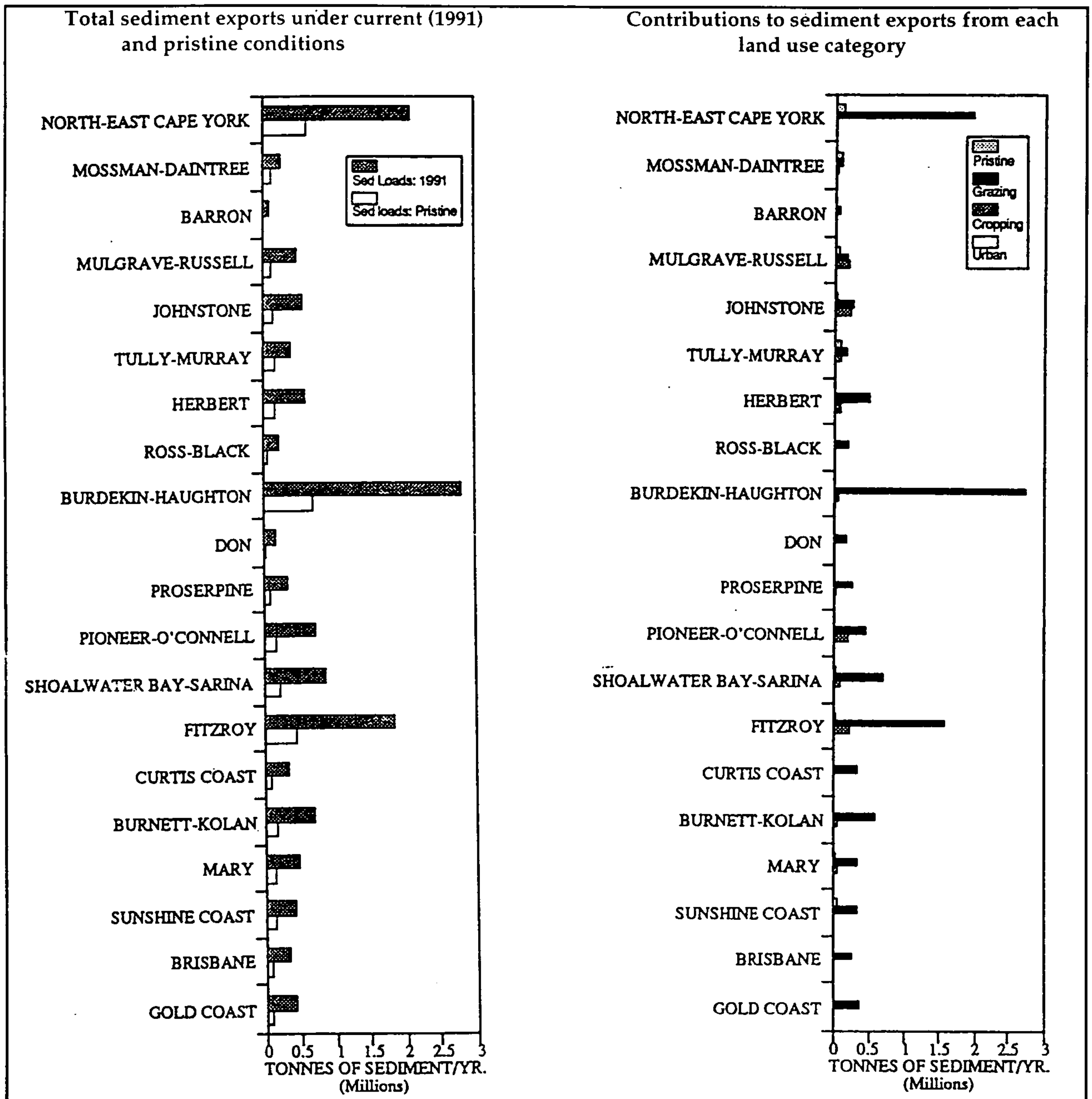

Figure 2: Sediment exports from major coastal catchment areas in Queensland. Adapted from Moss et al. (1992)

urbanisation, cropping and grazing as well as a comparison between current conditions and the 'pristine' situation prior to European settlement. Figure 3 is a comparison of the magnitude of point and diffuse sources for both nitrogen (N) and phosphorus (P) from each catchment area.

Tables 2 and 3, and Figures 2 and 3, show that substantial change to Queensland's coastal catchments has occurred since European settlement, resulting in a three- to five-fold increase in sediments and nutrient levels discharged. The Burdekin-Haughton, north-east Cape York and Fitzroy catchment areas contribute most catchment discharges of sediment and nutrients to the marine environment in Queensland. Of the estimated 15 million tonnes of sediment discharged annually by Queensland east-coast catchments, these three areas contribute 6 785 000 tonnes, or 45% of the total; and of the 77 000 tonnes of N and 10 000 tonnes of P exported annually, the above three catchment areas make the highest contribution. The Burdekin-Haughton catchment alone contributes around 14 000 tonnes of N and 2000 tonnes of P annually (Moss et al. 1992b). As these discharge estimates are based on mean flow conditions for each catchment area, exports can be at least three times greater during years of major flooding. In their summary, Moss et al. (1992b) state:

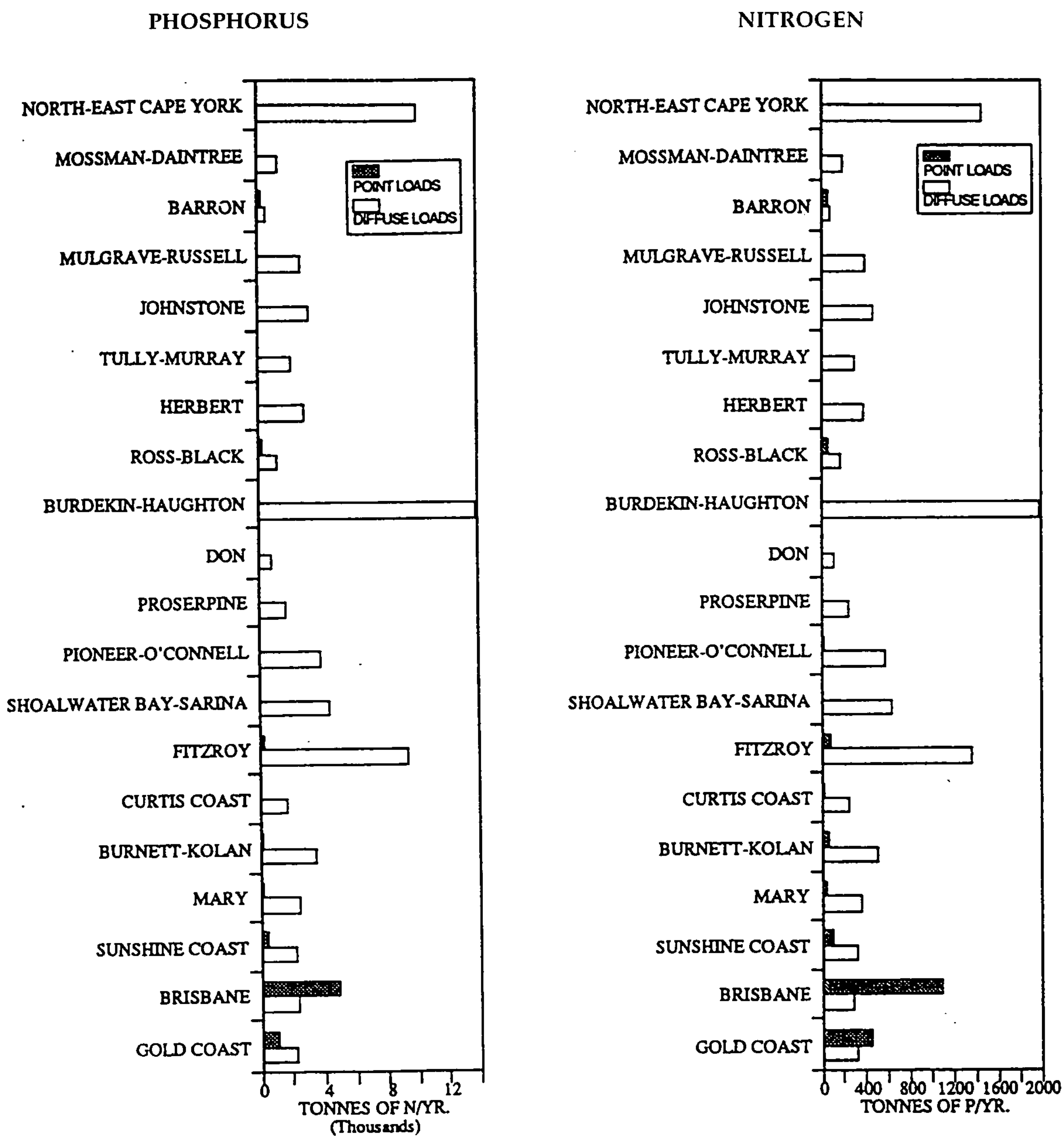

Figure 3: Comparison of magnitude of point and diffuse catchment sources of phosphorus and nitrogen. Adapted from Moss et al. (1992)

'The dominant land use in all catchments is grazing so that the bulk of sediment and nutrient export are derived from grazing lands. However, exports from cropping lands become relatively more significant in the wet tropic catchments. Except in the heavily populated Gold Coast-Beaudesert and Brisbane catchments, point sources of N and P were found to make up only a minor proportion of total catchment exports.'

Population growth

Most of Queensland's population is located in coastal towns and cities. Table 4 lists the major centres of population, 1986 population statistics, and the projected populations in 2006 (Cooper & Skinner 1992). While Queensland's overall population is predicted to grow 1.7% annually till 2021, this growth is likely to be concentrated in the five coastal areas with marked population growth trends shown in Table 4, namely south-east Queensland and the coastal centres of Hervey Bay, Whitsundays, Townsville and the Cairns area. Parts of these areas are likely to experience a 28% to 272% increase in population by 2006.

This predicted increase in population has serious implications for management of impacts on the marine environment adjacent to these areas.

Unless carefully planned and managed, effluent disposal, urbanisation and run-off resulting from servicing this expanding population, plus increased recreational pressures on coastal areas, will cause increased impacts. Additionally, there will be the impetus for substantially increased economic activity to meet the expected shortfall in employment opportunities for a fast growing population base. In south-east Queensland it is predicted that between 540 000 and 620 000 new jobs will be needed by 2011; however only 36% of these are likely to be generated by household expenditure from population growth (RPAG 1993).

Water Quality

Most water quality monitoring has occurred in parts of the Great Barrier Reef (GBR) Region. Some data are also available for Moreton Bay, but little work has been done in the northern waters of the GBR Region and the Gulf of Carpentaria. The Torres Strait Baseline Study, a special project managed by the Great Barrier Reef Marine Park Authority (GBRMPA), is specifically addressing heavy metal pollution to identify any major pollution problems resulting from extensive mining operations in the catchment of the Fly River in Papua New Guinea.

The GBRMPA has organised workshops since the mid 1980s addressing various aspects of water quality in the GBR (Baldwin 1988; Craik 1985; Dutton 1985). Additionally, monitoring and research programs addressing water quality effects, including the analysis of coral growth patterns, have been undertaken by various

Table 4: Projected population growth for Queensland's major coastal cities and towns, based on medium growth assumptions

Coastal Cities and Towns	Local Government Areas		1986 Population	Projected Population in 2006	% Change 1986-2006
Karumba *	Carpentaria S.C.		3 170	3 317	5
Weipa *	Cook S.C.		8 146	9 395	15
Thursday Island*	Torres S.C.		6 952	8 254	19
Port Douglas	Douglas S.C.		6 545	15 724	140
Cairns	Cairns C.C.		39 823	51 026	28
	Mulgrave S.C.		39 907	95 179	139
		Total	79 730	146 205	83
Townsville	Townsville C.C.		82 223	91 019	11
	Thuringowa S.C.		30 544	79 104	159
		Total	112 767	170 123	51
Bowen *	Bowen S.C.		13 967	14 077	1
Airlie Beach	Whitsunday S.C.		9 870	23 564	139
Mackay	Mackay C.C.		22 682	23 838	5
Rockhampton	Rockhampton C.C.		57 384	69 514	21
Gladstone	Gladstone C.C.		23 236	25 557	10
Bundaberg	Bundaberg C.C.		32 368	36 096	12
Hervey Bay	Hervey Bay T.C.		18 829	47 160	151
Maryborough	Maryborough C.C.		22 763	25 816	13
Sunshine Coast	Noosa S.C.		18 770	45 178	141
	Maroochy S.C.		61 047	126 524	107
	Caloundra C.C.		35 937	94 001	162
	Caboolture S.C. (part)		18 760	41 824	123
		Total	134 514	307 527	129
Brisbane (Statistical Division)	Brisbane C.C.		736 656	749 557	2
	Albert S.C. (part)		21 399	58 133	172
	Beaudesert S.C. (part)		4 319	16 082	272
	Caboolture S.C. (part)		29 839	95 205	219
	Ipswich C.C.		74 636	81 808	10
	Logan C.C.		121 337	239 019	97
	Moreton S.C. (part)		27 013	86 430	220
	Pine Rivers S.C. (part)		74 199	128 643	73
	Redcliffe C.C.		46 127	52 260	13
	Redland S.C.		60 521	166 832	176
		Total	1196 046	1 673 969	40
Gold Coast	Albert S.C. (part)		63 976	189 227	196
	Gold Coast C.C.		120 300	161 200	34
		Total	184 276	350 427	90

* The population figures are for the entire Shire Council area. However, the towns/shires noted have a dispersed population with the listed town representing the major population centre in the shire

Key: C.C. = City Council; S.C. = Shire Council; T.C. = Town Council

Source: Cooper and Skinner (1992)

research organisations. While there is still debate as to the extent of the problem (see Search 22 (4) pp. 115-121), there is general agreement that the major water quality problems for the GBR derive from excessive sediment and nutrient discharges into the near shore waters. These discharges are raising the levels of nutrients, and hence phytoplankton growth in the inner and mid lagoon waters, particularly in specific coastal locations such as the Cairns and Whitsunday regions. Elevated nutrient levels are considered a major factor in a worldwide trend of a general decline in coral reefs (Dr J. Veron, quoted in The Weekend Australian, June 12-13, 1993).

There appears to be insufficient evidence to establish a direct causative link between land use patterns in the coastal catchments and the changed water quality conditions in parts of the GBR. However, studies such as Moss et al. (1992b) supply strong evidence for the need for improved land management practices. The January, 1992 massive mortality of seagrasses in Hervey Bay (almost 1000 km^2 of seagrass meadow lost) has been linked to an extreme flooding event in two coastal rivers, the Mary and Burrum Rivers (Preen 1993), and provides further circumstantial evidence for water quality effects. Both rivers are impounded and their catchments are extensively used for agriculture.

Dutton (1985) notes that, 'Measured levels of most contaminants [namely heavy metals, polychlorinated biphenyls (PCBs) and other organochlorines and hydrocarbons] within the reef waters proper are generally close to the lower limits of detection, although in some adjacent coastal waters (particularly harbours), concentrations indicative of low to moderate pollution levels equivalent to those found elsewhere in Australia and overseas, have been recorded.' The potential for acute pollution events caused through spills of hazardous chemicals from shipping accidents or onshore facilities cannot be ignored.

For areas outside of the Reef Region, reasonable water quality data is only available for Moreton Bay in south-east Queensland. Moss et al. (1992a) have provided an overview of existing data. Again, nutrient and sediment loadings are cited as the major cause for concern, while toxicants such as metals, pesticides, PCBs and petroleum are at relatively low levels, although the data for these toxicants was collected in the late 1970s.

Certain areas on the western side of Moreton Bay show signs of nutrient pollution, in particular elevated levels of P. These areas are generally associated with major sewage treatment plant discharges, in particular the mouth of the Brisbane River and Bramble Bay. This pattern is likely to occur in other coastal estuaries where there is a combination of sewage treatment plant discharges and periods of low flushing. Because sediments act as a P reservoir which can be utilised by algae over long periods, the control of P from diffuse and point sources is of particular concern.

Table 5 summarises the volume and level of treatment of 137 sewage treatment plants discharging into Queensland coastal waters. The areas where most treatment plants are located and which have the highest discharge volumes correlate with the major sources of point source discharges of P and N identified in Figure 3, namely the major coastal centres of south-east Queensland, Hervey Bay, Fiztroy River, Townsville and Cairns. Other areas could experience pollution events given a combination of plant overload or malfunction and low river flows or limited tidal flushing.

Coastal Development

The Moreton Bay area has lost up to a 20% of its mangrove forests since European settlement, and 10.5% of salt marshes between 1974 and 1987 (Hyland & Butler 1989). This pattern of land reclamation of these biologically important intertidal areas to support urban, industrial, tourism, airport and port expansion is reflected elsewhere along the Queensland coast, particularly in the high growth areas of the Gold and Sunshine Coasts, Hervey Bay, Gladstone, the Whitsundays, Townsville and Cairns. In central and northern Queensland the land is generally filled, while in southern Queensland canal estate housing developments have proved popular for coastal urban areas.

An associated problem of dredging for canals and marinas has been the exposure of acid sulphate soils. This problem has been identified only recently, although anecdotal evidence suggests that acid sulphate soil events have occurred in a number of sites in south-east Queensland following excavation for canals. The Tweed River estuarine system on the New South Wales - Queensland border provides probably the best documented case of the long-term impacts of this problem.

Intertidal lands have also been reclaimed for agricultural purposes such as grazing and sugar cane production. More recently large tracts in

Table 5: Sewage discharges into Queensland rivers and coasts by catchment area

River Name	Total No. of Plants	Total Volume Discharged (m^3/day)	Level of treatment (volume discharged in m^3/day)	Approximate Discharges onto Land % of total	m^3/day
SOUTHERN COAST					
1. Gold Coast					
Logan R.	4	52 490	3 Secondary (51 700)	0	0
			1 Abattoir (790)	0	0
Albert R.	1	10 700	1 Secondary (10 700)	<100*	<10 700*
Nerang R.	1	19 500	1 Secondary (19 500)	0	0
Minor Rivers and Coastal Discharge	2	134 000	2 Secondary (134 000)	<65*	<84 000*
2. Brisbane area					
Brisbane R.	20	374 245	1 Tertiary (800)	0	0
			17 Secondary (366 595)	0	0
			2 Abattoirs (6 850)	0	0
Bremer R.	3	23 900	2 Secondary (21 800)	0	0
			1 Abattoir (2 100)	0	0
Stanley R.	1	400	1 Tertiary (400)	0	0
Lockyer Ck.	3	2 487	3 Secondary (2 487)	<25*	<650*
Minor Rivers and Coastal Discharge	9	59 200	8 Secondary (57 000)	<30*	<16 100*
			1 Waste Water (2 200)	0	0
3. Sunshine Coast					
Pine R.	3	37 390	1 Tertiary (8 500)	<100*	<8 500*
			2 Secondary (28 890)	0	0
Maroochy R.	5	23 750	1 Tertiary (16 000)	<100*	<16 000*
			4 Secondary (7 750)	0	0
Noosa R.	1	7 400	1 Tertiary (7 400)	<100*	<7 400*
Minor Rivers and Coastal Discharge	13	65 570	1 Tertiary (21 600)	<100*	<21 600*
			11 Secondary (39 570)	<20*	<7 070*
			1 Secondary into ground water (Bribie I.) (4 400)	0	0
4. Mary R. area					
Mary R.	4	17 950	3 Secondary (17 950)	<30*	<5 250*
Minor Rivers and Coastal Discharge	2	8 250	2 Secondary (8 250)	<100*	<8 250*
5. Burnett-Kolan area					
Burrum R.	1	600	1 Secondary (600)	0	0
Burnett R.	11	25 274	11 Secondary (25 274)	<10*	<2 200*
Kolan R.	1	600	1 Secondary (600)	0	0
Minor Rivers and Coastal Discharge	1	1 800	1 Secondary (1 800)	0	0
6. Curtis Coast					
Calliope R.	1	9 000	1 Secondary (9 000)	0	0
Minor Rivers and Coastal Discharge	2	3 000	2 Secondary (3 000)	0	0
CENTRAL COAST					
1. Fitzroy					
Fitzroy R.	6	37 340	4 Secondary (32 540)	0	0
			2 Abattoirs (4 800)	<15*	<800*
Comet R.	1	200	1 Secondary (200)	0	0
Dawson R.	3	1 800	3 Secondary (1 800)	<65*	<1 200*
Nogoa R.	1	6 500	1 Secondary (6 500)	<100*	<6 500*
Minor Rivers and Coastal Discharge	2	820	2 Secondary (820)	<40*	<320*
2. Shoalwater Bay -Sarina					
Plane Ck.	1	1 600	1 Secondary (1 600)	0	0
Minor Rivers and Coastal Discharge	1	1 350	1 Abattoir (1 350)	0	0
3. Pioneer O'Connell					
Pioneer R.	1	19 000	1 Secondary (19 000)	0	0
Minor Rivers and Coastal Discharge	1	2 100	1 Secondary (2 100)	<100*	<2 100*
4. Proserpine					
Proserpine R.	1	1 700	1 Secondary (1 700)	0	0
Minor Rivers and Coastal Discharge	6	4 510	5 Secondary (4 510)	30	1 462
5. Don					
Minor Rivers and Coastal Discharge	1	1 800	1 Secondary (1 800)	20	360
6. Burdekin-Haughton					
Burdekin R.	1	4 500	1 Secondary (4 500)	95	4 275
Minor Rivers and Coastal Discharge	1	2 900	1 Secondary (2 900)	0	0
7. Ross-Black					
Black R.	1	345	1 Secondary (345)	100	345
Minor Rivers and Coastal Discharge	5	41 200	5 Secondary (41 200)	50	19 850

* Treatment plants in these areas are known to dispose of some discharge onto land, but the amount is unknown

Source: Qld Dept. of Environment & Heritage sewage treatment plant licences, May 1993

Table 5 cont. over

Table 5 cont.

River Name	Total No. of Plants	Total Volume Discharged (m^3/day)	Level of treatment (volume discharged in m^3/day)	Approximate Discharges onto Land % of total	m³/day
NORTHERN COAST					
1. Herbert					
Herbert R.	2	5 280	2 Secondary (5 280)	<100*	<5 280*
Minor Rivers and Coastal Discharge	1	250	1 Secondary (250)	100	250
2. Tully-Murray					
Tully R.	1	1 600	1 Secondary (1 600)	0	0
3. Johnstone					
Johnstone R.	1	6 600	1 Secondary (6 600)	0	0
4. Mulgrave-Russell					
Mulgrave R.	1	1 430	1 Secondary (1 430)	0	0
Minor Rivers and Coastal Discharge	2	3 900	2 Secondary (3 900)	55	2 200
5. Barron					
Barron R.	2	18 200	2 Secondary (18 200)	0	0
Minor Rivers and Coastal Discharge	2	19 150	2 Secondary (19 150)	0	0
6. Mossman-Daintree					
Mossman R.	1	1 150	1 Secondary (1 150)	0	0
Minor Rivers and Coastal Discharge	2	13 000	2 Secondary (13 000)	100	12 870
7. North-East Cape York					
Endeavour R.	1	400	1 Secondary (400)	0	0

* Treatment plants in these areas are known to dispose of some discharge onto land, but the amount is unknown
Source: Qld Dept. of Environment & Heritage sewage treatment plant licences, May 1993

central Queensland have been utilised for ponded pastures. This practice involves building earth embankments to trap freshwater run-off and in some areas prevent tidal inundation. There are a number of major environmental problems associated with this practice. These include significant alterations to freshwater flows into tidal wetland areas, loss of tidal marsh habitat, and introduction of invasive exotic grasses and other weeds.

Ports

A substantial proportion of Queensland's economy is based on agricultural products and the mining of coal and mineral resources, much of which is exported. Table 6 contains details of Queensland's major ports, the number and maximum size of vessels visiting in 1991/92, and the total cargo handled as well as the major commodity. Queensland has six 'trading' ports, namely Weipa, Cape Flattery, Mourilyan, Abbott Point and Hay Point/Dalrymple, which essentially deal in the export of primary products. The other major ports including Brisbane, Gladstone, Townsville and Cairns handle both imports and exports and service regional population centres. These latter ports generally have major industries sited within relatively close proximity; for example, Brisbane has oil refineries and a major fertiliser manufacturing plant, Gladstone an aluminium smelter, and Townsville the Yabulu nickel refinery.

The siting of new ports and the operation and future expansion of existing ports can directly affect the quality of coastal waters. Handling of hazardous cargoes and bunkering fuel are the main operational areas where pollution incidents can occur. Recently the Queensland Department of Transport released a draft Environment Policy for Queensland Ports (Qld Transport 1993) as a commitment to ensure responsible environmental management by port authorities. Implementation of this policy should assist in reducing the risk to the marine environment of port operations.

Maintenance of ports can require the regular dredging of shipping channels and swing basins. Table 7 summarises the amount of material dredged from Queensland ports in the past decade and either dumped offshore or pumped ashore. The dredge spoil can be used either for reclamation purposes onshore, or is dumped at specified offshore dumping sites. Either practice can cause acute environmental damage through site run-off and sediment plumes, if the sites are not carefully located and the operation well managed. Table 7 shows that several ports including Brisbane, Townsville, Cairns and Weipa require regular dredging operations. Qld Transport (1993, p.7) notes that, 'most of the sediment so removed originates either directly or indirectly from the catchment. Good management principles by other authorities may minimise the process of erosion and silt transport during periods of run-off, controlling the introduction of sediments and contaminants into waterways.'

Shipping Traffic

Table 6 shows that 4 509 cargo ships visited Queensland ports during 1991/92. Additionally, in 1992 there are over 2000 commercial fishing

Table 6: Major trading ports in Queensland - 1991/92 cargo and shipping figures

Port	Total Cargo Handled (tonnes x 1000)			Major Commodity Handled	Total Number of Vessels	Longest L.O.A. (m)	Deepest Draft (m)	Largest GWT/ Largest DWT (x 1000t)
	Imports	Exports	Total					
Karumba					21	59	4.10	0.7/0.8
Weipa1	73	8637	8710	Bauxite	295	255	12.67	178.8/76.3
Thursday Island	32	3	35		193	105	4.70	4.3/3
Cape Flattery1	-	1574	1574	Silica sand	40	226	13.56	36.6/69.6
Cairns *	717	510	1227	Petroleum products (45% of total)	463	262	9.64	48.6/45
Mourilyan1	-	344	344	Sugar	25	184	9.79	21.8/42
Lucinda1	-	351	351	Sugar	16	223	11.85	23.3/35.9
Townsville *	3091	1834	4925	Nickel ore (47% of total)	376	262.08	12.49	51.2/69.1
Abbott Point1 (Bowen)	-	5926	5926	Coal	81	304	17.37	83.7/161.8
Mackay *	460	906	1366	Sugar (41% of total)	121	196.45	10.90	26.2/43.7
Hay Point/Dalrymple Bay1	-	40513	40513	Coal	516	315	17.58	118.5/231.9
Rockhampton * (Port Alma)	103	163	266	Salt (52% of total)	68	182	10.49	26.2/36.7
Gladstone * (Port Curtis)	8498	23276	31774	Coal (62% of total)	676	315	17.63	118.5/278.8
Bundaberg *	163	351	514	Sugar (68% of total)	38	189.9	9.62	26.2/42
Brisbane *	8023	8648	16671	Petroleum products (44% of total)	1580	276	13.24	68.8/127.8

Key: * Ports administered by specific Port Authorities; all other ports are administered by the Harbours Corporation.
1 Trading ports; essentially only handling exports.
L.O.A. - Length Overall; G.R.T. - Gross Registered Tonnage; D.W.T - Dead Weight Tonnage
Source: Various Port Authorities' 1991/92 Annual Reports plus Qld. Dept. of Transport 1991/92 Annual Report.

Table 7: Summary of dredged material placement in Queensland ports 1981 to 1993+

Placement Site	**81/82**	**82/83**	**83/84**	**84/85**	**85/86**	**86/87**	**87/88**	**88/89**	**89/90**	**90/91**	**91/92**	**92/93**
Weipa:												
- Hay Point									25	-	99	33
- Jackson Channel										74	179	80
- Albatross Bay	982	108	-	1142	-	924	19	562	20	324	590	394
Weipa Total	982	108	-	1142	-	924	19	562	45	398	868	507
Thursday Island (dumped at Weipa)	-	-	-	-	-	3	-	-	-	-	-	-
Cairns:												
- Inner dump (1)	-	296	208	545	-	427	194	392				
- Outer dump									* 321	* 923	687	197
Townsville:												
- Dumped (2)	-	-	109	346	-	282	355	262	-	232	184	176
- Pumped	-	-	-	-	-	-	-	-	-	430	112	-
Townsville Total	-	-	109	346	-	282	355	262	-	662	296	176
Abbot Pt. dump	* 851					4						
Mackay dump (3)	-	-	-	-	-	-	77	-	-	-	-	-
Hay Pt. dump	-	-	-	-	-	-	14	-	-	-	-	-
Port Alma	-	-	-	26	8	-	-	-	-	-	10	-
Gladstone:												
- Dumped (4)	-	-	-	-	-	10	* 1570	12	-	-	-	-
- Pumped ashore	-	-	-	-	-	-	-	-	-	-	-	35
Bundaberg:												
- S. dump (3)	94	192	208	286	165	108	59					
- N. dump								88	92			
- Pumped ashore										158	132	
Brisbane:												
- Mud Island (5)	1553	1310	2524	850	2721	605	893	1038	470	305	482	-
- Fisherman Islands (6)	384	1117	20	367	902	636	15	1	1302	591	412	-
- Moreton Bay dump	-	121	89	439	1557	1536	2556	1354	179	235	190	-
- Woorim (7)	-	-	-	-	-	-	96	236	120	83	-	-
- Fisherman Is. river sand(8)	276	229	226	162	-	-	137	232	273	265	56	-
- Whyte I. river sand (8)	-	-	-	97	203	295	61	-	-	-	-	-
- Caloundra (7)	-	-	-	-	-	-	-	94	-	-	-	-
- Bilinga (7)	-	-	-	-	-	-	-	85	-	-	-	-

+ Measured by dry tonnage of material; * Majority development work; (1) Small quantity of contracted and Local Authority grab dredging; (2) Small quantity placed at inner dump area by Local Authority grab dredger; (3) Small quantities placed by Local Authority's grab dredging operations; (4) Approx. 5 400 000 cu m. (8.0 m tonnes) of material placed in dump area during 1986/87 from development dredging by contractor; (5) From Brisbane River dredging including minor development work; (6) Includes sand from Moreton Bay channels and mud from Brisbane River from 1989 onwards; (7) Beach replenishment; (8) Development dredging by cutter suction dredger

Source: Port of Brisbane Authority (POBA) Annual Reports and POBA pers. comm. April 1993.

boats, some 600 Class I charter vessels primarily servicing GBR tourism, and 107 827 private pleasure vessels registered in Queensland in 1992, as well as private vessels visiting from interstate and overseas. Impacts on the marine environment from this volume of shipping traffic include:

- the risk of grounding or major accident by a supertanker or large ship carrying hazardous cargo;
- ballast water introductions;
- chronic 'small' fuel and oil spills at ports or under way;
- sewage and garbage disposal at sea;
- to the development of coastal environments for the provision of marina and port facilities and associated industrial developments.

Of particular concern is any adverse impact on the GBR. The Reef's Inner Route shipping lane, the Great North East Channel through Torres Straits, and the various designated passages through the Reef are considered high risk areas for shipping. About 2000 large ships transit the Inner Route of the GBR annually, approximately 100 of which are tankers (Raaymakers 1993). Table 8 shows the number of piloted ships through the Great North East Channel and the GBR Inner Route from June 1992 to February 1993.

In November 1990, the International Maritime Organisation (IMO) declared the GBR Region a 'Particularly Sensitive Area'. This resulted in the Australian Government proceeding with introduction of compulsory pilotage in October 1991. Consequently, all ships 70 metres in length and over and all loaded tankers, chemical carriers and liquefied gas carriers, irrespective of size, are required to carry pilots when navigating the northern part of the Reef (north of Cairns) and Hydrographers Passage (off Mackay).

Raaymakers (1993) notes that, 'Pilotage is not compulsory for the rest of the Great Barrier Reef, the Torres Strait and Great North East Channel. However ships transiting the inner route normally pick up their pilots at the western entrance to Torres Strait so most ships transiting Torres Strait and the Great North East Channel are piloted. The introduction of compulsory pilotage has substantially decreased the risk of ship groundings in the Great Barrier Reef. However it does not eliminate the risk and it does not address spills from collisions, structural failure and operational discharges.'

Australia has adopted three international conventions, formulated by the International Maritime Organisation (IMO), which deal specifically with marine pollution matters and has legislation giving effect to these conventions. Queensland is presently drafting new marine pollution legislation which will give effect to MARPOL 73/78 Annexes I (oil), II (noxious liquid substances), III (harmful substances carried in packaged forms) and V (garbage); unfortunately Annex IV, dealing with sewage, is not yet in force internationally. This should provide an adequate legislative base to limit the impacts from shipping traffic, provided sufficient resources are made available to the responsible agencies to implement the legislation, and provide adequate navigational aids and enforcement, inspection and monitoring staff.

Accidents and Spills

Data from the GBR gives some estimate of the frequency and type of shipping accidents and spills in Queensland waters.

Raaymakers (1993) states, 'there have been numerous large-ship incidents with significant pollution potential, including 19 collisions and 24 groundings, since 1979. In addition oil pollution from operational discharges from large ships is a common occurrence, with over 30 reports in the REEFPLAN Area since 1990, the largest being estimated at around 10 tonnes. There have also been a number of spills from bunkering and other operations in ports. Discharges from and accidents with small vessels are also a source of oil pollution, with about 350 collisions, sinkings, fires and other incidents having occurred in the Reef Region since 1980.' Further on he notes, 'Studies of the distribution of hydrocarbon-associated bacteria in Great Barrier Reef waters show higher concentrations of these bacteria in areas of greatest shipping activity, presumably indicating that background levels of hydrocarbons are already elevated in these areas (Reichelt, pers. comm. 1991).'

Operational discharges from ships can be reduced by the provision of adequate waste oil reception facilities in ports. According to Raaymakers (1993), the ports of Cairns, Townsville and Gladstone have such facilities, whereas Cape Flattery, Lucinda, Abbott Point and Hay Point ports do not.

Ballast Water

Elsewhere within SOMER there is a discussion of the introduction and impacts of exotic species into the marine environment with specific attention given to introductions by way of ballast water. Experience in southern Australia has shown that a combination of frequent visits of vessels from international ports as well as movement between ports within Australia increases the potential for introduction of exotics from ballast water or associated sediments (Jones 1991).

Table 9 documents international visits to Queensland ports, interstate domestic shipping movements as well as the estimated volume of ballast water likely to be discharged. Queensland ports receive 27% of international visits (i.e. 1284 of a total of 4779 visits) and 25% of domestic movements (i.e. 677 of a total of 2681 visits) (Kerr 1994). Table 9 indicates that the ports experiencing most international traffic are Hay Point, Brisbane and Gladstone (75% of total movements); while Brisbane, Gladstone and Weipa have the most domestic traffic (70% of total movements). Each of these ports also handle a significant dead weight tonnage of cargo.

Kerr (1994) has shown that in 1991 over 85% of Australia's ballast water 'imports' come from the Asian region, with the majority originating in Japan (54% of total ballast water). He notes that 'The number of vessel visits is a better risk indicator than tonnage of ballast water carried, although both are important.' This means that an increase in the volume of ballast water does not necessarily translate into an increased risk; however, an increase in the number of ship visits usually results in a greater likelihood of introductions.

This recent assessment of the risk of ballast water introductions indicates that the Queensland ports most likely to experience problems with ballast water introductions are Brisbane, Hay Point, Gladstone and Weipa.

Tourism

Just as most Queenslanders live in coastal centres, most of the State's tourism is based in coastal areas, many of which provide access to important marine and estuarine habitats including the GBR, and Hervey and Moreton Bays. Table 10 indicates where most tourists in Queensland spend their time, and the percentage change in tourism activity between 1991/92 and 1992/93. Not unexpectedly the focus of tourism activity is in the coastal centres already identified as areas of high population growth, in particular the Gold and Sunshine Coasts.

In its 1993 Annual Report, the Queensland Tourist and Travel Corporation (QTTC) notes that 1.237 million international visitors came to Queensland in 1992, this representing an increase of 16.3% over 1991. The Corporation considers that these figures indicate that the targets set in its Vision 2000 Plan released in March 1992 are still achievable; namely 4.7 million interstate and 5 million international visitors by the year 2000. The QTTC estimates that this will contribute directly $12 billion annually to the Queensland economy and create 320 000 jobs. To accommodate these targets, the QTTC estimates that hotel/motel rooms and units and flats will need to double, and hostel and budget accommodation to treble (QTTC 1992).

While there are 18 islands with tourist resorts on the GBR, the majority of tourists access marine areas from mainland centres using either commercial day trip boats or overnight charters. Consequently, many of the impacts associated with tourism are the same as those noted earlier for an expanding urban population. However, because of the attractiveness of high quality natural coastal sites to tourists, some developers have established resorts in undeveloped coastal areas that often are environmentally sensitive and of high conservation value. In Queensland this trend has been exacerbated by specific legislation which actively promotes integrated resorts such as Woodwark Bay in the Whitsundays and Corio Bay in central Queensland. Additionally, successive Queensland governments have funded the QTTC to market and develop tourism, and yet have not established a mechanism to develop environmentally sensitive strategic plans for the industry.

There are specific issues associated with managing the high volume, large group, day trip tourism industry which operates mainly in the Cairns and Whitsunday regions. These include location of mainland departure terminals, access to high quality destination sites, habitat interference and damage at destination sites, location of permanent facilities (e.g. pontoons) in remote areas, localised sewage pollution, interference with important fauna sites, and reduced access opportunities and amenity and aesthetic values for local users. For a more detailed discussion of the impacts of offshore tourism activities see the Draft Offshore Cairns Strategy (GBRMPA & QDEH 1991).

Fishing

Queensland's marine and estuarine waters support extensive commercial and recreational fisheries. Table 11 lists the annual average commercial fin fish and crustacean catch for 1988-1991 and includes an assessment of the status of these fisheries and the adequacy or otherwise of

Table 8: Ships piloted through the Great North East Channel and the Great Barrier Reef Inner Route, June 1992-February 1993

Month and Year	Great North East Channel General /Misc.	Bulk Carrier	Oil Tanker	Chemical Tanker (Hazardous Cargoes)	LPG Carrier	TOTAL	GBR Inner Route Oil Tanker	Chemical Tanker (Hazardous Cargoes)	LPG Carrier	TOTAL
June '92	6	4	7	-	-	17	6	3	2	11
July	13	4	5	-	-	22	6	3	7	17
August	4	5	10	1	-	20	7	3	3	13
Sept.	8	1	15	-	-	24	17	-	-	17
October	4	10	18	-	-	32	20	-	-	20
Nov.	6	4	14	2	-	26	3	3	3	9
Dec.	6	6	12	1	-	25	1	3	3	7
Jan. '93	1	6	4	-	-	11	4	3	-	7
Feb.	1	6	10	1	1	19	7	5	3	15
TOTALS	49	46	95	5	1	196	71	23	21	115

Note: An oil tanker was also taken through Grafton Passage in August and September 1992 and January 1993 (3 in total).
Source: Supplied by the Australian Maritime Safety Authority, April 1993

Table 9: Estimated ballast water receipts in Queensland ports from international and domestic shipping movements January to December 1991.

Port	International Visits D.W.T. (tonnes)	Visits	% of Visits	Est. Ballast Water * (tonnes)	Domestic Ship Movements D.W.T. (tonnes)	Visits	% of Visits	Est.Ballast Water * (tonnes)
Weipa	4 703 605	86	6.70	1 834 876	5 142 970	71	10.49	2 005 758
Cape Flattery	1 062 378	26	2.02	414 434			0.00	
Cairns	250 582	16	1.25	97 752	1 232 994	37	5.47	480 868
Mourilyan	192 160	9	0.70	74 962	83 970	2	0.30	32 748
Lucinda	260 251	9	0.70	101 524			0.00	
Townsville	2 252 566	74	5.76	878 726	1 993 209	54	7.98	777 352
Abbott Point	5 091 996	60	4.67	1 986 388			0.00	
Mackay	733 119	30	2.34	285 990	1 325 063	44	6.50	516 775
Hay Point/Dalrymple Bay	37 347 426	405	31.54	14 569 231	922 454	20	2.95	359 757
Rockhampton (Port Alma)	27 188	4	0.31	10 606	237 918	16	2.36	92 788
Gladstone	20 464 745	267	20.79	7 983 297	7 196 745	145	21.42	2 806 731
Bundaberg	20 118	1	0.08	7 848	687 229	28	4.14	268 019
Brisbane	11 237 281	297	23.13	4 383 663	8 189 201	260	38.40	3 193 788
TOTAL	83 643 415	1 284	99.99	32 629 297	27 011 753	677	100.01	10 534 584

* The average ballast tank capacity of bulk carriers is 39.01% of the dead weight tonnage (D.W.T.) of the vessel; ore carriers have an average ballast tank capacity of 34.31% of D.W.T.; oil tankers have 34.56% D.W.T.; while chemical tankers have 34.05% D.W.T.
Source: Kerr (in press)

knowledge for management purposes. Unfortunately, there is a lack of data for recreational catches for most fisheries. However, some data provide an insight to the relative catches for some fisheries. Quinn (1992) estimates that in Queensland approximately one third of angling effort occurs in the Moreton Region with some 300 000 recreational anglers catching approximately 2000 tonnes of fin fish; this compares with a commercial catch of 1600 tonnes. The Queensland Commercial Fishermen's Organisation (QCFO 1993) notes that if the commercial mullet catch is excluded, as these are not taken by recreational fishers, then the commercial catch becomes approximately 700 tonnes, substantially less than the recreational catch. The QCFO cites similar experiences elsewhere in Queensland and Australia (QCFO 1993, pp. 17-19) including one estimate that anglers take 70% of the GBR fish catch (Craik 1989).

The impacts of this intensity of fishing are similar to those found elsewhere in Australia and discussed in some detail in the Ecologically Sustainable Development Working Groups Final Report on Fisheries (ESD Working Groups 1991, pp. 78-82). This report states, 'Fishing activities can affect the environment in a number of ways: on the physical structure of the habitat, on water quality, on by-catch and wildlife species and on genetic diversity. Effects can be direct, as in the effects of trawling on the substrate, or indirect, as in eutrophication resulting from aquaculture operations.' The intensity of the combined commercial and recreational fishing effort in the Moreton Region combined with the high population growth in the region makes this area particularly vulnerable to the impacts of fishing, in particular overfishing.

While a variety of impacts result from fishing activities, the fisheries themselves rely on the maintenance of healthy ecosystems and good water quality. Consequently, Queensland's fisheries are vulnerable to the many impacts referred to in previous sections such as urban and agricultural run-off, reclamation of tidal wetlands, inadequate catchment controls and pollution discharges.

Recent research initiatives in the GBR to determine the impacts of trawling are of critical importance, as is the need to continue research and data acquisition into the rates of growth and mortality, stock structure and biomass for the various fishery species. The extent of the recreational fishing effort must be determined with necessary management initiatives implemented. In addition, the siting of future

Table 10: Visitor nights in commercial accommodation by origin of visitors

Destination Regions	Visitor Nights 1992/93 (x 1000) (Percentage Change over 1991/92)			
	Intrastate	**Interstate**	**International**	**Total**
Gold Coast	2 004 (9)	6 755 (4)	2 111 (11)	10 870 (6)
Brisbane	1 241 (-6)	1 461 (12)	900 (-4)	3 602 (1)
Sunshine Coast	2 845 (-10)	2 616 (43)	397 (7)	5 857 (10)
Moreton Balance *	388 (-20)	214 (-23)	28 (-42)	629 (-22)
Wide Bay Burnett	1 466 (-2)	842 (-7)	177 (-30)	2 485 (-6)
Fitzroy	954 (-7)	553 (7)	178 (-19)	1 684 (-5)
Mackay (inc. Whitsundays)	996 (-2)	934 (13)	423 (-9)	2 354 (2)
Northern (Townsville)	879 (0)	582 (3)	370 (-8)	1 831 (-1)
Far North (Cairns)	1 042 (11)	2 171 (-9)	2 594 (-1)	5 807 (-2)
Western Queensland *	377 (-19)	304 (-18)	59 (15)	740 (-16)
Darling Downs *	457 (27)	304 (-5)	18 (-5)	779 (11)
Great Barrier Reef	229 (-20)	516 (1)	303 (7)	1 048 (-3)
Total Queensland	12 648 (-3)	16 736 (6)	7 255 0	36 639 (2)

* These districts cover mainly inland areas.
Source: QTTC 1993.

Table 11: Average annual commercial catch in Queensland of finfish/crustaceans (1988-91)[1] and status of the fishery[2]

Species	State Total (tonnes)	Status of the Fishery: Over-fished	Fully Fished	Under-fished	Uncertain	Status of Knowledge for: Management	ESD
Crabs							
Mud crab	379		X			adequate	incomplete
Sand crab	452		X			adequate	incomplete
Spanner crab	533		X			adequate	incomplete
Other crab	16						
Prawns							
Banana prawns	731		X			adequate	incomplete
Tiger prawns	1861		X			adequate	incomplete
Endeavour prawns	1303		X			adequate	incomplete
Bay prawns	400		X			adequate	incomplete
King prawns	2395						
- Eastern (SE Qld.)		X				adequate	incomplete
- Ocean			X			adequate	incomplete
- Redspot			X			adequate	incomplete
- Eastern			X			adequate	incomplete
- Western			X			adequate	incomplete
Other prawns	583						
- Redspot (SE Qld)		X				adequate	incomplete
- Greasy			X			adequate	incomplete
- Leader			X			adequate	incomplete
- School			X			adequate	incomplete
Total prawns	7273						
Estuarine Fish							
Mullet	2153		X			adequate	inadequate
Yellowfin Bream	220						
Summer Whiting	356						
Winter Whiting	403						
Tailor	198		X			adequate	inadequate
Flathead	88		X			adequate	inadequate
Gar	92						
Black Bream	50						
Barramundi	795		X			adequate	incomplete
Total estuarine	5 983						
Reef Fish							
Snapper	90				X	incomplete	inadequate
Coral trout	1310						
- Inshore reef		X				incomplete	incomplete
- Offshore reef			X			incomplete	inadequate
Red Throat Emperor	630		X			incomplete	inadequate
Others	550						
Total reef fish	2580						
Pelagic Fish							
Mackerel	998						
- Spanish			X			incomplete	inadequate
- Grey					X	adequate	inadequate
Dart	37						
Total pelagic	1236						
Lobster	466						
Scallop	161900 (baskets)				X	adequate	incomplete
Squid	193						

Sources
1 - Table 8.1 in QCFO (1993)
2 - Table B.1 in ESD Working Groups (1991). The table is based on information given by Commonwealth and State Government agencies which has been assessed as 'good', 'adequate', 'incomplete' or 'inadequate'.

marina developments and other shore-based facilities must be better planned so that they are not located in environmentally sensitive areas, as has occurred in the past.

The potential impacts of a growing aquaculture industry cannot be overlooked. There are a number of land-based and offshore projects established along the Queensland coast with many more proposed. While this industry is advocated as a means of reducing the fishing effort on wild stocks, it can result in a range of impacts including reclamation/modification of coastal wetland sites for aquaculture ponds, effluent discharges from ponds, potential introduction of diseases and translocation of species, and use of wild stock to manufacture fish food.

Industrial development and mining

Queensland has a number of major industries sited along the coast. Generally, these either service large population centres (e.g. Brisbane's oil refineries), or they process or handle one of the State's agricultural or mineral products (e.g. the alumina refinery plants at Gladstone, coal loading facilities at Mackay, and nickel treatment plant and sugar mills in the Townsville region). Operations of these industries are controlled by a variety of Queensland legislation, and their environmental performance is overseen by the Queensland Department of Environment and Heritage. In a summary of future major development projects and proposals for Queensland, DBIRD (1992) refer to some 12 major development projects which are committed to, and a further 16 under study; these generally represent investments in excess of $10 million and all are to be located on the coast.

While Queensland's industries operate generally within the guidelines established by government, over the years there have been various serious pollution incidents. Prior to the introduction of the *Clean Waters Act and Regulations* in 1975 and other environmental control legislation during the 1970s, most industry operated with little regard to controlling environmentally harmful waste discharges. This was evidenced by various organic and chemical industrial discharges into the Brisbane River and other coastal streams, such as the 60-year history of high volume organic waste discharges from the Sarina (Australian National) Power Alcohol plant into tidal creeks discharging into Llewellyn Bay; and various mine and tailing site discharges into water bodies in major catchments.

Recent evidence submitted at the Criminal Justice Commission's Inquiry into the Improper Disposal of Liquid Waste indicates that while the situation has improved, there are still a number of major problems. Most importantly Queensland has no legislation that adequately controls the disposal of toxic waste. This has led to some operators dumping untreated, toxic liquid waste into streams and tidal wetlands. The lack of strong legislation and insufficient resources in both the Queensland Department of Environment and Heritage (QDEH) and local government has meant that this problem is only now being identified. Compounding this problem, the QDEH has been unable to carry out adequate monitoring of receiving waters. Consequently, the extent of contamination is still to be determined.

Probably some of the most contentious development proposals in Queensland have been those associated with the mining and petroleum industry. Various mining leases and exploration permits cover parts of Queensland's marine and estuarine estate. These include heavy mineral sand reserves, oil shale deposits, petroleum exploration permits, sand and gravel extraction, and limestone extraction. The focus for much of this activity include parts of the east and west coasts of Cape York, central Queensland and Moreton Bay. Conflicts arise when reserves coincide with areas of high conservation value such as the proposals to sand mine in the Shelburne and Shoalwater Bay areas, extract oil shale in the coastal wetlands of the Curtis coast and Repulse Bay, explore for petroleum in areas adjacent to the GBR, and mine subfossil coral from Moreton Bay's limited areas of reef flat.

Aboriginal and Torres Strait Islander use

The previous sections have discussed the variety of impacts on the marine environment resulting from European settlement of Queensland. Aboriginal and Torres Strait Islander communities have established within their cultures a range of rights and duties to marine areas adjacent to their coastal lands. The Torres Strait Islanders in particular are a seafaring people, many with wide-ranging sea territories.

For both Aboriginals and Torres Strait Islanders there are strong traditions of harvesting marine resources, hunting dugong and turtles, and collecting bird eggs; many communities in northern Queensland and the Torres Strait are heavily reliant on the sea as a major source of protein. The issues for these communities include ensuring that shore-based pollution such as sewage does not impact on marine areas; that economic enterprises such as commercial fisheries and ecotourism are sustainable; that modern hunting techniques and intensity do not cause local extermination of particular wildlife species such as dugong, turtle and seabirds; and that they are meaningfully involved in consultation and comanagement arrangements for parks, reserves and zoning plans. The reports by Mulrennan et al. (1993) and Smyth (1993) examine the issues and concerns of coastal Aboriginal and Torres Strait Islander communities.

Disturbed areas, trends and future problems

This paper has not attempted to present a list, either definitive or indicative, of chronically or

Table 12: Future problems

- Increased demand for access to reefs and islands.
- Areas that are presently remote will soon be accessible due to advances in water transport technology.
- Increased population and development in coastal areas of high conservation value.
- Shipping in the Great Barrier Reef - potential spills of toxic cargoes and introduction of exotic organisms through ballast water.
- Conflicts between wildlife protection and recreational use and tourism. For example: access to important nesting sights for seabirds and turtles; interference with whale migrations by whale-watching tourism; increased injury to dugong and turtle populations from propeller strikes of faster, more numerous vessels.
- Insufficient resources for management by agencies.
- Inadequate legislation for environmental protection. Various new Queensland Acts are still to be finalised including the *Environment Protection Act* and the *Coastal Protection Act*.

Table 13: Major resource assessment and monitoring programs

Great Barrier Reef Marine Park Authority:

Effects of Fishing Program.
- Visual surveys of Cairns Section closed reefs opened under the new zoning plan - Dr. Tony Ayling of Sea Research
- Effects of zoning changes on the fish populations of unexploited reefs - Dr. Ian Brown, QDPI
- The effects of prawn trawling in the far northern section of the Great Barrier Reef. 1992 was the first year of this 5 year project (fundc allowing) - Dr. Mapstone, CSIRO Fisheries Research and QDPI

Aerial monitoring of reef flat Communities: for changes in cover patterns
Human use database project
Crown-of-Thorns Starfish - Professor Graham Mitchell
Torres Strait Baseline Study of trace metals in the marine environment
Townsville Port Development reactive monitoring - with JCU, AIMS, QDEH
Water quality with respect to nutrients
Monitoring of the temporal changes in the distribution and abundance of dugong, turtle and cetaceans in the Great Barrier Reef. Ongoing monitoring usually repeated every five years - Dr. Helene Marsh
Reef quality program
Water quality monitoring to determine the effects of sedimentation of fringing reef colonies near Cape Tribulation. Has been ongoing since 1984 - Dr. Tony Ayling

Queensland Government Departments:

Sunfish Project: database of logbook data for commercial fishermen catch and effort - Neil Trainor, QDPI
Mapping mangrove and seagrass distributions in areas around Queensland. Hervey Bay, Moreton Bay, Cape York, and soon Burdekin Delta - John Beumer, QDPI. Trinity Inlet and Daintree - John Russell, QDPI
Broad-scale resource assessment of Queensland's biogeographic regions by QDEH. Of 13 regions targeted, 6 are completed, 3 started, and 4 yet to begin
Monitoring population density and distribution of species of concern. From the marine environment, green and loggerhead turtles are included - QDEH
Preparation of a Seabird Atlas of the Great Barrier Reef - Griffith Uni./QDEH
Tidal Wetlands Inventory - Australian Littoral Society/QDEH
Coastal Observation Program in Engineering - monitors beach, wave and wind conditions at 50 sites. Also storm surge at 20 sites, multiple-year hydrographic surveys, long- and short-term wave recording stations, meteorological data, and aerial photography. - QDEH
Long-term ambient water quality testing for physical and chemical parameters at 52 coastal and inshore sites in Queensland. Ongoing, began in 1992 - Dr. Phil Morgan, QDEH
Site-specific water quality investigations of a limited duration
- Raine Island: Green turtle nesting and population dynamics - QDEH
- Whitsunday-Mackay: Coast geology and vegetation surveys - QDEH
- Woongarra Marine Park: Study of the impact of trawling on turtles, and a study on the impact of an artificial recreational reef - QDEH/QDPI
- Swain Reefs: Survey biological integrity of and human impact on the reefs
- Cape York: Resource assessment and the extent and effects of commercial fishing - CYPLUS

Non-government:

Use of chemical control of mosquito and biting midge in mangrove and saltmarsh areas. - Fisheries Research Consultants
Keppel Bay and Islands, intertidal organisms - Uni. of CQ Biology Dept., Dr. Mike Coates
Fishermans Landing (Gladstone) trade waste outfall in relation to the benthic community, '92,'93 - WBM Oceanics, Commissioned by QDEH
Fisherman Islands Mangrove Monitoring - WBM Oceanics, '92, commissioned by the Port of Brisbane Authority
Crown-of-Thorns starfish monitoring. Ongoing as part of AIMS' long-term reef monitoring program - Dr. Peter Moran, AIMS
Various site-specific programs associated with tourist pontoon operations in the Cairns region

acutely disturbed sites in Queensland's marine areas. Given the paucity of adequate data for much of the area under consideration any list would be extremely subjective, and is likely to exclude more than it includes. What can be said however, is that substantial disturbance, particularly of estuarine and inshore marine areas, has occurred since European settlement with chronically disturbed areas associated with most major population centres. Many of the causative agents have been discussed earlier, and areas of particular concern identified. However, for many disturbances, the extent of the problem is only now being recognised.

In many instances disturbances have resulted in irreparable damage to ecosystems such as the loss of extensive tidal wetland areas. Other impacts, however, can be repaired often through natural processes, given a cessation of the cause and a sufficiently robust ecosystem. An example is improved water quality in coastal rivers and inshore marine areas following reduced nutrient and sediment inputs from urban and agricultural areas. Such an improvement will take time both in terms of reducing the nutrient and sediment loads, and eliminating excessive nutrients and other contaminants in marine sediments. Likewise, serious pollution incidents will occur resulting in massive fish kills and contamination of parts of the ecosystem. However, immediate remedial action can sometimes be taken, and in the longer term if the problem does not persist then the impacts will be mitigated.

Table 12 lists a number of future problems. While no new impacts are identified, it does reflect those impacts that are likely to increase in the future. This increase will be triggered by Queensland's expanding population and tourism and industrial activities. To meet these challenges, Queenslanders will need to become far more aware and knowledgeable of the variety of adverse impacts on the marine environment. As well, government must provide good legislation, integrated planning to manage development, and adequate resources for management agencies, community consultation, and monitoring and research.

Table 13 provides an overview of the monitoring and resource assessment programs presently under way.

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Issues in the South Australian marine environment

Karen Edyvane
South Australian Research & Development Institute (Aquatic Sciences)
Adelaide, South Australia

Introduction

South Australia has a large range of coastal habitats and ecosystems; from the rough-water rocky habitats of the south-east and west coast, to the calm-water seagrass and mangrove habitats of the gulf regions. Threats to these environments and their fauna and flora result primarily from the effects of land-based pollution discharges, habitat loss through urbanisation and coastal development, the effects of overfishing and fishing methods (such as trawling), sea-based aquaculture and conflict between competing user groups.

Most of South Australia's population of 1.4 million is situated on the coast (see Figure 1 for locations mentioned in the text), with major towns and cities concentrated on the Fleurieu Peninsula (including Adelaide) and northern Spencer Gulf (i.e. Whyalla, Port Pirie, Port Augusta). Other major regional centres include Port Lincoln and the towns of Robe, Kingston and Mt Gambier in the south-east. Within the coastal regions of the State, economically important activities such as commercial fishing, shipping and mineral and petroleum exploration occur. Of increasing economic importance is the developing mariculture industry which is primarily based in the coastal inlets and bays of Eyre Peninsula. Tourism and recreational fishing are particularly important in regional and local economies, especially in the towns on far-west coast and on Yorke and Eyre Peninsula. Despite the vastness of the South Australian coastline, human activities tend to be concentrated near centres of population and here most conflict or competition occurs. Hence, sound management and protection measures are needed to ensure the equitable and sustainable use of marine and coastal resources.

Marine environmental management in South Australia is achieved through several mechanisms, under a variety of State and Commonwealth legislation. Marine resources and marine protected areas are principally managed and regulated under fisheries legislation. In contrast, coastal development proposals are presently regulated under various State and Local Government planning legislation. Coastal development is regulated by the Planning Commission and overseen by the Coast Protection Board, however coastal management is often uncoordinated, fragmented and prone to jurisdictional and administrative overlap. Human activities such as mining, fishing, shipping, or tourism, which may detrimentally affect marine or coastal habitats, are generally regulated through conditions on the permits or licenses issued under the respective controlling legislation.

Effective control or regulation of marine pollution in South Australia was implemented in 1990 with the passing of legislation to control land-based point source discharges to the marine environment (DEP 1989, 1986). Under the Marine Environment Protection Act 1990, licensees are required to submit an environmental improvement program in order to meet targets within a timetable permitted under transitional arrangements. The arrangements allow a period of up to eight years for all existing discharges to comply with water quality guidelines. Discharges commencing after the Act received assent must comply with guidelines immediately they are licensed. No effective control or regulation of diffuse source pollution currently exists in South Australia. Point source marine pollution legislation in South Australia has recently been repealed and incorporated into new legislation to establish a South Australian Environmental Protection Agency (DEP 1991).

Although there are several major areas of concern in the marine environment of South Australia, overall, it appears to have been less affected by human activities than inland aquatic ecosystems (EPCSA 1988).

Marine pollution

Marine pollution in South Australia, as elsewhere in the world, is strongly linked to land-based activities. While there are no figures on the

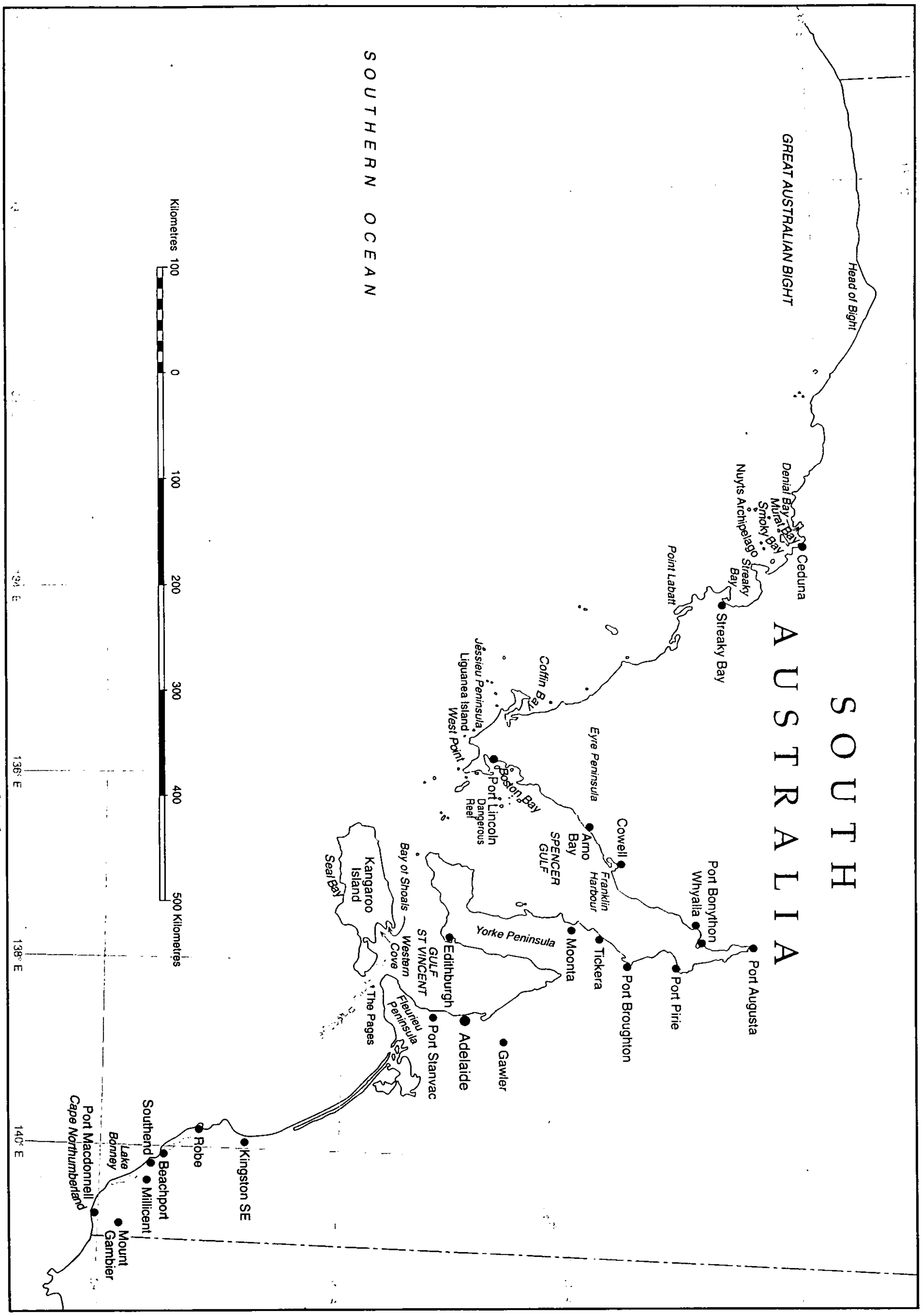

Figure 1: State map showing locations mentioned in the text.

Pollutant	Human impact	Ecological impact	Source	Areas most affected	Probable spread or increase	Scope to prevent or ameliorate	Action priority
nutrients and other organic wastes	boost algal growth; create 'nuisance' Special case is red tides - combination of nutrient build up and pest species	algal growth reduces light penetration, killing seagrasses. Change in nutrient ratios can alter make up of plant and animal communities; organic wastes deplete oxygen	point - sewers diffuse - drains, stormwater	metropolitan Adelaide Port Lincoln	moderate - through fish farming	moderate	high
	red tides restrict recreation and consumption of seafoods	red tides deplete oxygen during and after "bloom" and introduce toxins		red tides also off metropolitan Adelaide and Port Lincoln	red tides likely to increase with development of fish farming	moderate - but expensive	
faecal wastes	restricts recreation and consumption of seafoods	may promote filter feeders	point - sewage diffuse - other human and animal sources	Adelaide - West Lakes/Port R. River Torrens Patawalonga Onkaparinga R. Port Lincoln	low for human, high for other animals (pets)	moderate - but expensive	high
particulates and turbidity	aesthetic, swimming accidents	smothers substrate and changes species mix - (e.g. Aldinga)	stormwater; industrial discharge; dredging	all larger towns and ports	high - with further residential demands	good, but lies with Local Government	high
exotic pests and diseases	foul hulls free living algae may "bloom"	compete directly, or reduce advantages of local species	point - ships and boats fish farming	statewide and continuous	high	high to exclude, nil to eradicate	high
heavy metals	contaminates seafoods reduce numbers of fish that may be taken or consumed by humans	reduce diversity of marine organisms	point (municipal and industrial process) diffuse (agriculture and cars)	Upper Spencer Gulf Adelaide - Port River/West Lakes, Patawalonga	low falling	Pirie - good Whyalla - fair diffuse - poor	medium
litter	restricts recreation - accidents (needles stick)	kills birds, mammals	diffuse (drains, stormwater, boating)	statewide	moderate	high	medium
other chemicals **(pesticides, consumer and household products)**	contaminate seafoods recreational exposure	kill marine organisms	household and agriculture	statewide	low - many problem chemicals no longer registered (hence unavailable)	moderate	medium
process waste	perceived effects often aesthetic; contaminate seafoods; recreational exposure	may affect behaviour of organisms	industry	Adelaide regional centres Lake Bonney (SE)	low	high	
chemical spill/overspray (from pest control)	kill fish that may be taken/consumed by humans	kill marine organisms	point	statewide sporadic	low	high	low
hydrocarbons **(oil)**	foul structures and beaches may taint seafoods	probable metabolic effects on organisms; kill birds	point - tankers and pipelines, industrial (solvents etc) diffuse - road runoff	statewide but sporadic regular at Adelaide and Port Augusta	low	high for point sources, moderate for diffuse	low
bitterns (salt fields)	aesthetic	probably affects organisms	point (salt fields)	Adelaide Price (at intervals)	low	moderate	low
thermal	restricts recreation (but boosts fish growth)	excludes some organisms - facilitates exotic species	point - power stations	metropolitan and Upper Spencer Gulf	low	low	low

Table 1. Action priorities for estuarine and marine pollutants in South Australia
Source: Environment Protection Council of South Australia (1992)

contribution of land-based activities to marine pollution in South Australia, the majority of pollution sources are known to be close to land-based centres of human activity, in particular, the Adelaide metropolitan area and the northern Spencer Gulf region (EPCSA 1988). Because of this, marine and coastal management must address the strong land-sea-air interactions.

Nutrient enrichment or coastal eutrophication, as elsewhere in Australia and the world, is the highest-priority marine pollution issue in South Australia (Table 1). The most visible result of nutrient enrichment or eutrophication in South Australia is seagrass loss or degradation (Shepherd et al. 1989). In addition, increased nutrient loads to coastal waters have also been directly implicated in the increased frequency of algal blooms, particularly 'Red Tides', and more recently, in the loss of mangroves (Edyvane 1991; Connolly 1986).

In a study of land-based marine pollution in South Australia, 49 nutrient, 17 chemical and 15 thermal, point sources of pollution have been identified (Miller 1982). Nutrients in South Australia are from both point sources and diffuse sources, with the major contributions being clearly identified as sewage and stormwater discharges, respectively (EPCSA 1992; Steffensen et al. 1989). The main point sources of nutrients in South Australia are sewerage outfalls. Treated effluent is discharged at Bolivar, Port Adelaide, Glenelg and Christies Beach in metropolitan Adelaide, and at Whyalla, Port Augusta, and Port Pirie. Treatment of effluent at Finger Point (Mt Gambier) began two years ago, while untreated effluent is still discharged at Port Lincoln into Proper Bay. The environmental impacts of many of these sewage discharges have generally been monitored through water quality programs (e.g. Walters 1977, 1989; Steffensen 1981a, b, 1982, 1985; Steffensen & Walters 1980; Lewis 1975). The steelworks at Whyalla and food processing industries at Port Lincoln also discharge some nutrients. In addition, nutrients in the form of wastes from fish processing works are discharged into sea at Port MacDonnell, Cape Northumberland, Carpenter Rocks, Southend, Beachport and Robe in the south-east, Edithburgh and Moonta on Yorke Peninsula, and at Port Lincoln and Streaky Bay on Eyre Peninsula (EPCSA 1988; Miller 1982). The relative environmental impacts of sewage and stormwater discharges in South Australia is summarised in Tables 2 and 3, respectively.

The main sources of chemical discharges in South Australia are located at the industrial plants at Whyalla and Port Pirie, the Playford Power Station at Port Augusta, all at the northern end of Spencer Gulf, and the various sewerage outfalls, and saline discharges from salt and

Table 2: Ranking of the environmental impact of sewage discharges in South Australia (from EWS 1989)

Sewage Discharge	Environmental Impact Rating	Public Health /Use Impact Rating	Impact Score	Priority Rating
Bolivar Effluent	10	8	18	1
Port Adelaide Sludge *	4	9	13	2
Glenelg Effluent	6	6	12	3
Port Adelaide Effluent	8	4	12	4
Glenelg Sludge *	7	4	11	5
Port Lincoln	1	8	9	6
Christies Beach	1	5	6	7
Mt Gambier	1	4	5	8
Port Augusta East	1	4	5	9
Port Pirie	1	4	5	10

* - decommissioned in 1993

Table 3: Ranking of the environmental impact of stormwater discharges in South Australia (from EWS 1989)

Stormwater System	Receiving Water and Rating		Area (km^2) /Discharge Rating	Discharge Quality Rating	Impact Score	Priority Rating
Sturt Creek	Patawalonga	10	135/7	7	490	1
Brownhill Creek	Patawalonga	10	75/4	7	280	2
Onkaparinga	Onkaparinga Estuary	9	550/8	3	216	3
North Arm drains	North Arm	8	38/2	10	160	4
West Lakes	West Lakes	9	32/1.5	8	105	5
Dry Creek	Barker Inlet	5	90/4	4	80	6
Port Adelaide	Port River	7	15/1	10	70	7
Torrens River	Gulf St Vincent	1	450/8	8	64	8
Little Para River	Barker Inlet	5	85/4	3	60	9
Salisbury	Barker Inlet	3	65/3	3	27	10
Brighton	Gulf St Vincent	1	305/1.5	7	11	11
Gawler River	Gulf St Vincent	1	1350/10	1	10	12
Christies Creek	Gulf St Vincent	1	35/2	4	5	13
Smithfield	Gulf St Vincent	1	12/1	2	2	14

chemical works at Dry Creek and Osborne (Port Adelaide). Lake Bonney in the State's south east is the only case of pulpmill pollution in South Australia. In general, the levels of heavy metals in seawater appear relatively low and the levels of contamination of aquatic species are considered within defined limits (Jones 1989; Olsen 1988, 1983). However, this assessment has recently been brought into question (Rozenbilds 1991).

The main sites of marine pollution off metropolitan Adelaide are shown in Figure 2.

Seagrass Loss

Seagrass degradation in South Australia has been the focus of many studies because of the widespread loss of habitat and productivity it engenders (see Shepherd et al. 1989, for a comprehensive review). In South Australia, seagrass degradation was first linked to increased nutrient levels from sewage, when seagrass loss was observed adjacent to the Glenelg effluent outfall in 1970 (Shepherd 1970). Since this time, numerous studies have demonstrated a close link between elevated nutrient (and suspended solid levels) and extensive seagrass degradation (Shepherd et al. 1989; Clarke 1987; Clarke & Thomas 1987; Neverauskas 1987a, 1987b, 1987c 1985a, 1985b; Steffensen 1985; Johnson 1981; Shepherd 1970).

Off the metropolitan coast of Adelaide in particular, nutrients and suspended particulates from stormwater, sewage and sewage sludge, have been directly implicated in the loss since 1935 of some 4000 ha or 22% of the total seagrass area (Shepherd et al. 1989; Clarke & Thomas 1987; Neverauskas 1987a). Seagrass degradation off metropolitan Adelaide is concentrated in Holdfast Bay (Brighton to Outer Harbour), off the mouth of the Port River at Outer Harbour and between St Kilda and Port Gawler (DELM 1993).

Total seagrass degradation in the metropolitan region covers approximately 5000 ha. This represents 22% of seagrass in Holdfast Bay, 25% of the St Kilda-Port Gawler region and 3% of the total seagrass area in Gulf St Vincent (DELM 1993). In addition to the areas of total loss there has been selective loss of *Amphibolis* over 1100 ha in the vicinity of the Port Adelaide sludge outfall and current surveys in progress indicate that *Amphibolis* may have been lost over a further 3000 ha in Holdfast Bay (DELM 1993).

Of particular concern is the cycle of instability which seagrass loss causes. While seagrass decline is initiated by algal epiphytes shading and smothering the leaves, seagrass loss results in the release of sediments previously bound by the seagrass roots, and contributes to greater instability and even larger areas of seagrass loss or 'blowouts' (Clarke & Kirkman 1989; Clarke & Thomas 1987).

Seagrass loss, particularly off the metropolitan coast of Adelaide, is still continuing and possibly accelerating. Inshore loss of seagrass between Glenelg and Semaphore, occurred gradually until about 1961, when it increased rapidly due to fragmentation of the beds (Steffensen 1985). The inshore seagrass boundary is still receding with significant regression still occurring within the beds (Shepherd et al. 1989). Within existing beds off the metropolitan coast, seagrass cover has declined from 80% in 1949 to 28% in 1993 (Gordon-Mills, unpubl. data). With the present low level of water quality off Adelaide's metropolitan coast, it has been estimated that at the current rate of seagrass decline, no seagrass will be left off the metropolitan Adelaide coast (i.e. Holdfast Bay) by the year 2014 (E. Gordon-Mills, University of SA, pers. comm.). The implications for coastal erosion and fisheries depletion are considerable.

It is important to note that point source sewerage sludge outfalls are also a significant source of increased particulates and turbidity, particularly to the offshore areas of Adelaide (Steffensen et al. 1989). Suspended solids attenuate the light and can therefore have the same effect on seagrasses as epiphytes (Steffensen et al. 1989), and have also been implicated in the decline of seagrasses (see Shepherd et al. 1989).

Outside the metropolitan Adelaide region, large scale loss of *Amphibolis* (and to a lesser extent, *Posidonia*) has continued to occur in the poorly flushed northern Spencer Gulf region (Tickera to Port Pirie). The latest episode of loss followed an extensive algal bloom in February 1993. While the coastal area affected extends approximately 80 km, the causes of the loss have not been determined. They possibly include the effects of elevated nutrients and sediments from agricultural run-off, salinity and temperature changes or a pathogenic outbreak.

The effects of nutrient enrichment on the benthic fauna of areas not dominated by seagrass remains almost completely unexplored.

Algal blooms ('red tides')

High levels of nutrients (i.e. nitrogen and phosphorus) also result in excessive algal growth

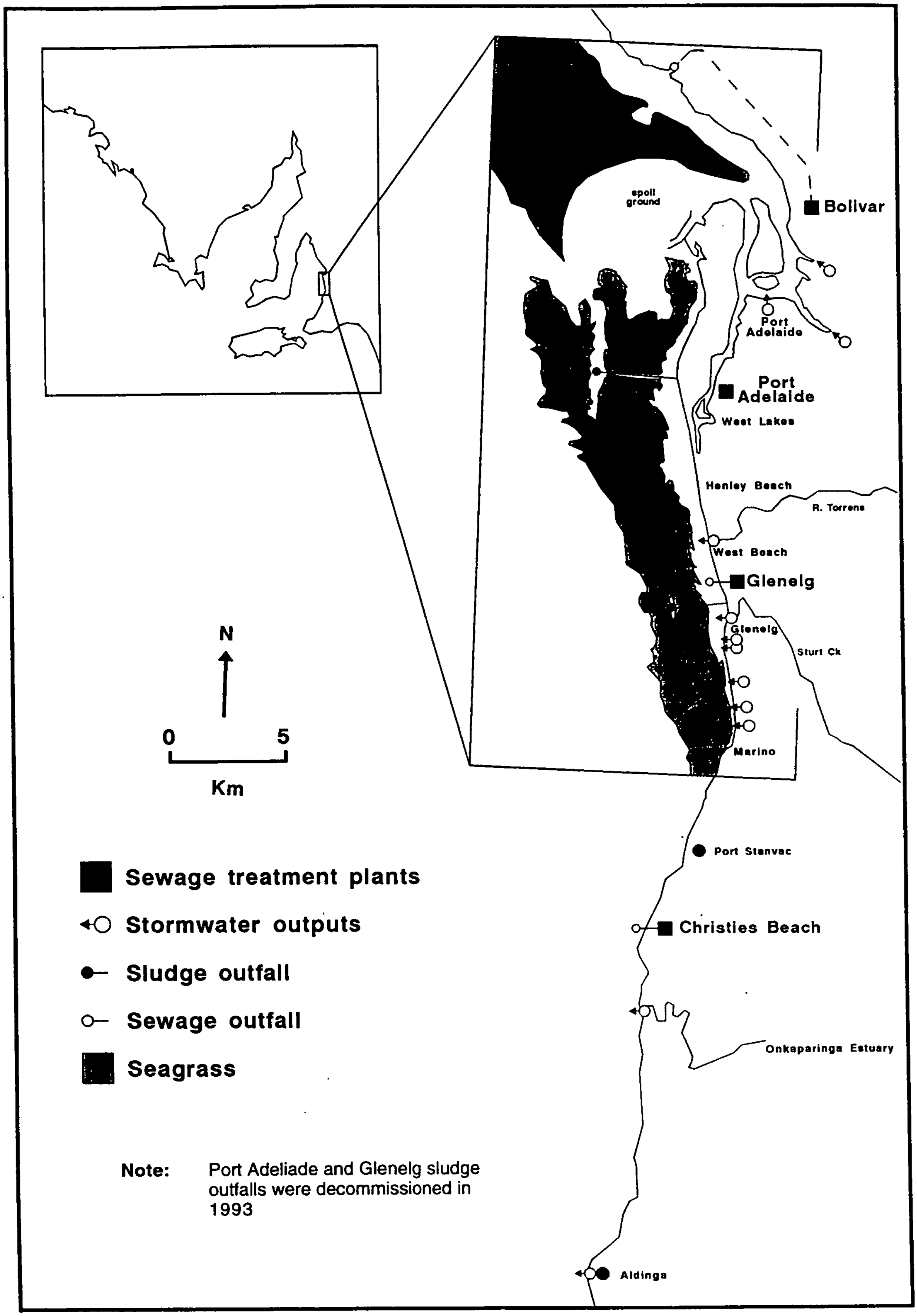

Figure 2: Main sites of sewage pollution off metropolitan Adelaide

or in the formation of algal blooms. In the upper reaches of the Port River, high levels of nutrients, due mainly to effluent discharges from the Port Adelaide sewage treatment works (Steffensen & Walters 1980), are utilised by several species of opportunistic dinoflagellates, some toxic, forming algal blooms or `red tides' (Cannon 1990). Shellfish in the region feed on these microscopic organisms, and with toxic species, accumulate their toxins. Consumption of contaminated shellfish by humans can produce the near-fatal condition, Paralytic Shellfish Poisoning (PSP). This has resulted in regular closures of the Port River - Barker Inlet system to the taking of shellfish; primarily during the spring months when conditions are most favourably for bloom formation.

Elevated nutrient levels have also resulted in the nuisance growth of the seaweeds, sea lettuce weed (*Ulva* sp.),*Gracilaria* sp. and *Giffordia* sp. off metropolitan Adelaide. The brown algal species, *Giffordia* sp. bloom off Adelaide beaches mid-summer causing nuisance drifts to swimmers and result principally from the significant nutrient enrichment of the waters by urban sewage and stormwater inputs (DELM 1993). Nuisance seaweed growths are also of particular concern in the northern metropolitan area and in the Barker Inlet estuary, where nutrient enrichment is primarily from effluent from the Bolivar sewage treatment works (Connolly 1986). Under prevailing conditions, drift *Ulva* (and to a lesser extent, *Gracilaria* sp.) can accumulate in mangrove and beach areas (such as St Kilda), where it forms large, decomposing drifts. Until recently, these seaweed drifts were primarily considered an aesthetic problem through producing odours and looking unsightly.

Mangrove Loss

Recent studies are now indicating that elevated nutrient levels, from sewage and stormwater discharges, could also be affecting mangrove ecosystems adjacent to outfalls. These studies suggest that the progressive build-up of *Ulva* in the coastal waters of metropolitan Adelaide due to increased nutrients have not only resulted in the large-scale loss of seagrass, but also the loss of mangroves (Edyvane 1991; Connolly 1986). In shallow sheltered areas, large drifts of *Ulva* (together with dead seagrass), prevent or retard the establishment and growth of young mangrove seedlings, and also choke established trees by smothering and eventually killing the aerial roots or pneumatophores (Edyvane 1991; Connolly 1986). The major area of `nutrient-induced' mangrove dieback is the shallow tidal flats between St Kilda and Port Gawler, in particular, adjacent to the Bolivar sewerage outfall (Edyvane 1991; Connolly 1986).

Work to date indicates that the gradual loss of mangroves adjacent to the Bolivar effluent outfall began 6 years after the commissioning of the Bolivar Sewage Treatment Works and the rate of loss is increasing (Bayard 1992). In contrast, in regions such as Light River, out of the zone of influence of the effluent, there has been a seaward increase in mangrove area at approximately 18 metres/year between 1935 and 1979 (Burton 1982). Approximately 68 hectares of mangroves have died in the region between St Kilda and Port Gawler since 1969 , with the greatest area of loss concentrated around the Bolivar sewerage effluent outfall (Bayard 1992). However, significantly greater areas of mangroves are presently in poor health. Recent estimates indicate that in the region immediately adjacent to the Bolivar sewerage outfall approximately 250 ha have been lost since 1956 (Bayard 1992). The full extent of nutrient-induced mangrove loss in the metropolitan Adelaide region has not been estimated.

In the long-term, continued poor recruitment and increased mortality of mangroves, particularly in the St Kilda to Port Gawler region, could result in severe reductions in the productivity of these ecosystems. Since the tidal wetlands in this region represent the most important nursery area in Gulf St Vincent for commercial and recreational fisheries (Jones 1984), this problem potentially rivals seagrass degradation in its significance to the State's gulf fisheries.

Industrial discharges

Port Pirie:

The largest lead and zinc smelter in the world is situated at Port Pirie on the eastern shore of the upper end of Spencer Gulf. Since 1890 it has been polluting the surrounding environment with aerial and liquid discharges. While Broken Hill Associated Smelters (BHAS), the company operating the smelters, has made considerable efforts to reduce pollution, the effects of pollutants are persistent and long lived. Liquid effluent containing 250 tonnes of zinc and 100 tonnes of lead each year is still discharged into Spencer Gulf via First Creek. This is in marked contrast to BHAS's affiliate at Port Kembla, which effectively removes all metals (Rozenbilds 1991).

The effects of the smelter operations on the marine environment have been considerable. In 1979 the CSIRO, sponsored by the International

Lead Zinc Research Organisation (ILZRO), began a four year study of the effects of pollution at Port Pirie on the adjacent marine environment. The study concluded that sediments over an area of 600 km^2. were contaminated by particulate cadmium, lead and zinc, the main sources of which were smelter stack emissions (since ceased), ore spillage and fugitive dusts. Lesser areas were contaminated by copper, arsenic and manganese.

In addition to large scale contamination of sediments, almost all the biota found in these contaminated areas displayed elevated levels of cadmium, lead and zinc (Ward et al. 1986). Despite this, metals in the flesh of species commonly consumed by humans did not exceed health standards, provided only the muscle was eaten. However, three species approached the limit, and some reservations were expressed about the accuracy and definition of the recording techniques (Ward et al. 1982). Measures to reduce pollutant discharges to the marine environment are currently being supervised by the newly established Environment Protection Authority.

There has also been considerable long-term effects on the ecology of the adjacent seagrass community. Widespread contamination in the region has resulted in changes to the structure of the seagrass community. For the seagrass fauna, species richness and composition (both measures of diversity), and species abundance (number of individuals of a species) all decrease as contamination increase (Ward & Young 1982). Of the species in the seagrass community, 20 were identified as sensitive to metals, and a further 15 as sensitive to metals or clays (Ward et al. 1986, 1982).

In a recent report, liver cadmium levels were shown to be elevated in adult Bottlenose Dolphins, *Tursiops truncatus*, inhabiting the inshore gulfs of South Australia. The cadmium emissions from the lead smelter at Port Pirie have been implicated as the prime source of cadmium (Kemper et al. 1994a).

Whyalla:

Spencer Gulf is also the region for the largest chemically contaminated effluent discharge into the marine environment in South Australia. Broken Hill Pty. Ltd. (BHP) steelworks is located at Whyalla on the western side of Spencer Gulf. Effluent from the combined steelworks, blast furnace and coke oven is contaminated with solids, metals, cyanides, ammonia compounds and phenols, and discharged to an area open to the sea. Additionally, discharges from the magnetic plant tailings dam, which contain high levels of dissolved iron, also percolate through to the sea (Miller 1982).

The immediate effects of these discharges are most probably the elevated concentrations of zinc, cadmium, chromium, copper and lead which occur in the intertidal mudflats around Whyalla (Harbison 1984). The effects of these effluents on marine life have not been studied but are considered likely to be similar to those of Port Pirie. A cause for concern is the bio-availability of these metals and the consequent contamination of the marine food chain (McLaren & Wiltshire 1984; Thomas 1981). While zinc was considered the only metal which could be taken up by organisms in a soluble form, the other heavy metals, which attach to fine particulate matter, could be readily taken up as food by the benthic organisms (Harbison 1984).

Thermal pollution

The most significant thermal discharges in South Australia are from the power stations at Torrens Island (Port Adelaide) and Port Augusta, although most major industries discharge some cooling water (Miller 1982).

Monitoring studies at the Torrens Island and Port Augusta power stations, conducted by the Electricity Trust of SA (ETSA), have reported changes in the composition of benthic faunal communities in the intertidal zone, and the fringing seagrass subtidal zone, adjacent to the cooling water outfalls (Ainslie et al. 1989; Thomas et al. 1986).

Further, elevated heavy metal contamination near the power station at Port Augusta, at the head of Spencer Gulf, is thought to be due to fly ash in the power station effluent (Harbison 1984).

The fly ash ponds at the Playford power station at Port Augusta were relocated following reports of mangrove dieback (Kinhill Stearns 1986). These particular areas of dieback have since stabilised, however the cause of a recent and on-going patch of dieback adjacent to Hospital Creek is presently unknown (Bayard 1993).

Pulpmill pollution

Lake Bonney in the State's south-east is the only case of pulpmill pollution in South Australia. Lake Bonney is a permanent, shallow coastal lake, heavily polluted by effluent from two pulp and paper mills located near Millicent. The lake's water level is regulated by the Engineering and

Water Supply Department, and it is usually necessary to release water to the sea in spring or early summer, through the outlet channel. The contaminants of major concern in the effluent are halogenated organic compounds, measured as Adsorbable Organic Halogen (AOX) in water, or Extractable Organic Halogen (EOX) in sediments and biota. Halogenated organic compounds, such as organochlorines, range from completely harmless substances to extremely toxic ones (such as dioxins and furans), which are generally persistent, lipophilic, small, or polychlorinated and often strongly bioconcentrated (Fandry et al. 1989). Although the lake is thought to effectively act as a treatment basin, studies to date have found no trace of dioxins in the lake (Kinhill Stearns 1990).

The effects of the lake discharge on the marine environment are also inconclusive. From September to November 1989, over 35 tonnes of AOX was released to the sea from Lake Bonney, causing a visual plume covering over 55 km^2. However, studies found no contaminants in either the sediment or the biota tested (Neverauskas 1990). Recent changes in the pulpmilling process has virtually eliminated all chlorine in bleaching and reduced other pollutant loads to Lake Bonney. Monitoring is required to document any potential recovery of the lake ecosystem.

Diffuse sources

It has been estimated that 90% of land-based discharges in South Australia are derived from diffuse sources (EPCSA 1988). Stormwater run-off and river catchment discharges are the principal components of diffuse source pollution, with the water quality of the discharge being primarily determined by the dominant land use of the catchment area. Urban run-off contains solid wastes, litter, chemicals, vehicle pollutants, pesticides, bacteria, soil and dust. In addition, offensive domestic chemicals, and oils and greases from backyard garages are usually directed into stormwater drains, as are chemical spills and sewer pumping overflows. In contrast, rural run-off may contain a combination of animal wastes, fertilisers, pesticides, agricultural chemicals and soil.

In South Australia, problems with urban run-off are principally of concern in metropolitan Adelaide. Stormwater has been identified as a major source of faecal bacteria in Lake Patawalonga at Glenelg, the Onkaparinga Estuary (Manning & Associates 1985), and West Lakes. The Patawalonga receives stormwater flows via stormwater channels from the Sturt River and a large catchment of creeks and drains controlled among approximately 11 separate local government councils. Water quality in the basin is poor because of restricted flushing, a result of a barrage and lock system, and deteriorates whenever stormwater enters (Patawalonga Basin Task Group 1989). As a consequence, bacteriological standards for recreation in the lake are exceeded most of the time and the Council of the City of Glenelg has banned contact water sports. The Patawalonga also has a high sediment and nutrient loading, and unsightly floating debris, rubbish and trash, which accumulates in high volumes. The discharge of these waters into the sea has possibly contributed to the decline in seagrasses in the vicinity of the outlet and has affected the quality of the local beaches.

West Lakes, an artificial lake, receives stormwater run-off from a smaller catchment area. However, this is sufficient to cause short-term bacteriological contamination, nuisance growths of seaweeds and algae, and toxic contamination of shellfish by dinoflagellates (one occasion), and lead in 50% of mussels samples (Steffensen 1988).

Recently it has been realised that the quality of stormwater run-off in the Onkaparinga Estuary could be improved significantly by filtering through artificial wetlands (Manning & Associates 1986). As such, a number of suitable sites have been identified in which to establish wetlands (Onkaparinga Estuary Task Group 1990).

Pollution from diffuse sources in South Australia can also contribute amounts of industrial pollution to marine environments. For instance, the total load of heavy metals discharged by the River Torrens annually is an order of magnitude equivalent to the effluent load from the Bolivar sewage treatment works. For copper and cadmium, the mass loads are higher than the Glenelg sewage treatment works sludge outfall. The loads for each of the four major stormwater drains between Glenelg and Seacliff are equivalent to the effluent load from Christies Beach or Finger Point sewage treatment works (EPCSA 1988). Of particular concern is the North Arm of the Port River Estuary, which receives discharges from four major and several minor stormwater drains.

The Port River estuary is the most diversely polluted estuary in South Australia and receives pollutant inputs from numerous point and diffuse sources (Rozenbilds 1991; Hine et al.

1989). This has resulted in significant heavy metal contamination of sediments, particularly of lead and zinc (Harbison 1986a, 1986b). Inputs include effluent from the Port Adelaide sewage treatment works and the outflow from West Lakes to the head of the Port River, discharges from the numerous stormwater drains along the North Arm, discharges from Dry Creek and the Little Para River into Barker Inlet, thermal effluent from the Torrens Island Power Station in Angus Inlet, and run-off from a heavily industrialised local catchment. Within the estuary the cumulative effect of these inputs results in water quality which consistently exceeds the recommended national and state criteria for protection of aquatic ecosystems (PPK Consultants 1992).

Ship-based pollution

Oil spills:

Port Adelaide and Port Stanvac remain the major sites for oil spills in South Australia. However, the number of oil spills over the past decade is considerably greater than during the first half of the 1970s and the annual volume of oil spilled remains high (DELM 1993). Between January 1988 and June 1992 there was a total of 14 oil spills in South Australian waters, in which 8610 litres was released (DELM 1993). During this time there were 2 spills at Port Adelaide and 10 at Port Stanvac. However, in August 1992, an accident at Port Bonython resulted in the largest coastal oil spill in Australia's maritime history, in which approximately 300 000 litres (296 tonnes) of bunker oil were released into a region of the sensitive mangrove-seagrass communities of upper Spencer Gulf. Prior to this, the largest oil spill in South Australia was a spill of 234 325 litres at Port Stanvac in 1982 (EPCSA 1988). All clean-up operations for oil spills in South Australia are coordinated under the national Oil Spill Contingency Plan.

The effects of oil spills on the marine environment in South Australia have until recently generally received little attention. The monitoring of a minor spill upon mangroves in the Port River indicated few long-term effects (Wardrop & Wagstaff 1988). However, the monitoring of the recent 'Era' oil spill in upper Spencer Gulf has revealed that approximately 23 hectares of mangroves are dead or totally defoliated in heavy oiled areas (Butler 1993, Wardrop et al. 1993) and show no sign of significant recovery 2 years post-spill (Edyvane, SARDI, unpubl. data). No hydrocarbons were detected in benthic sediment samples collected within the upper Spencer Gulf region or in flesh from collected fish and crab specimens (Butler 1993). No tainting of prawns was observed. However, biochemical studies of 2 fish species, Yellow Fin Whiting and Yellow Eye Mullet, indicate post-spill changes in the level of mixed-function oxidases (K. Bellette, University of Adelaide, pers. comm.).

The long-term effects of frequent minor spillages at the main oil-handling facilities at Port Stanvac, and in the Port River are not known (Rozenbilds 1991). However, the impact of spillages and ballast water discharges at the port and terminal facilities at Port Bonython (Stony Point) have been monitored as a condition of licensing. No effect from any test, including taste testing for tainting of prawns has been observed (SANTOS 1985, 1984).

Antifoulants:

Organotin compounds, especially tributyltin (TBT), have been used extensively throughout the world and in Australia as marine antifoulant paints preventing encrustation of the hulls of ships and small boats by tubeworms and barnacles. Recent studies have shown TBT to be highly toxic, having effects upon marine life at levels as low as parts per trillion. At lesser concentrations, TBT has been shown to cause oyster shell deformities and induce severe reproductive abnormalities in some gastropods (i.e. neogastropod imposex). This, coupled with frequent findings that TBT concentrations are rising in waters subject to high levels of boating activity, has sparked growing concern about TBT (Champ 1986). New South Wales, Queensland, Victoria and Tasmania, have banned the use of TBT as an antifoulant paint on boats less than 25 meters, and imposed restrictions upon its rate of leaching from larger vessels. Similar legislation banning the use of TBT does not exist in South Australia.

In South Australia, a recent survey of neogastropod imposex in the marine gastropod *Lepsiella venosa* by Nias et al. (1993) revealed 100% imposex in specimens collected from Barker Inlet, Port Lincoln and Coffin Bay. All these places had significant moorings of boats.

Ballast water discharges:

The discharge of ballast water from international shipping appears to be responsible for the introduction of a number of exotic microscopic algae in Australia. Of particular concern is the introduction of toxic dinoflagellate phytoplankton, which under favourable conditions can lead to the occurrence of toxic 'red tides'. These algal blooms not only discolour the water, but toxic species can cause health problems for humans who consume contaminated shellfish and sea farm products.

South Australia is the location for 3 of the 16 introductions of exotic organisms attributed to ballast water or sediment in Australia: the polychaete, *Pseudopolydora paucibranchiata* and the crustaceans, *Tanais dulongi* and *Eurylana arcuata* (Jones 1991). In particular, the toxic dinoflagellate, *Alexandrium minutum*, which is responsible for the regular toxic red tides in the Port River, is thought to have been introduced to the state from the ballast water of shipping (Hallegraeff et al. 1988). Other similar ballast water introductions are thought to have occurred in Hobart and Port Phillip Bay, Melbourne. The introduction and spread of *A. minutum* in South Australia has been directly linked with shipping, including recreational craft. A recent survey has shown *A. minutum* cysts in the sediments of other major ports and bays in South Australia, including Port Lincoln, Ceduna (Thevenard), Kangaroo Island (American River, Penneshaw, Ballast Head, Kingscote), Coffin Bay, Franklin Harbour and Streaky Bay (J. Cannon, University of Adelaide, unpubl. data). The introduction of *A. minutum* is of major concern to the oyster industry in many of these areas.

Overfishing

Over-exploitation of fish resources has been documented in many fisheries around the world. In South Australia, marine resources, particularly fish, crustacea and molluscs, have long been important sources of food and other materials for humans (EPCSA 1988). Aboriginal communities, prior to the coming of European settlers, caught fish using stone fish traps in shallow waters and early whalers and sealers established fishing communities on Kangaroo Island even before the arrival of settlers in 1836. However, the commercial and recreational fishing industries are now the main users of marine resources in South Australia, and ensuring their sustainable and equitable use continues to present a major challenge to managers.

Approximately 20 fish species and 3 species of crustacea and molluscs provide the basis for the fishing industry in South Australia. The 1991-92 commercial marine fisheries reported landed catch was 18 087 tonnes with a value of production of $128.4 million (excluding processing and marketing), which represents approximately 10% of the national total (DELM 1993). The major fisheries in terms of value of landed catch were Southern Rock Lobster, Western King Prawn, Abalone, Tuna and Marine Scalefish.

Modern fisheries management measures were first introduced in South Australia in 1968 in recognition of the fully exploited status of the State's traditional fisheries (i.e. marine scalefish and Southern Rock Lobster). Since then, these measures have developed to include all the State's fisheries. Nevertheless, several commercial fisheries have become seriously overexploited despite improved management practices (EPCSA 1988). Commercial catches of Western King Prawn have dropped substantially from 1981 to 1991, while Southern Rock Lobster catches have stabilised despite a significant increase in fishing effort due to satellite navigation (DELM 1993). Annual commercial catch limits or quotas have been proposed for several major commercial finfish species in South Australia (Rohan et al. 1991), however these have yet to be introduced. Following declines in catches, quotas have already been introduced for Southern Bluefin Tuna and Greenlip and Blacklip Abalone in South Australia.

In South Australia, there are three fisheries which are considered to be 'overfished': Catfish (FW), Murray Cod (FW), and Western King Prawn (Gulf St Vincent) (Commonwealth of Australia 1991). A further twelve fisheries are considered 'fully fished' (see Table 4). However the status of knowledge for management is considered 'adequate' for only 5 of 27 fisheries (i.e. 19%) in South Australia: Blacklip and Greenlip Abalone, Southern Rock Lobster, King George Whiting and Australian Salmon. Further, the knowledge required for 'ecologically sustainable development' is considered 'adequate' for only 2 fisheries in South Australia (i.e. 7%): Blacklip and Greenlip Abalone (Commonwealth of Australia 1991).

In Australia there are relatively few fished species for which the state of biological knowledge is adequate to undertake even the most basic stock assessment for management purposes (Commonwealth of Australia 1991). There are a number of reasons for this. Firstly, sound management of fisheries needs a wide range of data: biological, environmental and economic. Secondly, our state of knowledge about the aquatic environment is very poor relative to land-based environments, because research is both difficult and costly (Commonwealth of Australia 1991). Hence, we have little understanding of the interdependence of species, their relative

Table 4: Status of South Australian commercial fisheries (from Commonwealth of Australia 1991)

'Over Fished'	'Fully Fished'	'Uncertain Status'	'Underfished'
Catfish (FW)	Golden Perch (FW)	Redfin Perch (FW)	Bony Bream (FW)
Murray Cod (FW)	Blacklip Abalone*	Bream	Yabbie (FW)
Western King Prawn (GSV)	Greenlip Abalone*	Cockles	Blue Crab
	Garfish	Snook	Ocean Jacket
	Mulloway	Blue-Eyed Trevalla	Yellow Eyed Mullet
	Western King Prawn (Spencer)		Tommy Ruff
	Southern Rock Lobster		Australian Salmon*
	Snapper		
	Squid		
	King George Whiting*		
	Yellowfin Whiting		

* - status of knowledge for management considered 'adequate'

positions and importance in the food web, or how they interact with both natural and human-induced changes in their environment. While we can be certain that a fishery ecosystem is being affected by the physical impact of trawling operations on habitat, and by the relatively large by-catch, our knowledge base is such that we cannot quantify the effect, nor understand the implications for crucial issues such as marine biodiversity (Commonwealth of Australia 1991).

In South Australia, fishery information does not extend to the take of bycatch which is discarded, nor to the physical impact of fishing. In some fisheries, such as prawn trawling, the weight of discarded bycatch can be in the order of eight times the catch retained. Thus, for the estimated 1991 prawn catch of approximately 2000 tonnes, in the order of 16 000 tonnes of non target species were probably killed as bycatch (DELM 1993).

There are 4 commercial licenses for scallop dredges in South Australia. However license conditions and regulations so restrict the use of these dredges that they are unlikely to have any effect on the sea bottom. As such, scallop dredging activities are restricted within major bays and the gulfs.

Sea-based aquaculture

Aquaculture in South Australia is defined as the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. It includes the breeding, hatching, rearing and cultivation for sale of all aquatic organisms. Farming is defined as the input of labour and attention to promote or improve growth of stock, implying individual or corporate ownership of that stock. This definition is in line with that proposed by the Draft National Aquaculture Strategy. Australian aquaculture production (including oysters, pearls, salmonids, prawns, marine and ornamental fish) was valued at $277 million for 1991-92. Production increased at 16% in comparison with 1990-91, and now constitutes approximately 20% of the total Australian fisheries production.

Aquaculture in South Australia is a relatively new industry, with only three sea-based industries: Pacific Oyster (*Crassostrea gigas*) farming, cage culture of Southern Bluefin Tuna (*Thunnus maccoyii*), and cage/barrel culture of Abalone (*Haliotis rubra* and *H. laevigata*). Land-based aquaculture industries include: extensive crayfish pond culture of Yabbie (*Cherax destructor*) and marron (*Cherax tenuimanus*); raceway based abalone culture; extensive euryhaline pond culture of the microalgae, *Dunaliella salina*; and finfish farming of Trout (*Oncorhyneus mykiss*) in extensive ponds and Barramundi (*Lates calcarifer*) in intensive culture systems. Only Abalone and *D. salina* are dependent on the water quality of seawater for successful cultivation. There are presently (30 June 1993) 88 approved marine aquaculture sites in South Australia comprising 76 oyster leases, 11 tuna farm leases (9 farms, 1 R&D farm and 1 tourist facility), and 1 sea-based Abalone farm site (located off Cape Forbin, Kangaroo Island). A further 20-30 applications on a variety of tried and new species are pending, including Snapper (*Pagrus auratus*) and Southern Rock Lobster (*Jasus edwardsii*).

Pacific Oyster culture using the intertidal rack method occurs in six main regions in South Australia: Coffin Bay (19 approved), Denial Bay (16 approved), Streaky Bay (6 approved leases), Smoky Bay (13 approved), Franklin Harbour (12 approved leases) and Western Cove - Bay of Shoals, Kangaroo Island (4 approved). Unlike oyster culture in other countries, or interstate, farming is restricted to inverse estuaries that are productivity dependent on ocean water exchange. The low phytoplankton productivity of South Australian coastal waters and the extreme environmental culture conditions (12-35°C and 35-42 ppt) has likened farming oysters in SA to the equivalent of marginal wheat farming. Farmers can expect to have several years where the equivalent of drought conditions prevail. This has considerable ramifications on the impact of farmed oysters on competing filter feeders during these periods.

Tuna farming is presently isolated to the Boston Bay region adjacent to Port Lincoln. Capture boats purse seine suitable tuna stocks (15 to 40 kg fish), that are then transferred by divers through an underwater raceway into a towing cage. The fish are then towed back to Boston Bay, where the underwater transfer process is reversed into 40-50 m cages. Fish are then fattened for between 3 and 9 months, currently using pilchards or mackerel. Approximately 1.5 tonnes of feed is added to each cage daily. Harvesting starts within two to three months of capture to take advantage of the high market values in Japan. By holding the tuna, fishers control market timing to optimise their product value and increase the meat quality, which is essential for the sashimi market. There are presently 11 approved tuna farming sites with the potential to use 98 cages of 40m diameter at an initial stocking rate of 2.4 kg/m^3.

Planning

Aquaculture development proponents submit applications to the appropriate local council, which then forwards all developments involving crown land to the South Australian Aquaculture Committee (SAAC), a sub-committee of the South Australian Planning Commission with representatives from the Department of Primary Industries (DPI), Department of Environment and Natural Resources (DENR), Office of Planning and Urban Development (OPUD), South Australian Conservation Council, South Australian Fishing Industry Council (SAFIC) and an independent chair appointed by the Planning Commission). All applications are assessed by a Technical Advisory Group (TAG) with representatives from DENR, OPUD and the South Australian Research and Development Institute (SARDI). The advisory group inspects the site and then makes recommendations to SAAC on the validity of the proposal, taking into account public comments. Depending on the nature of the development, the TAG will also recommend planning conditions and the statutory authority which will administer them. Incorporating DPI and DENR in the planning process approval by SAAC also implies the applicant will be granted a DPI licence and a DENR miscellaneous lease. Currently DPI licences are renewed yearly, while DENR miscellaneous leases are for one year plus ten and ten, subject to appropriate surveying of the site in the first year. Fees are levied from farmers in two main areas as part of their planning approval: firstly, for environmental monitoring (tuna farmers pay $9000 and oyster farmers $500); and secondly, for public resource allocation (rent). A right of appeal exists for both the developer and concerned members of the public. Since the inception of SAAC no environmental group has been successful in overturning a planning decision.

To remove the uncertainty inherent in developing the coastal zone, DENR and DPI have initiated a series of aquaculture management plans (Coffin Bay, Murat and Smoky Bay, Streaky Bay, Franklin Harbour, Kangaroo Island and Port Lincoln) that provide both a zoning of the area concerned and a series of development guidelines (Bond 1993, 1991; PPK Consultants 1992a, 1992b, 1992c, 1992d; Wilson 1989, 1988). This has allowed for a more systematic and strategic approach to aquaculture planning, in South Australia. However, plans often have to be modified due to the failure to incorporate other, often conflicting, coastal uses and future development strategies within the coastal zone (such as tourism, recreation, nature conservation and fishing). As such, there is a need for integrated, multiple-use, coastal management plans for specified areas which address the cooperative management of specified areas for the range of existing and potential coastal uses and activities.

Environmental impact

There are two issues concerning the environmental impact of aquaculture activities. Firstly the impact of the activity on the environment and, secondly, the impact of the environment on the farm. While sea-based aquaculture developments rely on a clear and healthy environment for their viability, the developments themselves have the potential to introduce exotic species and diseases to wild stock. Further, unless adequately controlled through management plans, aquaculture activities can result in the pollution of adjacent areas and/or the eutrophication of confined water bodies. Defining what constitutes an aquaculture impact creates conflict between competing resource users. Farmers tend to focus on local water quality effects and do not consider such issues as aesthetic and noise pollution, bird and marine mammal impact, fish behaviour and ecosystem changes from nutrient accumulation. In some cases such effects are often described as environmental improvements by fish farmers.

The major environmental problem attributed to aquaculture in South Australia is the establishment of natural breeding populations of the exotic Pacific Oysters in areas adjacent to farm sites. One of the major factors in approving the introduction of Pacific Oysters into South Australia was scientific evidence that showed successful settlement could not occur. This was based on the fact that Pacific Oyster larvae could not survive the high salinities that occur in all growing regions during the summer spawning period.

Sea-based fish farming in South Australia has the potential to result in significant habitat modification, possible environmental degradation from waste and effluent, introduction of diseases and chemicals, translocation of exotic species, and conflict over space with other resource users. Further, because this activity often relies on the use of fish food manufactured from wild stocks, demands are also placed on those resources. This can be a negative aspect if those wild stocks are improperly managed. Further, fish farms may attract natural predatory species, such as sharks, which are then treated as pest species.

Sea-based fish farming activity in South Australia is presently confined to the 'growing out' or 'fattening' of wild-caught juvenile Southern Bluefin Tuna in cages in the Boston Bay region, described above. Serious concerns exist over the impact on pilchard stocks which are used as fish food and the present poor water quality in Boston Bay, particularly, the elevated nutrient levels in the bay and the potential for algal blooms and disease outbreaks. In accordance with the recommendations of the Port Lincoln Aquaculture Management Plan (Bond 1993), by 1995 a total of 17 sites comprising 158 cages could be located in Boston Bay and the adjacent Spencer Gulf zone.

Environmental monitoring

Environmental monitoring of aquaculture activities in South Australia is conditional for both the DENR miscellaneous lease and DPI licence. To facilitate this, DPI and SARDI have established the Shellfish Environmental Monitoring Program (SEMP) and the Tuna Environmental Monitoring Program. The SEMP started in December 1991 while the TEMP is still in the documentation and development phase. The SEMP currently measures and records :

the influence of oysters on competing filter feeders at control and impacted sites;

changes in vegetation cover and diversity associated with control and impacted sites;

the accumulation of litter associated with oyster farming;

water quality parameters including pH, oxygen, redox, chlorophyll a, temperature, salinity;

sedimentation rates in impacted and control sites;

boundary changes, for example sand bank disturbance, sea floor scouring or seagrass removal, by annual aerial photographic surveys;

violations of planning conditions regarding methods of farming, site location, stocking density.

In addition, research has started on determining how to quantify carrying capacity for each shellfish growing region. At present this research has focused on the waterways of Coffin Bay. One of the current problems with the SEMP is the development of appropriate management responses to monitoring results. This is currently being reviewed to insure that quantified impacts have appropriate management responses.

The focus of the proposed TEMP is to develop a predictive assimilative capacity model for Boston Bay. The main components of the model include modelling the hydrodynamic pattern, and measuring changes in phytoplankton productivity and seagrass cover.

Conflict between user groups

The multiple, and generally conflicting, uses of coastal and marine environments can often result in habitat loss and destruction. In short, there are major conflicts between using coastal habitats and their resources as places to live, as places to recreate, or as places to work. Activities in coastal and marine environments range from those which require the maintenance of the natural state, such as tourism, recreation, scientific research, education and conservation; to exploitative or extractive activities which modify the ecosystem, such as urban or industrial developments, fishing, aquaculture, and mining. Inevitably, without integrated and coordinated management of these activities through integrated coastal zone management, the range of different activities and uses of the marine environment will continue to conflict with each other and create considerable discord amongst the different user groups.

In South Australia, there are major conflicts between urban and industrial development and fishing interests. Commercial and recreational fishing groups have been concerned for a long time over the impact of sewage and stormwater pollution on the destruction of seagrass habitats, particularly in Gulf St Vincent; the loss of mangrove and saltmarsh habitats due to coastal developments; and also the potential contamination of fish stocks from oil spills and the considerable industrial discharges in the upper Spencer Gulf region. Even in the more remote areas of South Australia (for example, Smoky Bay), sewage pollution from the septic tanks of shack developments are of concern to local fishers. Of particular concern is the proposed freeholding of coastal shack developments in South Australia, which will perpetuate existing environmental problems, including septic tank seepage, destruction of coastal habitats, rubbish, coastal erosion and flood and storm risk.

Aquaculture, although a relatively recent industry in South Australia, is particularly prone to land-based pollution. Oyster farms, in particular, require high water quality and hence are generally incompatible with urban developments. In the USA, approximately 40% of all shellfish farms have been closed due to sewage pollution. In New South Wales, several commercial oyster farms have been closed due to faecal contamination from nearby sewage discharges. Shipping and port and marina developments are also incompatible with oyster farming activities because of the widespread use of antifoulants. Tin-based paints, particularly, are known to result in shell loss and deformities in oysters.

In South Australia, aquaculture developments in some areas directly compete with other users of marine resources. Oyster racks and caged tuna farms in South Australia reduce visual aesthetics, which may reduce tourist or conservation values; aquaculture sites may compete with netting or angling sites for commercial or recreational fishers; oyster farms may reduce the overall productivity of bays; effluent from tuna farms may degrade nearby habitats; the farming of exotic species may introduce disease or result in the release of exotic species into natural areas. In particular, the incremental development of oyster leases in many scenic areas of South Australia (e.g. Coffin Bay) is causing local conflict with community, fishing and tourism interests (Wilson 1988).

While tourism generally capitalises on the natural values of areas, uncontrolled tourist developments can lead to the destruction of the very features that made them attractive in the first place. Visitors often require facilities such as parking, marinas, toilets and accommodation, all of which can detract from the natural beauty of wild places. Unfortunately many of the remote and wild coastal areas of South Australia, particularly on the west coast and Eyre and Yorke Peninsulas, are suffering from the results of uncontrolled tourism. Uncontrolled shack development, off-road vehicle usage, and parking and camping areas, are causing considerable erosion of some of South Australia's most scenic coastal regions and their wilderness values.

Key marine habitats under threat or significant in South Australia

Estuaries

Coastal estuaries in Australia, as elsewhere in the world, are seriously threatened by human activities (Hutchings & Saenger 1987). As such, there has been considerable documentation on the decline of estuarine resources, in particular seagrass beds, which have been fragmented, and loss and destruction, through such practices as sewage discharges, urban run-off, dredging, boating, and land reclamation (Shepherd et al. 1989).

Estuaries are of special importance in South Australia because of the State's generally arid nature. The majority of rivers in South Australia are temporary streams which flow (and flood) only after local rains have fallen. Hence, many of the estuaries receive irregular freshwater inputs. For this reason, many have been called 'reverse estuaries' because they are often most saline at the top, rather than at the mouth, of the estuary.

The small numbers of rivers which were permanent at the time of European settlement have been severely affected by their use as water supply sources. This has resulted in a drastic reduction in their flow, and the virtual elimination of flow downstream of storage and diversion structures. This has had major impacts on the extent of flowing water available as habitat, and points to the urgent need for the State's remaining streams to be protected from development (EPCSA 1988). A number of rivers and streams have already been identified in South Australia as being of outstanding environmental value and consequently recommended for declaration as wetland reserves (Table 5; Lloyd & Balla 1986).

South Australia has the least number of estuaries in Australia. Of the 738 estuaries (and enclosed marine waters) identified in Australia, 15 occur in South Australia, compared with 307 in Queensland; 145 in Western Australia; 137 in the Northern Territory; 81 in New South Wales; 63 in Tasmania; and 35 in Victoria (Bucher & Saenger 1989).

In an inventory of Australian estuaries, Bucher & Saenger (1989) have identified 5 (out of 15) estuaries under threat in South Australia (i.e. threat to fisheries and conservation values). These include: the Coorong, due to increasing salinity in the lower reaches of the Murray River, reduced flow and lower flood frequency; Port Adelaide River, due to poor water quality from pollution, and threat of adjacent urban and industrial development; Second Creek, Port Pirie, due to the threat from the nearby sewage treatment works; Port Pirie, due to run-off and discharges from shipping, residential and heavy industrial development; northern Spencer Gulf, due to potential poor water quality from port facilities, sewage treatment plant, power station and urban run-off from Port Augusta (see Table 6).

However, only 3 of these estuaries have been assessed as `moderately' or `considerably affected' ecologically by human activities: Port Adelaide River (considerably), the Coorong (moderately), and Port Pirie (moderately). Port Douglas (25-50% cleared) and Franklin Harbour (50-75% cleared) are also significant estuaries in that their catchments are the only catchments which are not `intensively developed' (i.e. >75% cleared of native vegetation).

There is an urgent need for a state-wide wetlands policy in South Australia, as has been developed in New South Wales, Victoria and Western Australia (DELM 1993). Wetland management in South Australia is uncoordinated, with management being conducted on a project or regional basis. While recent activity has been concentrated in the Murray Valley and South East, areas such as the Eyre Peninsula, Yorke Peninsula, Mount Lofty Ranges, Flinders Ranges and Kangaroo Island remain neglected (DELM 1993).

Seagrasses

Seagrass beds are one of the important habitats within estuaries threatened by development (see

Table 5: Inland waters of South Australia of outstanding environmental value recommended for status as Wetland Reserves

Region	Environmentally important waters	
	Type	Location
South east	Swamps	Marshes, Mt McIntyre perched swamps, Mt Lyons perched swamps, Lake Frome-Mullins Swamp, Sawpit Swamp
	Lakes	Bool Lagoon, Woolwash, Blue Lake
	Rivers	Eight Mile Creek (the only significant river in the whole region)
River Murray	Swamps	Opposite Cooinda, Complex N. of Swan Reach
	Lakes	Coorong, Lakes Alexandrina & Albert, River Marne mouth, Milang....Roonka, Irwin Flat, Chowilla Region
	Rivers	Tookayerta Creek, Dawson Creek, Finniss River, Marne River, River Murray Channel (none of the Murray's main channel is within a conservation park or reserve), Murray Mouth (including islands within Lake Alexandrina)
Gulfs	Swamps	Ducknest Ck Perched Swamps (FP), Myponga Swamp (FP), Peesey Swamp (YP), Grainger Lagoon (KI)
	Lakes	Big Swamp (EP), Lake Wangary (EP), White Lake (KI), Lake Ada (KI), Halls Rd. Salt Lake (KI), Cygnet River Billabongs (KI)
	Rivers	Little Para River (M), Tod River (EP), Harriet River (KI), Stunsail Boom River (KI), Cygnet River (KI)
Lake Eyre		Enbarka Swamp, Tirrawirra Swamp, Coopers Creek, Mound springs - Francis Swamp, Mt Dennison, Billa Kalina, Neales River
Western Plateau		Lake Newland, Lake Hamilton and Sheringa Lagoon.

Source: Lloyd & Balla (1986)
FP=Fleurieu Peninsula; M=Metropolitan; YP=Yorke Peninsula; EP=Eyre Peninsula; KI=Kangaroo Island

Table 6: The status of estuaries in South Australia (data from Bucher & Saenger 1989)

Estuaries	F	T	C	A	E	L	Q	W	I	M	S
Coorong	M	P	H	M	M	I		310	<1	0	0
Port Adelaide River	M	P	M	H	C	I		3	12	17	13
Port Davis Creek	M	N	M	M	S	I		3	<1	2	10
Fisherman Creek	M	N	M	L	S	I		14	8	12	10
Third Creek	L	N	L	M	S	I		40	25	7	17
Second Creek	M	P	M	L	S	I		24	21	15	9
Port Pirie	M	P	M	H	M	I		1	7	8	13
Northern Spencer Gulf	M	P	H	H	S	I		3	2	6	12
Franklin Harbour	M	N	M	L	S	H		69	67	17	
Port Douglas	M	N	M	L	S	M		119	<1	3	
Venus Bay	M	N	M	L	U	I	E	65	15	<1	
Baird Bay	L	N	L	L	U	I	E	45	0	0	
Blanche Port	M	N	M	L	U	I	E	32	7	3	
Smokey Bay	M	N	M	L	U	I	E	16	11	8	
Tourville Bay	M	N	H	L	U	I	E	16	42	13	

F fisheries value [H=high, M=moderate, L=low]; **T** threat [R=real, P=perceived, N=none]; **C** conservation value [H=high, M=moderate, L=low]; **A** amenities value [H=high, M=moderate, L=low]; **E** ecological status [U=unaffected, S=slightly, M=moderately; C=considerably affected]; **L** land use [I=>75% developed, H=50-75%, M=25-50%]; **Q** water quality [E=excellent]; **W** area of water [sq.km.]; **I** intertidal flats [sq.km.]; **M** mangroves [sq.km.]; **S** samphires [sq.km.]

FISHERIES VALUE: Criteria considered include the importance of the estuary as a recreational or commercial fishing ground, significance as a breeding/nursery area for exploitable stocks, use or suitability for use as mariculture site and records of potentially exploitable stocks.

CONSERVATION VALUE: Criteria considered include the importance of the estuary as a scientific reference area (eg. representative example of a habitat type, a convenient study site, type locality, etc.), a remnant example of the natural condition in an otherwise developed area, its general habitat resources, educational value, unique habitat types, unusual communities, habitat for rare or endangered species, range limits and breeding/nursery grounds for fish, etc. other than commercial species.

review by Shepherd et al. 1989). Seagrass habitats in Australia, as elsewhere in the world, have been lost, fragmented and damaged through such practices as sewage discharges, urban run-off, dredging, boating, and land reclamation (Shepherd et al. 1989). In South Australia, sewage and stormwater discharges are thought to be responsible for the loss since 1935 of approximately 4000 hectares of seagrass off metropolitan Adelaide (Shepherd et al. 1989; Clarke & Thomas 1987; Neverauskas 1987a).

Seagrass meadows are particularly important for a number of reasons: as primary producers they occupy the base of the food chain; they provide important or `critical' habitats such as nursery, breeding or feeding areas for the juveniles and adults of many fish, crustaceans and other marine animals, including a large number of commercial species (Bell & Pollard 1989; Howard et al. 1989); and their extensive root and rhizome systems stabilise nearshore sediments and sand banks, enhancing coastal water clarity and reducing coastal erosion (Scoffin 1971).

In South Australia there are extensive meadows of seagrass all along the metropolitan coast, Gulf St Vincent, Spencer Gulf, Backstairs Passage offshore from Robe on the south-east coast, and in bays along the western coast and Eyre Peninsula wherever suitable substrate occurs (Greenwood & Gum 1986). It is estimated that there are over 15 000 km^2 of seagrass beds in Southern Australian waters (Greenwood & Gum 1986). As such, the seagrasses of South Australia (together with Western Australia) represent one of the largest temperate seagrass ecosystems in the world.

The sheltered gulf ecosystems of Gulf St Vincent and Spencer Gulf comprise the largest areas of seagrass in the state, providing the essential basis for many commercial and recreational fisheries and playing an important role in stabilising seabed sediments. However they are also the areas under greatest threat of increased urban and industrial development and consequently, land-based marine discharges. As mentioned previously, seagrass communities are particularly sensitive to the effects of sewage and stormwater discharges.

In addition, the effect of prawn trawling activities on seagrass habitats in both Gulf St Vincent and Spencer Gulf, although relatively uninvestigated, is likely to be considerable. A review of the marine scalefish fisheries in South Australia in 1991 concluded that prawn trawling had affected the ecology of the seabed by reducing diversity of animals and changing seabed characteristics (Rohan et al. 1991). Increased trawling in Hardwicke Bay appeared to correlate with reduced catches of King George Whiting. Further, studies both in Australia and overseas have demonstrated that bottom trawling activities result in significant modification or destruction of habitat, with resultant changes in the structure or composition of benthic communities (see Craik et al. 1990). The quantification of the physical and ecological impacts of fishing in South Australia should be a high priority area for future research.

Mangroves

In South Australia, mangrove forests are composed solely of one species, the Grey Mangrove, *Avicennia marina* var. *resinifera*. Mangrove forests occur at a number of sheltered sites on the South Australian coast and cover a total area of about 230 km^2 (EPCSA 1988). The most significant stands occur near Ceduna on the West Coast, Franklin Harbour near Cowell, around the northern ends of Gulf St Vincent and Spencer Gulf, near Port Pirie and between Port Adelaide and Port Gawler (Butler et al. 1977).

In South Australia the removal of mangroves is controlled both by regulations under the Fisheries Act, 1971-1982, and also, the Harbours Act, 1936-1981, which controls the development of coastal land. However, mangroves are still under considerable threat in South Australia due to small, incremental losses. These losses arise from adjacent urban and industrial developments, such as the salt ponds and waste and landfill areas in the Port River estuary region which are preventing the natural landward colonisation of mangroves (Burton 1982) and also, changes due to predicted greenhouse effects (Ainslie 1988); from changes in terrigenous sediment flow which are altering the seaward colonisation of mangroves in the northern metropolitan area (Burton 1982); from trampling of seedlings and pneumatophores by recreational fishers in the Barker Inlet-Port River estuary and Port Gawler region; from the effects of the recent oil spill in upper Spencer Gulf; and north of metropolitan Adelaide, from the effects of drift seaweed and seagrass, smothering young seedlings and adult trees and preventing the recruitment of young plants (Edyvane 1991a; Connolly 1986). Together, these threats pose significant potential losses of mangroves in South Australia.

In addition, another eight areas of mangroves have been recognised as being subject to physical disturbance (from recreational activities and structural development): Arno Bay, Cowell, Whyalla South, Whyalla North, Port Augusta South, Port Pirie, Port Broughton, St Kilda. Another three areas are affected by possible leaching of contaminants from nearby tailings or slag-heaps: Port Augusta, Port Pirie South, Whyalla (Burton 1984). A monitoring program has been recommended at these sites. A system has been devised to monitor the condition of mangroves in South Australia and to detect and identify any areas undergoing stress (Burton 1984).

Saltmarshes

In contrast to mangroves and seagrasses habitats, it is only recently that the importance of supratidal saltmarshes to coastal fisheries and the functioning of estuarine ecosystems has been recognised (Morton et al. 1987; Boesch & Turner 1984; Blaber & Blaber 1980; Subrahmanyam & Coultas 1980; Haines 1979; Subrahmanyam & Drake 1975). As such, coastal saltmarsh communities are an important buffer zone between the terrestrial and marine environments and form an important habitat for both terrestrial and marine fauna. In South Australia, a number of plant species within them, such as *Centrolepis cephaloformis* (dwarf centrolepis), *Halosarcia flabelliformis* and *Wilsonia* spp. have a high conservation rating (DELM 1993).

Together, mangrove and saltmarsh communities along the South Australian coast total approximately 82 000 ha, with the largest communities occurring in Spencer Gulf (46 000 ha) and Gulf St Vincent (20 000 ha). Other substantial communities occur in lower Spencer Gulf (6 000 ha), on the west coast of Eyre Peninsula (9 000 ha) and on Kangaroo Island (7 000 ha) (DELM 1993). In South Australia, as elsewhere in Australia, saltmarshes are under considerable threat from agricultural, urban and industrial developments. Unlike mangroves, saltmarshes are presently afforded no legislative protection in South Australia.

In the Adelaide metropolitan and northern beaches area alone, some 80% of the original saltmarshes have been lost to land reclamation for salt pans and industrial development. The remaining saltmarshes in the area are presently under threat from the recently proposed Multi-Function Polis urban development (PPK Consultants 1992). Although saltmarsh communities in South Australia are highly diverse (D. Fotheringham, Coastal Management Branch, pers. comm.), no inventory has ever been conducted to determine the status of these communities in South Australia. This should be a high priority area for future research.

Rocky reefs

Status not known.

Key marine species under threat or significant in South Australia

With the exception of marine mammals, reptiles and birds, the status of most marine species in South Australia, as elsewhere in Australia, is generally poorly-known. In contrast, the status of our terrestrial fauna is relatively well-known (see Greenwood & Gum 1986). For terrestrial species, the offshore islands of South Australia are particularly important because they often contain relict species that were once common on the mainland, but now only remain on offshore islands.

While the status of many marine organisms is uncertain or unknown, a number of marine organisms, particularly mammals are legally protected. However, legislative protection of the species alone is not enough and should extend protection to include `critical' habitats (i.e. nursery, breeding and feeding areas) and key ecological processes (such as upwellings and currents, water quality) which sustain these species.

Fishes

Knowledge of fish species in South Australia and their status is limited. There are 370 species of fish recorded from South Australian waters (Scott et al. 1974). Of these, some 77 species are utilised commercially, but only 20 contribute to most of the annual commercial fish catch (DELM 1993). Although no marine species is regarded as endangered, the status of the Southern Bluefin Tuna (*Thunnus maccoyii*) is of particular concern. Tuna catches declined from 14 000 tonnes in 1981 to 2 500 tonnes in 1991. The catch is now restricted to a quota at a level reflecting the real concern for the survival of this stock from overfishing (DELM 1993). Gummy and School Sharks (*Galeorhinus australis*) are also seriously overexploited. Although effort has increased over the 1980s, the stock has seriously declined. This is primarily because these species have been treated like `fish', rather than `sharks', with the assumption that they produce abundant offspring. Concern also exists over local depletions of Snapper (*Pagrus auratus*) in Gulf St Vincent, particularly the large individuals or `megaspawners' which contribute significantly to the egg biomass.

In contrast to the status of marine fish, the status of river fish are of considerable concern. All of the South Australian fish species which are officially designated as `rare', `vulnerable', `endangered' are freshwater species. Since 1988 an additional 15 species have been recorded for the State and a further 3 species have been rated as extinct (DELM 1993). In addition, two major freshwater fisheries in South Australia, Catfish and Murray Cod are considered `overfished' (Commonwealth of Australia 1991). The Department of Primary Industries (Fisheries) has imposed a moratorium on the taking of Murray Cod as there has been no significant recruitment of this species since flood flows in 1973-75 (DELM 1993).

The infrequent failure of freshwater to flow through the Murray Mouth during dry years seems to prevent Mulloway (*Sciaena antarctica*) from spawning (Hall 1986). This can mean an absence of adult fish three years later, by which time they would normally have reached maturity and returned to the Murray to breed, and can therefore eliminate a whole season's catch of the fish. Fishing and gear restrictions have been introduced for this species and a decline in catch reported in 1988 is no longer evident (DELM 1993). No significant catches have been taken from the southern Coorong Lagoon in recent years. Due to the decline, measures have been introduced to prevent spawning stocks from being depleted to a level from which they cannot regenerate.

Some legal protection has been given to several marine species in South Australia, including the Leafy Seadragon (*Phycodurus eques*) which is completely protected. This unusual fish resembles the fronds of seaweed amongst which it lives. It is now completely protected in South Australia because demand for aquarium specimens threatened the species with extinction. The Blue Groper (*Achoerodus gouldii*), a large attractive reef fish which has been depleted by spear fishing activity, is protected within the gulfs but can still be caught and used as bait to catch other fish. There has also been recent proposals for complete protection of the Great White Shark (*Carcharodon carcharius*) (Rohan et al. 1992).

Marine mammals

A number of rare and endangered species of marine mammals are found in South Australian waters. There are 31 recorded species of marine mammals (seals, whales and dolphins) in South Australia and these are largely known from occasional sightings and stranded specimens. Although the international status of many marine mammals is known, there is generally inadequate data available to quantify the status of many marine mammals in South Australian waters (EPCSA 1988). Despite this, the occurrence of the two species of pinnipeds which occur in South Australian waters, the New Zealand Fur Seal (*Arctocephalus forsteri*) and the rare Australian Sea Lion (*Neophoca cinerea*), is relatively well documented. Both these species have significant breeding colonies in South Australia, with populations representing a major proportion of

Table 7: Breeding sites of Australian Sea Lions in South Australia (adapted from Robinson & Dennis 1988*; Gales 1990; T. Dennis, SANPWS pers. comm.#)

Breeding Island	Pup Number	Pup Production	Population Estimate (pup number x 5.09)
Western Nuyts Reef	?	28	143
Middle Nuyts Reef	?	28	143
Purdie Island	49	49	249
Fenelon Island	8	50	255
Small NE Franklin Is.	43	43	219
Olive Island	25	25	127
Jones Island	2	2	10
Ward Island	?	28	143
Liguanea Island	23	25	127
Albatross Island	12	12	61
North Islet Island	8	8	41
Peaked Rocks	23	30	153
English Island	40	40	204
Dangerous Reef (NW)	236	236	1 201
Dangerous Reef (SE)			
Kangaroo Island	162	180	916
North Pages Island	280	310	1 578
South Pages Island	242	260	1 323
SA Islands (% Australian)	**707**	1 354	**6 892 (69%)**
Point Labatt *	1-3	180	68-46
Nullabor Cliffs#	90		1 000 (10%)

the world complement for both species. Although all whales, dolphins, porpoises and seals in Australian waters are completely protected under the Commonwealth Whale Protection Act 1980, there is a clear need to protect the key feeding and foraging areas of these mammals, in addition to their breeding areas.

Pinnipeds:

The Australian Sea Lion in particular is one of Australia's most endangered marine mammals and one of the rarest and most endangered pinnipeds in the world (Gales 1990). Prior to seal hunting, this species occurred along the whole of the southern coastline, but is now confined to the waters of South Australia and Western Australia. The estimated population of 6900 sea lions in South Australia represents approximately 69% of the estimated Australian or world population of 10 000 for this species (Gales 1990). Major breeding areas for sea lions in South Australia include the Pages, Dangerous Reef and Seal Bay, and Kangaroo Island (Gales 1990; Robinson & Dennis 1988). Point Labatt on western Eyre Peninsula remains the only and largest mainland breeding site for this species in the world. In South Australia, Australian Sea Lions have been recorded on a total of 69 offshore islands and reefs and three mainland sites (Robinson & Dennis 1988). A total of 18 offshore islands, particularly off the Eyre Peninsula, support breeding populations of sea lions and a further 18 islands have been identified as possible breeding sites (see Table 7).

New Zealand Fur Seals (*Arctocephalus forsteri*) are also well represented in South Australian waters, comprising approximately 22 600 individuals or 83% of the Australian population (Shaughnessy 1990). The major breeding colonies for this species occur on the Neptune Islands (the northern of the South Neptune Islands and the western of the North Neptune Islands), southern Kangaroo Island and Liguanea Island, which comprise approximately 13 800, 5800 and 2200 individuals, respectively (Shaughnessy 1990). In addition, the offshore islands in South Australia, particularly off the Eyre Peninsula (i.e. Sir Joseph Banks Group, Nuyts Archipelago and islands off the Jussieu Peninsula) comprise smaller but significant breeding and haulout sites for both these species. In South Australia, fur seals have been recorded on a total of 36 offshore islands and reefs and 14 sites on Kangaroo Island (Shaughnessy 1990). Of these, 11 have been identified as breeding sites (see Table 8).

As the New Zealand Fur Seal population increases in South Australia, interaction between fur seals and fishers can be expected to increase (Shaughnessy 1990). This will take the form of covert interaction (with boats and gear) and overt interaction (competition for common prey species). One outcome of the former is entanglement of fur seals in marine debris and incidental mortality of seals during fishing activity. Although the feeding areas of fur seals are not known, they spend a considerable proportion of their time either resting or traversing waters in the immediate vicinity of colonies. Therefore some of the adverse effects of the covert interaction between fishers and fur seals could be alleviated if marine reserves were declared in waters surrounding fur seal colonies. Such reserves should prohibit fishing activity, but it would be unrealistic to prohibit fishing vessels from using well established anchorages in the lee of fur seal colonies (Shaughnessy 1990).

Breeding populations of both *Neophoca cinerea* and *Arctocephalus forsteri* are highly susceptible to disturbance by humans (Gales 1990; Shaughnessy 1990). As such, affording breeding colonies prohibited area status has been recommended as the most straightforward method of protecting these colonies (Gales 1990; Shaughnessy 1990).

Whales:

Many coastal bay and inlets around South Australia are also popular sites for visits by the endangered Southern Right Whale (*Eubalaena australis*) (Ling & Needham 1991, Kemper et al. 1994b). In particular, the waters at the Head of the Great Australian Bight (and to a lesser extent, at the Merdayerrah sand patch) in the Nullabor Cliffs region, is the most significant breeding and calving site for this endangered species in Australia (S. Burnell, University of Sydney, pers. comm.). The Head of Bight region is also one of the few areas in the world where Southern Right Whales breed and nurse their young in an area that is within close proximity to shore and readily accessible to the general public. Estimates currently put the world population of Southern Right Whales at around 3000, with an estimated Australian population of 400-800 (see Bowker 1994; Stephensen 1993).

The Great Australian Bight region is also recognised as a significant seasonal habitat for many other species of rare and endangered marine mammals. At least 17 species of cetaceans have been recorded including Blue Whales, Sperm Whales, Minke Whales and Humpbacks (Kemper & Ling 1991).

Dolphins:

Two species of dolphin are commonly sighted in the coastal waters of South Australia, the Bottlenose Dolphin (*Tursiops truncatus*) and the Common Dolphin (*Delphinus delphis*), both of which have a cosmopolitan distribution.

Table 8: Estimates of New Zealand fur seals at breeding localities in South Australia, 1989-90 summer (from Shaughnessy 1990)

Locality	Pup No.	Population Estimate (pup no. x 4.0)
Cape Gantheaume (KI)	525	2 100
North Casuarina (KI)	442	1 768
Cape du Couedic (KI)	477	1 908
Kangaroo Island (other)	2	8
South Neptune Island	1 974	7 896
North Neptune Island	1 472	5 888
Liguanea Island	555	2 220
Little Hummock Island	7	28
Four Hummocks Island	42	168
Rocky (South) Island	75	300
Greenly Island	11	44
Ward Island	64	256
SA Population	5 646	22 584
(% Australian)		(83%)

KI-Kangaroo Island

Sea birds

The bird fauna is probably the best known of all the faunal groups in South Australia, owing largely to the efforts of many amateur ornithologists over the years. Information from this source is collated by the Royal Australian Ornithological Union at a national level, and by the State Museum and the South Australian Ornithological Association in South Australia. Despite this, the abundance and population trends of practically all species of sea birds breeding in Australia are not known (van Tets & Fullagar 1984).

There are six species of penguins and over 75 species of marine birds recorded from South Australia. Little is known of most species, the main exceptions being those species that nest and rear their young on land. The oceanic sea birds are the least well understood (Greenwood & Gum 1986). Information on the seasonal movements of birds has been gleaned from the ringing of chicks while still in the nest and the subsequent recovery of the rings when birds are washed up on the shore.

Of the six species of penguins which occur in South Australia, five species are considered `occasional visitors'. As such, South Australia does not form an essential part of the range for these species. However one species of penguin, the Little Penguin (*Eudyptula minor*), commonly occurs on a number of islands and coastal and offshore regions, with a total of 21 breeding sites recorded in South Australia (van Tets & Fullagar

1984). This represents approximately 14% of the total number of breeding sites recorded for this species in Australia. Although the species is common in South Australia it has rarely been reported in the Head of the Bight region, which may reflect lack of observers as breeding occurs at the foot of the Nullarbor cliffs (Reilly 1974); many observations of Little Penguins have been between Victor Harbour and Port MacDonnell .

Two species of sea birds which may have been affected by human activities are the Osprey (*Pandion haliaetus*) and the White-Breasted Sea Eagle (*Haliaetus leucogaster*) for which there have been no known breeding records in the upper Spencer Gulf region since 1890 (Greenwood & Gum 1986). The Port Pirie lead and zinc smelter commenced operations in 1889. If the heavy metals released affected the survival of any species, those high on the food chain would be most likely to be in danger. It is possible that other factors may also be involved in the loss of these species of birds. The Osprey, previously rated as endangered in South Australia, have been upgraded to the less severe category of vulnerable (DELM 1993).

Marine reptiles

Three species of tropical and subtropical marine turtles are recorded from South Australian waters, the Loggerhead (*Caretta caretta*), the Green Turtle (*Chelonia miydas*) and the Leathery Turtle (*Dermochelys coriacea*). All three species have the major parts of their ranges in tropical and subtropical waters and individuals encountered in South Australia are likely to be vagrant individuals. Their status here is not known, but all are considered under threat on a worldwide basis, owing to human predation of adults and eggs, and disturbance of breeding beaches (Greenwood & Gum 1986).

Marine invertebrates

The status of invertebrates of economic importance (such as the Southern Rock Lobster, Western King Prawn and Green and Blacklip Abalone) are relatively well known in South Australia. Of the commercially-fished invertebrates, only the Western King Prawn is considered `overfished' (Commonwealth of Australia 1991). However, the status of the remainder of the invertebrate fauna is poorly known in South Australia. In part this is due to the lack of taxonomic knowledge and research. Of the 6440 species estimated to occur in South Australian waters, only a third of these have been collected and described to date (EPCSA 1988). The crustacean and mollusc fauna is very diverse in South Australia, however less than half of the fauna has been described (W. Zeidler, SA Museum, pers. comm.). Some groups such as the jellyfish and echinoderms are well documented, however other groups such as sponges, acoelomate worms and plankton, are either variable in growth forms, small in size or belong to groups that are difficult to identify.

The lack of detailed taxonomic information and the lack of information on distribution and numbers, means that estimates of the status of many marine invertebrate species in South Australia is impossible. Many diverse groups of marine invertebrates produce few, large eggs and have small numbers of direct developing young and therefore may be expected to have extremely patchy and localised distributions. For these reasons, habitat rather than individual species protection is a more effective strategy for protection of marine invertebrate faunas.

The most pressing threat to marine invertebrates is habitat destruction resulting in extinction at the local or regional level. In South Australia, estuaries and bays near centres of population represent the major affected habitats. As such, the local loss of seagrasses, mangroves and saltmarshes is generally accompanied by local reduction or extinction of the marine invertebrates which inhabit these habitats. As in many parts of Australia, many edible intertidal invertebrates near large human population centres are now subject to over-exploitation at high levels unknown a few decades ago. In South Australia, uncontrolled harvesting of intertidal invertebrates for bait or food is common along the metropolitan Adelaide coast and is probably having a major local impact on these intertidal ecosystems. The extent of harvesting of intertidal organisms has not been investigated in South Australia.

Marine monitoring in South Australia

South Australia was the last State in Australia to legislate to control marine pollution from point sources. As such, the introduction of the *Marine Environment Protection Act* in 1990, occurred approximately 17 years after all other States in Australia (Rozenbilds 1991). The last State to introduce legislation before South Australia was Tasmania in 1973 when it passed it's *Environment Protection Act.*

The *Marine Environment Protection Act 1990* requires the Minister to protect the marine environment and keep it's condition under review. Virtually all point sources of pollution (115) are now licensed, with conditions which require licensees to monitor their discharges and to reach guidelines values before the year 2001, or discontinue the activity. However, diffuse source pollution is not addressed under the act. Further, sea-based fish farming and areas of severe pollution such as the Patawalonga and Lake Bonney, are exempt under the legislation. Ambient marine monitoring is coordinated by a Marine Environment Protection Committee (MEPC). The MEPC has budgeted funds and sought co-operation of other State and Local Government agencies and research organisations to plan ambient monitoring of nutrients, faecal contamination, suspended particulates, exotic species and heavy metals in areas of known contamination. This reflects action priorities for South Australia, published in the `State of the Environment Report'. Apart from license conditions requirements for the monitoring of point source discharges, no ambient marine monitoring programs have been established to date in South Australia. Existing marine monitoring programs are often irregular and generally inadequate (Rozenbilds 1991). Monitoring programs are principally outfall-based and often lack biological/ecological criteria (see Reichelt 1990 for an outline of environmental monitoring in South Australia).

Of particular concern is the significant lack of biological information on South Australian coastal marine ecosystems, specifically the distribution, nature and composition of subtidal benthic habitats. This baseline information is essential if the effects of pollution or coastal developments are to be assessed in monitoring programs. Both comprehensive marine faunal and floral surveys and detailed taxonomic studies (particularly of marine invertebrates) are required if the status of South Australia's coastal marine ecosystems are to be accurately monitored and assessed.

The regulatory provisions of the *Marine Environment Protection Act 1990* will be taken up into integrated pollution management under the *Environment Protection Act 1993* (DEP 1991). The newly established Environment Protection Authority has allocated a budget of approximately $150 000 for ambient marine monitoring in South Australia for 1993/94.

State of the environment reporting

A preliminary report for South Australia was issued in 1985 and was followed by more comprehensive reports in 1988 and 1993. The *Environment Protection Act 1993* requires a further report every 5 years. A total of fifteen pages of the current report deal with the marine environment, including pollution, fishing and the conservation status of its flora and fauna. No specific environmental goals or monitoring guidelines (for example, physical indicators, biological indicators, sampling regimes) are indicated either for particular coastal areas or for particular coastal or marine habitat types.

Summary & conclusions

South Australia possesses a large range of coastal habitats and ecosystems; from the rough-water rocky habitats of the south-east and west coast, to the calm-water seagrass and mangrove habitats of the gulf regions. Threats to these environments and their fauna and flora result primarily from the effects of land-based pollution discharges, habitat loss through urbanisation and coastal developments, the effects of overfishing and conflict between competing user groups. These problems have resulted primarily from the lack of a national or state marine conservation strategy to provide a coordinated framework in which to protect South Australia's diverse coastal and marine ecosystems.

The two extensive gulf systems of Gulf St. Vincent and Spencer Gulf represent one of the largest, sheltered coastal ecosystems to be found anywhere in Australia, comprising one of the largest temperate seagrass ecosystems in the world (Shepherd et al. 1989). However the considerable level of human activity and the sheltered nature of these ecosystems have made them particularly vulnerable to the effects of pollution. This has resulted in a significant decline, since the 1960s, of the nearshore seagrass communities along Adelaide's metropolitan coast (due primarily to sewage and stormwater run-off) and more recently, in the loss of mangroves. In northern Spencer Gulf, seagrasses and mangroves, an essential ecological component of the commercial and recreational fisheries in the area, are under increasing pressure from the industrial activity in that region. This comes, in particular, from the continued industrial and urban discharges of Port Pirie and Whyalla and the threat of oil and chemical spills from shipping.

According to the State of the Environment Report for South Australia (DELM 1993), land-based pollution has a significant impact on the coastal areas of South Australia. Major areas of concern identified include the northern Spencer Gulf, the Port River, and the outfall areas of treated and untreated sewage along the Adelaide coast, Port Lincoln and the South East. In areas adjacent to intensive urban development, such as the city of Adelaide, pollution from stormwater run-off is a significant source of contaminants to offshore coastal waters (DELM 1993). While the levels of heavy metals in seawater appear relatively low and the levels of contamination of aquatic species with heavy metals are generally considered within defined standards, this assessment has recently been brought into question (Rozenbilds 1991). In a recent comprehensive review of marine pollution in South Australia, Rozenbilds (1991) has highlighted the lack of the scientific rigour of past studies; the lack of comprehensive monitoring of marine pollution, particularly biological monitoring; and the lack of monitoring of diffuse sources of pollution. In general, monitoring programs are limited and outfall-based. As such, very little is known of the effects of marine pollution on the coastal ecosystems of South Australia (Rozenbilds 1991).

The paucity of biological information, particularly the distribution, nature and composition of marine benthic habitats, is seriously limiting the accurate monitoring and assessment of the status of South Australia's coastal marine ecosystems and habitats. To this end, urgent baseline studies are required to document the range of habitats, their distribution, and identify key monitoring organisms. Taxonomic studies are also required for many marine invertebrate groups if local or regional species extinctions are to be detected.

However, while some localised instances of severe pollution do give cause for concern, the South Australian marine environment is overall, relatively unpolluted (Rozenbilds 1991). The main problem is currently nutrient enrichment, and is likely to remain so for the foreseeable future (Rozenbilds 1991). Stormwater run-off and sewerage effluent, as the major contributors to coastal eutrophication, are the probable issues of growing concern over time, while dinoflagellate blooms have the potential to become an increasingly significant and intractable problem. While their contribution to nutrient enrichment is likely to be negligible, the full ecological effects of sea-based aquaculture activities, such as caged tuna farming, and the effects of prawn trawling, have yet to be assessed.

In addition to marine pollution, overfishing by commercial and recreational fishers also poses a considerable threat to South Australia's aquatic resources. Three fisheries are considered to be `overfished'; twelve are considered `fully fished', seven are considered `underfished', and five are of `uncertain status' (Commonwealth of Australia 1991). Further, the status of knowledge for management is considered adequate for only 5 of 27 fisheries (i.e. 19%): Blacklip and Greenlip Abalone, Southern Rock Lobster, King George Whiting and Australian Salmon. The knowledge required for Ecologically Sustainable Development is considered adequate for only 2 fisheries in South Australia (i.e. 7%): Blacklip and Greenlip Abalone (Commonwealth of Australia 1991).

In South Australia, the sheltered gulf ecosystems are the major centres of urbanisation and industrial development, and are particularly prone to habitat loss. In these ecosystems, major areas of concern are: extensive seagrass loss and potential mangrove loss in the metropolitan area due to sewage and stormwater pollution; loss of saltmarsh and mangrove habitat due to urban and industrial developments; and damage to soft bottom benthos due to trawling activities.

Some habitats are of particular ecological importance in South Australia. Estuaries, for instance, worldwide are not only under considerable threat from human activities, but are also places of outstanding ecological importance. South Australia however, has the least number of estuaries of any state in Australia. For this reason they are of special importance to the state. Of the 15 estuaries in South Australia, it has been estimated that one third are either considerably altered or under threat (Bucher & Saenger 1989).

In addition to habitats, there are a number of rare and endangered species in South Australia which require specific management strategies. Of particular significance are two species of marine mammals: the rare Australian Sea Lion (*Neophoca cinerea*) and the endangered Southern Right Whale (*Eubalaena australis*). For both these species, South Australian waters represent the most significant breeding and calving sites in the world. While these species have legislative protection, there is also a clear need to protect the `critical' habitats of threatened species, such as breeding and calving areas, and the key ecological processes which sustain these habitats.

South Australia's diverse marine and coastal ecosystems and their resources are of immense ecological, cultural and economic importance to South Australians. The adoption of both a coordinated approach to the management of marine resources and activities, and the preservation of the fundamental ecosystem processes and habitats which produce and maintain these resources, will be essential for the continued protection and conservation of the State's marine heritage, and also the economic welfare of the State's aquatic resource base.

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Issues in the Western Australian marine environment

James A. Stoddart* & Christopher J. Simpson

Kinhill Engineers Pty Ltd.
Victoria Park, WA*, and
Environmental Protection Authority
Perth, WA

Summary

Due to the relatively undeveloped status of most of the Western Australian coast, instances of environmental deterioration of its marine ecosystems are few. For those recorded thus far, the primary pathway of impact has been through the deterioration of water quality, caused by the addition of pollutants. Thus impacts have been most pronounced in waters with restricted mixing and estuaries are seen to be at particular risk.

Extremely low levels of population density outside of Perth and a few coastal centres apparently place little stress on marine systems and, in general, remote systems are considered to be largely pristine. However, the extent and remoteness of these systems also restricts our ability to determine their status. Knowledge of the 'natural' state of these systems is too rudimentary to detect any but the most profound impacts on their components and minor impacts may occur without detection.

In most documented cases of severe impacts on Western Australia's marine and estuarine systems, the pollutants implicated are nutrients; although adjacent to the concentration of industry in Cockburn Sound and Princess Royal Harbour, some instances of elevated heavy metals have been detected. Management programs to redress most of these severe instances of pollution at their sources have been initiated. In order of decreasing importance, statewide, these sources are:

- agriculture (impacting principally on estuaries);
- domestic wastewater;
- industrial wastewater.

Introduction

The Western Australian coastline contains the greatest diversity of marine and estuarine ecosystems of any Australian state. It stretches for over 12 000 km, through some 20 degrees of latitude, from wave-battered cold/temperate kelp beds in the south to low energy, mangrove-fringed mudflats in the north. Outside the metropolitan area, the coast supports an average of less than 30 people/km and most of its ecosystems are regarded as pristine. Nevertheless, human influence has severely degraded some Western Australian ecosystems and without careful management could do so again.

Western Australia is amongst the most urban of the Australian states, with 72% of the population of 1.7 million living within the Perth metropolitan region, and 80% between Geraldton and Esperance. Not surprisingly, it is in the waters adjacent to these populated regions that the major episodes of marine degradation have arisen. In this examination of the state of the marine environment in Western Australia, these episodes receive the greatest treatment. However, they should not obscure the high quality of the majority of the State's waters, nor our lack of information on the baseline conditions prevailing in most of these marine systems.

This treatment follows a geographic theme to allow the consideration of cumulative impacts from diverse sources. The geographic division of the state's waters (Figure 1) follows that described in the Western Australian Government's recent State of the Environment Report (Western Australian Government 1992) with some additions. Within each division, the status of the marine environment is addressed through considering the sum of impacts resulting from the primary human uses of marine and coastal resources. Conclusions drawn in this paper are essentially similar to those of the Western Australian Government report.

Uses are grouped into categories representing the major anthropogenic influences which might, at present, be affecting the Western Australian

Figure 1: State map showing localities mentioned in the text and major geographic divisions.

marine environment. The addition of a natural impacts category recognises that our ability to distinguish perturbations which occur as a result of natural cycles from human-induced changes to normal levels of ecosystem variability, is severely limited. Impacts in this category may require further investigation to determine if human sources have a role in their causation, or may need to be considered in placing human impacts in context.

In many cases, categories contain references to 'concerns raised' on possible impacts. These references are included to provide a comprehensive treatment of issues-by-area and the needs for future research. They should not be viewed as an endorsement of what, in most cases, are unsubstantiated opinions. Locations mentioned in the text are shown in Figure 1.

Regional issues

Offshore North-western Australia (off the Continental Shelf)

Australian territory off the north of Western Australia includes a variety of coral reef habitats, including the platform reefs of Ashmore and Cartier Islands, reefs fringing the volcanic Christmas Island, and the coral atolls of Rowley Shoals and Cocos-Keeling Islands. Several marine protected areas have been declared by Federal and State agencies for the management and conservation of these ecosystems and a number of marine surveys have been carried out, primarily by the Western Australian Museum.

While the Western Australian Museum surveys have provided synoptic information on the biological resources of these areas, little is known of the natural variability of these systems and whether human influences are a significant issue in their present ecology. Unless otherwise referred, the treatment below is sourced from Hatcher (1987).

Tourist and housing developments

Tourism is currently a minor activity: Christmas Island was closed to tourism until 1992. Presently, the tourist potential of Christmas and Cocos Islands is being actively investigated and could increase (Western Australian Tourism Commission, pers. comm. April 1993). On habitable islands, some infrastructure development has occurred, although developments are small and sited inland without marine structures such as wharves or marinas. Boat-based visitation of areas such as the Rowley Shoals by SCUBA divers is increasing in popularity but remains small due to the remoteness of the destination.

Fishing

Illegal fishing by South East Asian fishers , both through subsistence and commercial operations, on offshore coral reefs, such as Ashmore Reef, has been reported to have caused impacts on target species such as trochus, dugong and turtles to the extent where trochus are now described as scarce (Sarti 1983). Although fishing methods such as dynamiting have been used (Hicks 1983) protective surveillance by Federal and State authorities seems to have avoided severe disturbance to the reef habitat. The remoteness of these areas precludes any regular program of resource surveys to support claims of impacts (or their lack).

Recreational fishing and collecting of invertebrates (e.g. shells and corals) is associated with tourist visitation. Should tourism increase further, the potential for local depletion of these stocks may arise.

Aquaculture

There is no reported aquaculture activity in this area, although some proposals to undertake giant clam farming have been raised in the past.

Industry, mining and sewage

The only substantive industry presently operating in these areas is the phosphate mining operation of Christmas Island. Some minor, localised, reef damage has been reported from the anchorage at Flying Fish Cove where phosphate is exported. Spillage of phosphate and discharge of sewage into this area occur without apparent deleterious effects.

Some interest has been shown in petroleum and gas exploration in these areas, although to date production activity has been confined to the more easterly Timor Sea field.

Agriculture

Agricultural activity on these islands is minimal. There is no indication that impacts such as the increased erosion and run-off reported to result from agriculture on many Pacific islands is occurring here.

Natural impacts

Cyclones occasionally cause damage to reefs in this area. Colin (1977) reported the presence of numbers of the crown of thorns starfish, *Acanthaster planci*, around the Cocos-Keelings and attributes an apparent decline in coral cover around the mid 1970s to predation by them. More recently, Simpson et al. (in press) suggest that the impoverished fauna in the Cocos Lagoon is more likely the result of hypoxia caused by the breakdown of trapped slicks of coral spawn. Hatcher (1987) suggests that the 1982/3 El Nino greatly reduced coral cover in shallow areas around Christmas Island.

Summary
Coral reef ecosystems of the islands off the continental shelf of north Western Australia are largely undisturbed, with the exception of some impacts on species targeted by illegal fishing.

The Kimberley Coast (NT border to Broome)

This macrotidal section of coastline is composed principally of tidal flats and mangroves. Some areas in the West Kimberleys include sections of rocky coast . Sandy beaches are few, being well developed only around Broome. Most of the Kimberley coast is inaccessible from a landward direction and difficult to reach by sea. Thus the coastal waters are known mostly from those sections adjacent to the ports of Wyndham, Derby and Broome.

Tourist and housing developments
The tourist potential of this coastline has been constrained by its remoteness. Significant tourist developments with a marine focus are restricted to the Broome region; attracted largely by the transition from mangrove and mud-flat to sandy beaches in this area. Other developments, such as fishing camps for tourists have been proposed but are yet to eventuate. No assessment of the impacts of functioning operations on the marine environment have been made to date.

Fishing
Commercial: The major fishery in the region is the western extension of the Northern Prawn Fishery, which stretches into Joseph Bonaparte Gulf (JBG), where it seasonally targets banana prawns, *Penaeus merguiensis*. Some limited trawling for western king prawns, *P. latisulcatus*, occurs off Broome. The impacts of this fishery on the population ecology of pearl oysters was studied and assessed as minimal before the fishery commenced in 1989. No studies of the impacts on nontarget species of the prawn fleet operations in JBG have been conducted.

Recreational: A growing local population and tourist component targets a restricted set of fish, predominantly by line, with some netting and spear fishing. Around populated areas, mud crabs are fished enthusiastically, resulting in depleted catch rates (assessed from perceptions by Broome and Derby residents).

Little is known about the impacts of recreational fishing on fish stocks.

Aquaculture
The Kimberley hosts an extensive pearl culture operation, which is WA's largest and oldest aquaculture industry. Pearls produced in 1990 were worth about $90 million, largely as exports to Japan (Western Australian Government 1992). Pearl oysters, *Pinctada magaritifera*, are captured from the wild by divers, with the majority of shell coming from the coast between Broome and Onslow. Some concerns have been raised about the effects of pearl farming, particularly shell dumps, on the benthic habitat immediately beneath operations (Malone et al. 1988). Despite the existence of a number of farms, no specific examples of impacts have been documented.

Industry, mining and sewage
Little industrial development is present on this coast. Meatworks in various centres discharge effluent, mainly into well-flushed estuaries, with no reported adverse impacts.

Agriculture
Concerns exist that modification of catchments by the extensive pastoral industry of the Kimberley is impacting on coastal and estuarine waters through increased sedimentation caused by erosion (Western Australian Government 1992).

Natural impacts
Shallow water ecosystems in this region are prone to the effects of cyclones which occur predominantly in mid summer to early autumn (Lourensz 1981). The strongly seasonal river flow may also cause occasional habitat disturbance through extreme sediment loads deposited on areas under the river plume.

Summary
The marine environment of the Kimberley region is considered largely untouched, although this assessment certainly reflects the rudimentary state of our knowledge of these waters.

The Pilbara Coast (Broome to Exmouth)

Much of this coast is dominated by the large tidal range characterising the Kimberley Coast, although towards the southern parts of this section, tidal range is down to 2m -3m (Easton 1970). In nearshore waters, small to medium stands of mangroves occur shoreward of habitats that commonly include low lying sandy or rocky shores with some coral reefs, usually developed over rocky substrates. Mangroves are best developed around the eastern shores of Exmouth Gulf.

Tourist and housing developments
Marine based tourism in the region is small. That which exists concentrates primarily on recreational fishing. There is little infrastructure associated with tourist developments: some fishing camps exist on islands but support relatively few visitors.

Fishing
Fisheries in the area present a diverse array of target species, fishing methods and size of operation. Examples of the larger operations include prawn trawling in Nickol Bay, trawl, line and trap fisheries targeting finfish, and the deep water trawl fishery for scampi and deep water prawns which extends past the continental shelf (Jernakoff 1988). Pair trawling for demersal fish by international vessels on the North West Shelf has been shown to have caused significant damage to bottom communities. Operations have subsequently been discontinued, although it appears that recovery of these communities will be slow (Sainsbury et al. 1992)

Recreational fishing around centres of population is prevalent although unlikely to be sufficiently intense to alter stocks.

Aquaculture
Despite the presence of many areas of sheltered water, little marine aquaculture has developed, outside of a few small operations targeting winged pearl oysters. Land-based aquaculture is largely constrained by a lack of freshwater sources, high temperatures and the enormous evaporation rate. Some culture of milkfish within the primary ponds of a salt producer has undergone trials.

Industry, mining and sewage
Over the past 10 years, substantial offshore oil and gas reserves have been developed on the North West Shelf and the area is due to become the major supplier of domestic energy within the decade (Fraser 1992). As a result of marine research undertaken by government and private industry in support of managing the impacts of this industry, an extensive knowledge base exists for the region's broad scale oceanography and the distribution of benthic habitats.

To date, there is no record of any oil spill having a significant effect on the area's marine ecosystems. Neither has monitoring associated with oil and gas operations shown widespread impacts on marine communities, although localised mortality of coral and mangroves has occurred. Further increases in exploration, drilling and production are planned for the next decade and will raise the potential for some form of impact. Past experience suggests that the potential for adverse impacts from routine discharges of production water may be of more concern than the effects of accidental oil spills, which are likely to be of limited volume given the high level of technology and management planning of current operations.

The region's substantial focus on the mining of high volume products such as iron ore has led to the development of substantial port facilities at Port Hedland and Dampier. On a tonnage basis, the port of Dampier, which handles iron ore, salt and liquid gas exports, processes the greatest volume of product of any in Australia.

A large solar salt field operates around Dampier. Other than the mortality of mangroves, caused during resumption of areas to create the initial ponds, this operation has not been shown to impact marine ecosystems (Robertson 1993).

Agriculture
Pastoral leases within this area of low rainfall and run-off are not considered to impact on the marine environment.

Natural impacts
With extensive areas of shallow (<10 m depth) waters, habitats on the inner North West Shelf are especially at risk from cyclones. Monitoring studies associated with the oil and gas industry have observed several widespread episodes of coral bleaching, which has been attributed to natural causes similar to other coral reef areas (see Brown 1990 for references). Coral predation by *Acanthaster planci* has also been documented as a regular feature of reefs within the western section of the Dampier Archipelago (Simpson and Grey 1989; Johnson & Stoddart 1988).

Summary
Despite the presence of a variety of human activities on this broad expanse of continental shelf, few adverse impacts have been recorded. Some localised damage around port facilities has degraded small areas of bottom; the only extensive damage recorded has been caused by demersal trawling for fish which has since ceased.

The Gascoyne Coast (Exmouth to Kalbarri)
Coastal waters of this area are characterised by their clear oceanic nature which results from a narrow continental shelf and low, or very seasonal, run-off from the land. Much of this coast, particularly that to the south of Shark Bay, is comprised of rugged cliffs which make access difficult.

Tourist and housing developments
A tourism industry with a focus on Shark Bay has been under way for some years. A large proportion of this tourism is based on the dolphin viewing area of Monkey Mia where the regular visits of dolphins to beach areas has been developed into a well known attraction. Some impact of visitors and their support facilities has resulted from pressure on nearshore ecosystems from beach-side toilet blocks (WAEPA 1989) and access to stromatolites. Recent incorporation of sensitive areas within marine protected areas could provide the management necessary to mitigate such impacts.

Fishing
Large gill nets for shark have been banned from Shark Bay as a response to perceived risks of entangling and drowning dugong or turtle in this area (Western Australian Government 1992). Trawling for scallops continues to provide good catches, with over 2500 tonnes of meat in 1991 (Western Australian Fisheries Department 1993)

Aquaculture
Aquaculture operations in this area are minimal. A historical pearl farming operation based on *Pinctada albina albina* in Shark Bay is now represented by a single operator. No environmental impacts of this activity have been raised.

Industry, mining and sewage
Industry along this section of coast is minimal. Some small developments occur at Carnarvon, but have not been implicated in any pollution events.

A large solar salt industry exists within Shark Bay. Recent expansion of this operation met with some opposition on the grounds of excluding fishing operations from some traditional grounds and annexing part of the local fish nursery area. There are no documented impacts of this salt industry outside of pond areas. North of Shark Bay, another salt production facility operates a shipping jetty at Cape Cuvier - also without reported impact. Shipping associated with the industry has caused marine impacts, with the wreck of the Korean Star and associated oil spillage near Cape Cuvier in 1988 (May 1992).

Agriculture
Pastoral leases within this area of low rainfall and run-off are unlikely to impact on the marine environment.

Natural impacts
Disturbance to coral reefs as a result of bleaching and predation by corallivorous snails has caused substantial impacts in some areas (Stoddart 1989). The cyclical nature of this latter impact, which has caused the loss of coral over hundreds of kilometres is yet to be verified. In 1989, corals, fish and many of the reef animals were killed within an area of 3 square kilometres at Coral Bay on the Ningaloo Reef as a result of oxygen starvation caused by the decomposition of slicks of coral spawn trapped within the Bay (Simpson et al. in press).

Summary
Marine impacts of human activities are either minor or nonexistent in this sparsely populated area of coast. Much of the area has now been declared as marine parks and is subject to management.

Temperate West Coast (Kalbarri to Cape Naturaliste)
This section of coast houses the bulk of the state's population and industry. It is also an area of coast which slopes gently to meet the sea at sandy beaches, often protected from the full force of ocean waves by offshore lines of limestone reefs. This physiography acts to increase the potential for anthropogenic impacts by facilitating developments on the fragile dune systems adjacent to the sea.

Tourist and housing developments
Coastal developments within this section are the most intense for the coastline. Marinas predominate as a focus for tourism, housing and fishing harbours. Of 29 marinas listed as planned, under construction or developed, 23 occur here (Western Australian Auditor General 1991). Other than their initial construction in greenfield sites, these marinas are not recorded as causing detrimental impacts to the shallow marine ecosystems in which they are sited.

Fishing
A pot fishery for the Western Rock Lobster dominates fishing in these waters, both in terms of fishing effort and economic value. This fishery is the most valuable single species fishery in

Australia (DPIE 1992). The impacts of this fishery have been largely confined to impacts on the target stocks. Some isolated instances of mortality on sea lions and turtles have been noted when these animals are trapped in fishing gear.

Where the fishery extends into coral reef areas at the Houtman Abrolhos Islands, concerns have been raised over the potential for lobster pots to damage sensitive coral communities (Abrolhos Islands Task Force 1989). In most cases, coral communities and preferred fishing sites are spatially separated. A management plan to provide for fishing and conservation is being developed to address areas of potential conflict.

Some impacts of trawling have been suggested for the inshore waters around Geographe Bay. A research program studying the impacts of trawling on nontarget species in this area is due to report in early 1993 (Western Australian Government 1992).

Aquaculture

Aquaculture activities in these waters are limited. Culture of mussels, *Mytilus edulis*, in waters in and around Cockburn Sound and Warnbro Sound expanded in the late 1980s. These operations have had no apparent environmental or social impacts. Rather, the concern has been with the possible impacts of water of poor quality emanating from Cockburn Sound. Elevated levels of heavy metals and tributyltin (TBT) have been reported from wild mussels occurring in the waters of Cockburn Sound (see below). No such impacts on mussel flesh from farmed mussels have been reported.

Industry, mining and sewage

The major concentration of industry on the west coast occurs in Kwinana, approximately 10 km to the south of Fremantle. A primary consideration in siting industry at Kwinana was its location adjacent to the sheltered waters of Cockburn Sound which provided an excellent (in engineering terms) environment for constructing port facilities and wastewater outfalls, and in some cases, a source of raw materials. The well-studied decline of the ecosystems of Cockburn Sound during the 1960s and 1970s is largely attributable to this sheltered nature, which results in low flushing of waters.

The natural ecosystem of Cockburn Sound and areas immediately adjacent to the north contained dense meadows of seagrass, dominated by species of *Posidonia* and *Amphibolis*. Addition of excessive amounts of nutrients, primarily nitrogen, to these waters from industrial effluents and treated sewage resulted in the prolific growth of macroalgae which subsequently caused the loss of more than 75% of a seagrass cover estimated at 4000 ha in 1954 (Western Australian Government 1992). As a result of studies in the 1970s which revealed the extent of seagrass loss and its probable causes, nutrient reduction to the Sound has declined under stringent management guidelines.

Despite the improvement in water quality, it appears that the original seagrass beds are unlikely to return as a result of the poor colonising ability of *Posidonia*, the major structural component of these beds. This substantial shift in the dominant habitat type may not have had a substantial impact on the Sound's fisheries. Catches from beach and purse seine, gill net, crab net, mussel diving, line and pot fisheries are reported as increasing since 1977 (Western Australian Fisheries Department 1993), although fishery status was not recorded statistically prior to the major habitat perturbation.

Currently, the majority of Perth's domestic wastewater (treated sewage) is discharged to the adjacent marine environment. While there are few obvious effects of this discharge to date, substantial increases predicted to occur over the

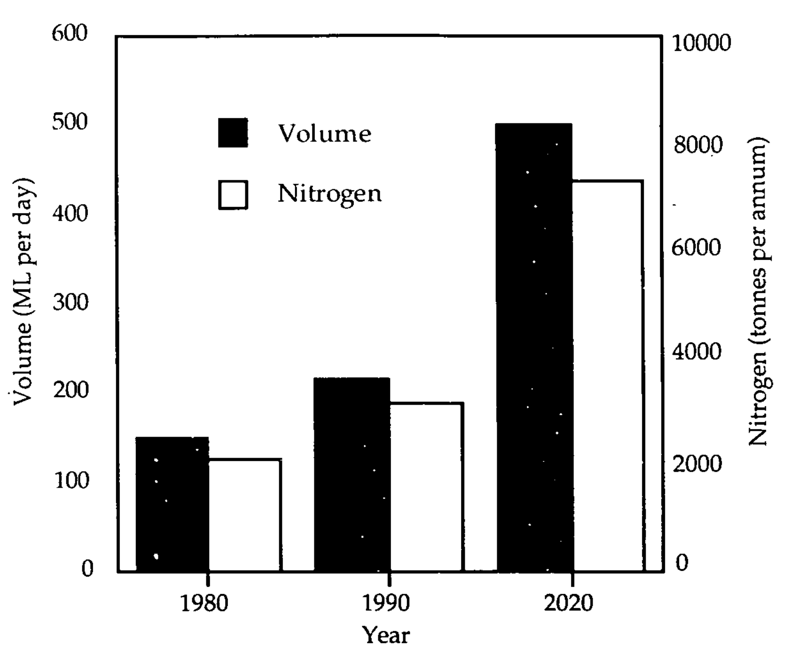

Figure 2: Discharge of treated wastewater to Perth coastal waters (2020 projection)

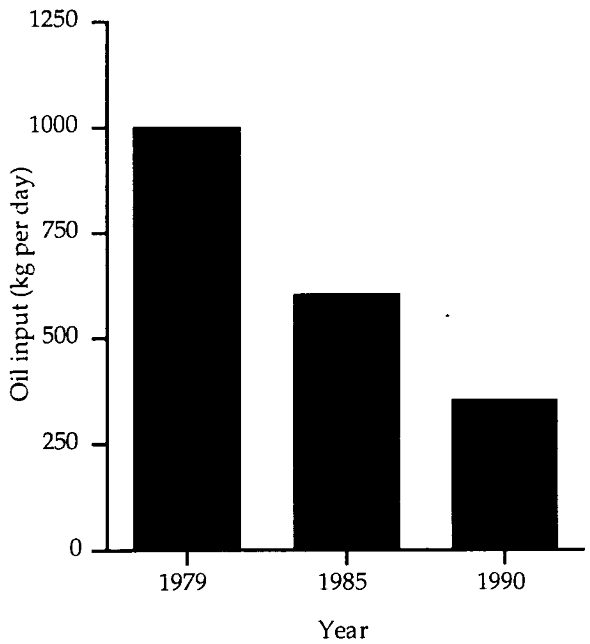

Figure 3: Oil input to Cockburn Sound

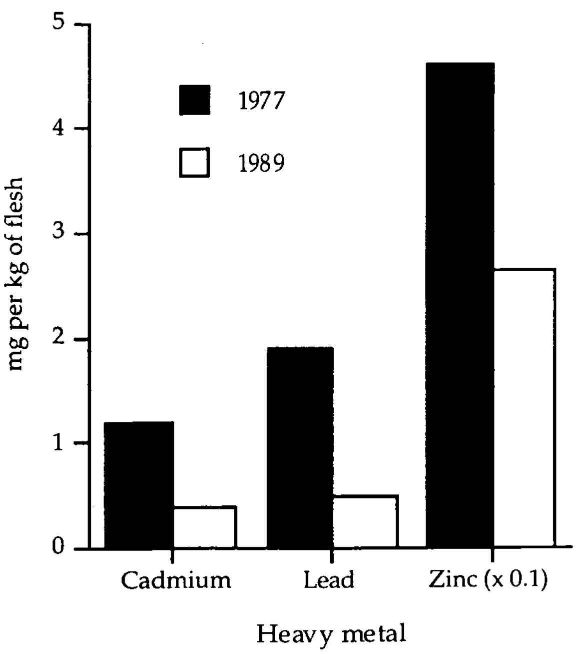

Figure 4: Heavy metals in Cockburn Sound mussels

next 30 years (Figure 2) with a doubling of the population served by this system may exceed the nearshore ecosystem's assimilative capacity. In April 1991, the State Government initiated a comprehensive program of study of the existing and predicted future impacts of this discharge. Joint studies coordinated by the EPA and Water Authority of Western Australia which focus on the cumulative impacts of nitrogenous discharges to coastal waters between Yanchep and Mandurah will provide the information needed to develop a long-term strategy for management of waste discharge. The overall program, due for completion in December 1994, contains a predictive modelling and a comprehensive monitoring approach to avoiding eutrophication within these oligotrophic systems.

Heavy metals derived from industrial pollution have also caused problems in Cockburn Sound in the past. However, a recent survey by the Western Australian Environment Protection Authority (WAEPA) shows that levels of all pollutants discharged into Cockburn Sound have decreased dramatically over the last 10 years as a result of better waste treatment and control; oil discharge for instance (Figure 3) has dropped by about 70%. Consequently, WAEPA studies have shown that toxic contaminants (heavy metals, pesticides and hydrocarbons) in mussels and marine sediments have fallen considerably since the late 1970s (Figure 4).

Associated with the concentration of industry within this location is the regular transit of ships carrying a variety of cargoes with potentially significant implications for marine pollution. A recent incident underscoring the potential for pollution derived from shipping occurred in 1991 when the tanker *Kirki*, carrying 70 000 tonnes of crude oil, lost its bow in heavy seas off the Cervantes area and was taken in tow only a few kilometres off the nearshore reef line. Had the tanker grounded and broken up, the impact on the shallow rock lobster grounds would have been substantial.

A less obvious form of pollution associated with the shipping and boating industry derives from the antifoulant TBT. A recent report (WAEPA 1990a) points to detectable levels of this highly toxic chemical around Cockburn Sound and studies suggest that impacts are occurring in molluscs at least (Kohn & Almasi, in press). It is likely that similar studies in other areas sustaining high boating or shipping use could find similar results. Present regulations prohibit the use of TBT on vessels below 25 m.

Agriculture

Extensive modification of the catchments of streams and rivers in the south-west of Western Australia caused by agricultural clearing and the addition of nutrients, either as fertilisers or animal wastes, has had a severe impact on rivers and estuaries. Of 22 estuaries assessed in the WA

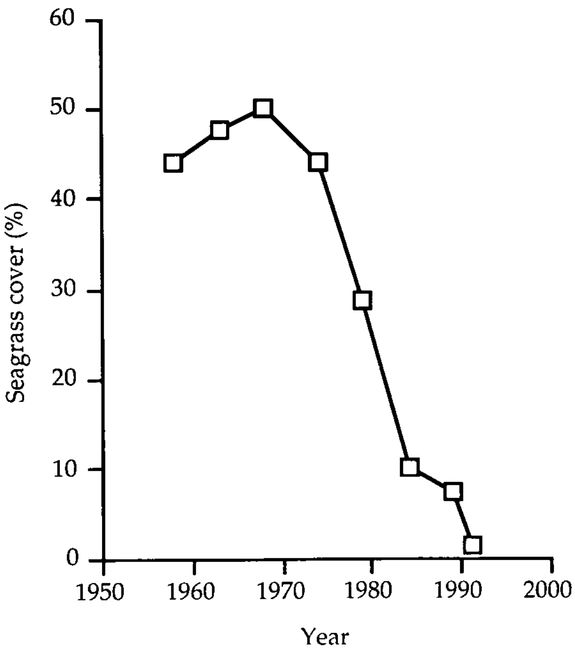

Figure 5: Decline in seagrass cover in a nearshore meadow in Geographe Bay

State of the Environment Report (Western Australian Government 1992), nine are listed as in poor condition. For eight of these nine, agricultural sources are shown as the primary cause of eutrophication.

Perhaps the most severe case of estuarine eutrophication in Western Australia involves the Peel-Harvey estuary, a shallow lagoon 70 km south of Perth. The system's natural productivity and restricted flushing predispose it to eutrophication. Symptoms of an increasing phosphorus load within the catchment were first observed in the 1960s as extensive floating accumulations of the alga *Cladophora*, but escalated steeply in 1973 with the appearance of severe blooms of *Nodularia*, which are now regular features in late Spring/early Summer (Kinhill 1988).

Poor phosphorus binding capacity in the sandy soils of the coastal plain results in a rapid passage of phosphorus fertilisers applied in agricultural operations into drains and streams within the estuary's catchment. At present, a multifaceted management strategy is under way to reduce the problem through algal harvesting to ameliorate the symptoms of eutrophication, catchment management to reduce inputs of nutrients, and enhancement of flushing through the provision of a more direct connection with the sea.

Another site where eutrophication may be occurring as a result of agriculture and/or urbanisation is Geographe Bay. Preliminary studies of the Bay's seagrasses show a progressive thinning of an inshore meadow near Dunsborough (Figure 5). A recent underwater survey found substantial algal growth on leaves of the seagrasses at this site; a common indication of excessive nutrient loading which may lead to seagrass death.

Summary

As a result of the relatively high population density of this section of Western Australia's coastal waters, the majority of documented impacts have occurred between Kalbarri and Cape Naturaliste. Outside of water bodies with restricted circulations, these impacts have been minor. Most impacts relate to deterioration in water quality due to nutrient loading, although some heavy metal pollution has been apparent from industry. Management of nutrient problems in Cockburn Sound and the Peel-Harvey estuary has largely redressed water quality issues, although the original ecosystems have not been restored to any degree. Investigations of the possible impacts of nutrient loading and TBT in Perth waters are under way.

The South Coast (Cape Naturaliste to the South Australian Border)

Rugged rocky outcrops dominate this high energy coastline which is flanked largely by deep waters supporting extensive temperate kelp ecosystems.

Tourist and housing developments

Coastal developments within this area are few and extremely localised. With the complex physiography of the coast in this region providing a surplus of natural harbours, minimal alteration of coastal structure has been necessary to provide havens for boats or ports.

Fishing

Fishing operations in this region are diverse, ranging from deep offshore trawling in the Great Australian Bight, to purse seining for bait fish, some tuna fishing and a traditional onshore beach seine fishery for Australian salmon. Little is known about the impacts of these fairly remote operations. In general these operations are at a small scale and unlikely to cause substantive perturbations.

Aquaculture

Attempts to establish cage culture of Atlantic salmon at Albany have proven unsuccessful and

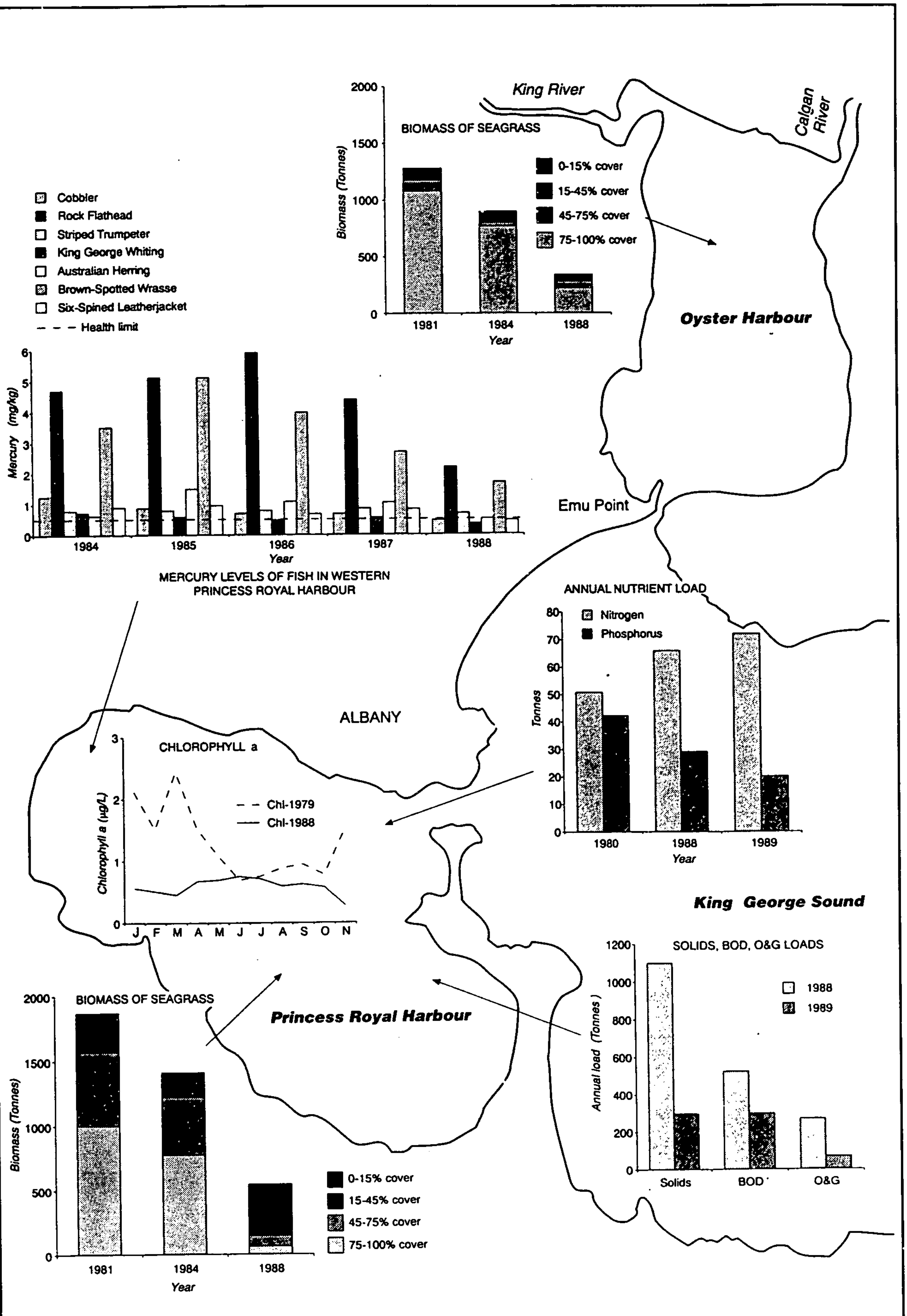

Figure 6: Albany harbours - contamination and biomass

the cages been removed. Present aquaculture is directed at establishing hatchery and grow-out operations for the flat oyster, *Ostrea angasi*, at Albany and some interest has been shown in oyster culture in other estuaries. These operations are not expected to lead to adverse environmental impacts.

Industry, mining and sewage

Princess Royal Harbour is a moderate sized embayment adjacent to the town of Albany, with a narrow opening to the sea. Nutrient discharges from industrial and domestic wastes have led to the loss of most of the bay's lush seagrass meadows (Figure 6), which have been smothered by epiphytes and free macroalgae. Industrial discharges have also caused enrichment of heavy metals leading to the contamination of marine biota (Figure 6) to a level where harvesting of fish and shellfish has been banned from some parts of the harbour.

An intensive study by the Western Australian Environmental Protection Authority (WAEPA 1990b) examined the causes of this degradation and made a series of recommendations for controlling pollutant inputs. Many of these recommendations are now in place or planned and metal levels in biota have been reduced to levels which are safe for human consumption. Harvesting of macroalgae has also commenced to reduce recyclable nutrient pools.

Agriculture

Oyster Harbour (Figure 6), an estuary adjacent to Princess Royal Harbour has shown a similar loss of seagrass as a result of nutrient enrichment. In this case, the phosphate loading emanating from farms on the river catchments has been the primary causal agent. Following the WAEPA study cited above, catchment management initiatives are under way to reduce these inputs.

Wilson Inlet near Denmark, to the west of Albany, shows evidence of increasing levels of nutrients, both in sediments and as an increased standing crop of macrophytes (Lukatelich et al. 1987). Although no signs of severe eutrophication have appeared as yet in the biota, it is likely that the system is on the brink of such a change in state.

Summary

The eutrophication of estuaries, and perhaps embayments, resulting primarily from nutrient loading of catchments by agriculture is a common feature in this section of coast. Otherwise, nearshore ecosystems are in near pristine condition.

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Issues in the Tasmanian marine environment

Chris Rees

Prepared for the Parks and Wildlife Service
Department of Environment and Land Management
Tasmania

Introduction

Although Tasmania has been described as a region of low level development, with extensive areas of its coastline still largely intact (DELM 1991), from an ecological viewpoint little of the coastal zone has remained unchanged since European occupation. The environmental impacts of the issues described here have arisen from our centres of population, agriculture, industry, recreation, and exploitation of living and nonliving resources.

This review is restricted to the impacts of both land and sea based human activities on the marine component of the coastal zone. These activities are grouped according to type, looking at polluting activities, extractive activities, some problems arising from development and management issues, and actual changes to the coastal marine ecology. Because of this focus on problems, the overall picture is a negative one by design. It is therefore important to acknowledge that many people and organisations are engaged in reducing these impacts and working towards the ecological sustainability of our activities.

Characteristics of the Tasmanian marine environment

Around the main landmass of Tasmania are a number of small to medium sized islands, giving the State a considerable coastline with a wide range of coastal environments. The coastal climate is temperate maritime, but there are significant differences between various regions of the State. These are due to the nature of the prevailing winds, offshore currents, rainfall in adjacent catchments, tidal patterns, water and air temperatures. Tasmania's marine flora and fauna have been placed in the Maugean subprovince, but the northern and north-eastern coasts are also influenced by the Flindersian and Peronian provinces of south-eastern Australia.

Major features include: headlands interspersed with sand beaches and lagoons in the north-east; cliffed coast, sheltered bays and drowned river valleys in the south-east; cliffed coast and sand beaches in the south; sand beaches, headlands, river estuaries and harbours in the west; and open coast and river estuaries with numerous islands in the north.

Mean summer coastal water temperatures in the south approach 18°C and in the north 19°C. In winter, southern mean temperatures are 12°C, and in the north 13°C. Inshore water bodies experience a broader range of temperatures. The prevailing wind direction for Tasmania is north-westerly. These winds are strongest in winter and spring. Air temperatures for the State range from mean summer maxima of 17°C to 23°C, and mean winter minima of 3.1°C to 7°C. Tidal ranges vary from maximum of around 0.8 m in the southern Tasmanian region to as much as 3.3 m in parts of the Bass Strait.

Coastal water may be diluted for some distance offshore by the large volumes of fresh water flowing from some of the State's rivers. This is particularly true on the west coast where the annual rainfall averages around 3700 mm compared to 500 mm on the east coast. There is also heavy tannin staining in rivers on the west and north-east coasts, derived from organic soils.

Polluting activities

Many of the State's estuaries have urban and industrial development and associated coastal water pollution problems. The principal marine contaminants are localised in parts of the north coast such as the Burnie area and Tamar River, on the west coast in Macquarie Harbour and the Pieman River catchment, and the Derwent estuary in the south-east. These are the major centres of population and industry, or mineral extraction. Locations mentioned in the text are shown in Figure 1.

Mining

Most mining is concentrated in the west of the State in the Pieman catchment which drains directly into the sea [Renison (tin), Rosebery (tin,

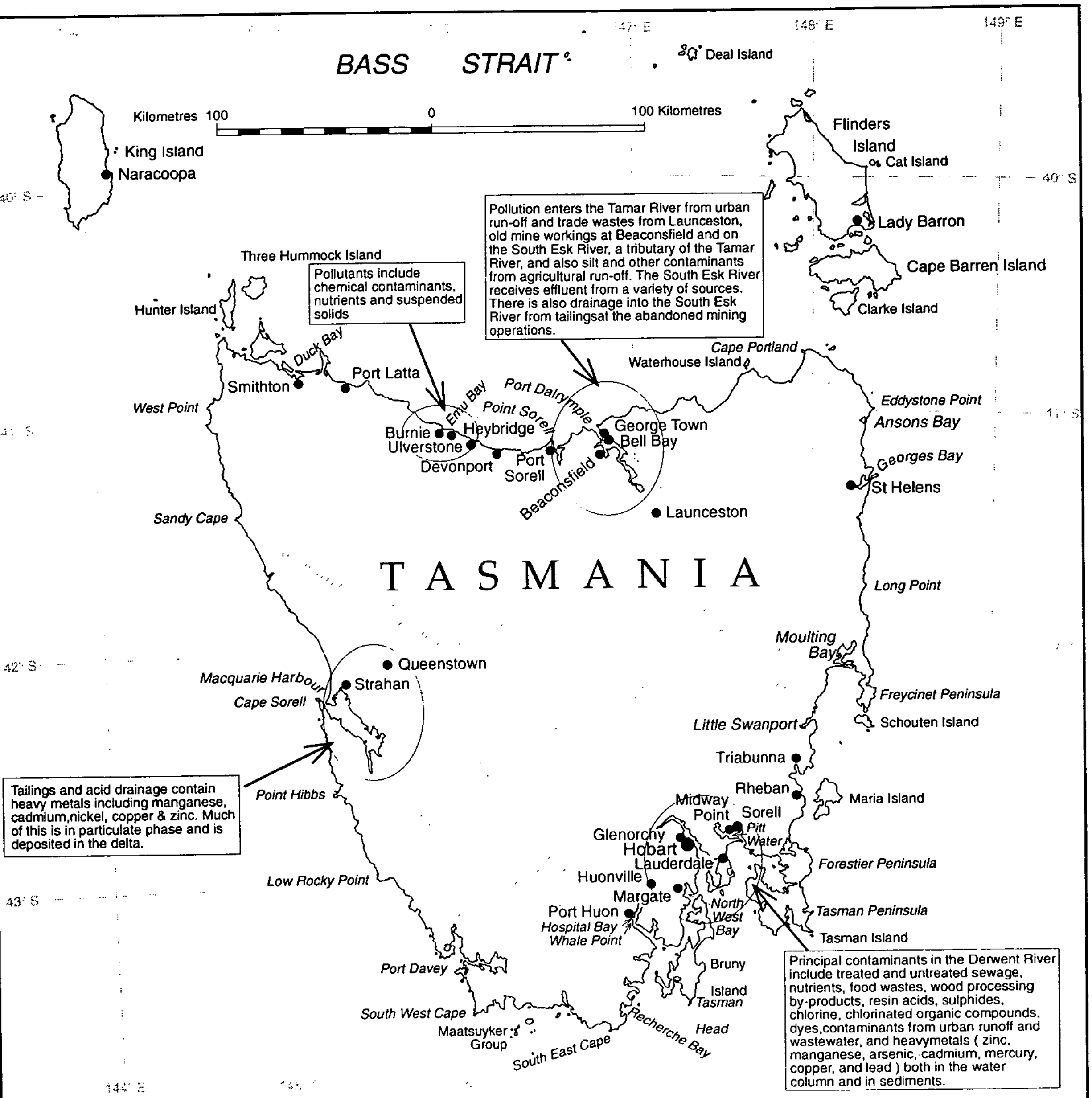

Figure 1: State map showing locations mentioned in the text, including areas containing chronically degraded zones.

lead, zinc), Savage River (iron ore), Que River (tin, lead, zinc - now closed)], and the King river catchment which drains into Macquarie Harbour [Mt. Lyell (copper)]. The adverse effect on the marine environment is the release into rivers of dissolved and particulate waste, including chemical contaminants and heavy metals.

In addition, some west coast mines, in particular Rosebery, Que River, and Mt. Lyell, are engaged in the mining of sulphide ore bodies. Waste dumps and exposed ore faces can continue to oxidise indefinitely from these mines to produce acid mine drainage (AMD). Worldwide this is recognised as a serious environmental problem, and once it is established there is at present no practical way to eliminate it. The lowered pH of AMD mobilises metals bound up in the ore body and sediments. At Mt. Lyell approximately 700 tonnes of copper leaves the site in AMD each year (Wood 1991).

The Pieman River was subject to an environmental monitoring program following a large fish kill in the lower river in March 1990 (Koehnken 1992), and reports of arsenic dumping and a tailings spill in the same period. The fish deaths were subsequently shown to have been caused by the release of a large volume of oxygen-depleted water from the Pieman dam.

Some 25% of water discharged at the mouth of the Pieman is derived from tributaries affected by mine discharges. The greater part of the sulphate, heavy metals, and suspended sediments carried comes from mining operations. Metal levels in fish caught in the Pieman catchment were within National Health and Medical Research Council (NH&MRC) guidelines (Koehnken 1992). Impacts of human activity in the Pieman catchment on the adjacent marine environment have not been researched.

Mineral processing

Mineral processing requires large industrial plants. The three major processing sites in Tasmania are in estuarine or coastal areas, and include Tioxide near Burnie on the north west-coast, COMALCO and BHP-TEMCO on the Tamar, and Pasminco EZ Ltd. on the Derwent.

Derwent River

Situated on the Derwent River just north of Hobart, Pasminco EZ Ltd. has been processing zinc ore since 1916. Prior to the 1970s the bulk of the waste from the plant was flushed into the Derwent River where much still lies in the sediments (H. Bloom, pers. comm. 1990).

A change from river to ocean dumping of waste by Pasminco EZ began in 1973, with approximately 200 000 tonnes per annum dropped 25 nautical miles south-east of Tasman Island. This is under a Commonwealth Government permit that expires on 31/10/95. Called Jarosite, the waste mixture contains mostly iron and ammonia (NH_3) with various anions (e.g. NO_3 & SO_4). The dumping is within the range of the major fisheries. Pasminco EZ is proceeding with a program leading to enhanced extraction of metals from Jarosite and land based disposal methods.

North-west coast

The release of effluent from the Tioxide plant at Heybridge east of Burnie results in the deposition of a plume of iron oxide waste into Bass Strait. This settles out on the sea bed over a large area, locally suppressing the benthic biota and altering the marine biodiversity. Another major impact is to cause turbid conditions which reduces the growth of marine algae. A ministerial exemption on Tioxide's Bass Strait discharges is due to cease in 1994.

Tamar River - Bell Bay

Bell Bay has been targeted by the State Government as an industrial zone. In this area BHP-TEMCO produces specialised ferrous alloys using iron and manganese ores, and COMALCO operates a large aluminium smelter. Both operations were attracted to Tasmania by low electricity prices. There is only limited knowledge about pollution from these plants in the Tamar River or nearby marine environments , although COMALCO does have atmospheric fluoride emissions which may precipitate into the aquatic environment. Despite levels of wastewater treatment at both sites, there is still potential for heavy metal contamination from diffuse emissions draining into the river. An environmental baseline program for Bell Bay has been outlined by the Department of Environment and Land Management, and is expected to provide comprehensive data on the estuarine and marine biota of the Lower Tamar.

Other major industries

Pulp and paper mills

A pulp mill owned by Australian Paper Mills (APM) operated intermittently at Port Huon from 1967 to 1987. The mill contributed to the general loading of dissolved nutrients and particulate waste in the lower reaches of the Huon River. In particular, a substantial buildup of solids occurred in Hospital Bay, immediately adjacent to the mill. Since the mill's closure, this blanket has retreated

There were concerns from salmon farms a short distance downstream from the mill that wood fibres being washed from the foreshore loading areas could lead to fish gill irritation. In response to these concerns, the company installed foreshore bunding around the loading areas.

The Huon Estuary is the focus of periodic toxic dinoflagellate blooms. The dinoflagellates appear to have been introduced through ballast water discharges in the estuary, and ships visiting the Port Huon pulp mill may have contributed to these discharges. An increased movement of shipping into the estuary as a consequence of a proposed woodchip mill development at Whale Point will give rise to a greater risk of discharge of additional exotic organisms that may be toxic to aquaculture species and the estuarine biota.

ANM Ltd. operates a newsprint mill at Boyer on the Derwent River, which until recently has been responsible for considerable wood fibre (prior to 1988 between 80 to 140 tonnes per day) and chemical contamination of the river, including mercury. Effluent quality has now been improved, and should continue to do so with the commissioning of a secondary treatment facility in 1996.

A summary of the Derwent River Phase 2 Study of Wood Fibre Rich Sludge in the Derwent River

Estuary, Spring 1991 and Summer 1992 (Derwent Estuary Advisory Committee, Department of Environment and Land Management 1992, p. 1) noted that:

> 'Major deposits of sludge studied in Spring 1991 and Summer 1992 were found to occur in four areas: in the mixing zone for 200 to 300m below the ANM Ltd outfall; between Green Island and Bridgewater Causeway intermittently on both shores; between Whitestone Point, Austins Ferry Bay and Dragon Point mostly on the western shore; extensively in Elwick Bay.
>
> A limited number (11) of core samples of upper Derwent estuary sediments was obtained in Summer 1992 by means of a Pelva "bomb" sampling device. The maximum thickness values of the sludge layers of 900 mm in the mixing zone and 150 to 350 mm in various areas downriver were found to be considerably less than in cores examined in earlier studies, viz. up to 2.3m in the mixing zone in 1990, and 1 to 1.3m between Bridgewater Causeway and Bilton Bay in 1989. These results also suggested that the quantity and nature of the woodfibre load discharged by ANM Ltd at Boyer has decreased considerably since 1990.
>
> A first (crude) estimate of the volume of sludge in the Derwent estuary in Summer 1992 was 571 500 m^3 (tonnes) consisting of 82 500 m^3 (tonnes) between the ANM Ltd outfall and Green Island, and 489 000 m^3 (tonnes) between Green Island and Bowen Bridge. These estimates represented decreases of ~20% and ~40% respectively in these areas compared to their values in 1990.'

Overall, the upper Derwent estuary appears to be continuing to recover slowly from the severe impact previously caused by effluents containing excessive woodfibre discharged by ANM Ltd. Limited microscopic observations of sludge showed an increased abundance of viable microalgae and decreased abundance of bacteria compared to earlier studies. The abundance of organisms higher in the food chain, however, was not investigated.

Associated Pulp and Paper Manufacturers (APPM), owned by North Broken Hill Peko, have two factories on the north coast at Burnie, and Wesley Vale near Devonport. The Burnie plant produces paper, whilst Wesley Vale is currently involved with coating paper from Burnie.

The Burnie plant bleaches the paper using chlorine. Organochlorines from this process together with fibres, organic staining and plant washings form a 'turbid, coloured and odorous' effluent which is discharged into Emu Bay just below the tide line. A ministerial exemption applies to the plant's discharges. Wesley Vale similarly has the potential to use chlorine bleaching, and ocean discharges include kaolin clay, wood fibre, organics and hosings. A clarifier was installed to remove solids from the effluent at the time of the recent proposal to build a much larger mill nearby.

Food processing

Most waste disposal from food related industries is adequately treated, though there are some areas of concern (J. Wood, DELM, pers comm.). Fish processing plants at Margate, Glenorchy and Triabunna treat their waste on site, while abattoirs in the State direct their waste to sewage treatment plants (STPs). However, waste from Edgells at Ulverstone enters the offshore outlet from the STP downstream of the treatment, and has high nonfiltrable residues (NFR). For this reason the STP requires an exemption.

The Cadbury factory on the Derwent discharges some dairy waste with a high biochemical oxygen demand (BOD) into the Derwent under ministerial exemption. However, an on-site treatment plant is being built which will discharge into the Cameron Bay STP.

Agricultural and urban pollution

Landfill

Urban and industrial waste is discarded in landfills in all municipalities except those which buy landfill space in adjacent areas. The siting of landfills on river banks at Huonville, Ulverstone and Queenstown, and on reclaimed wetlands at Lauderdale is no longer an acceptable practice. At least two of the riverside sites are due to be closed in the near future.

A number of the smaller rural landfills are unsupervised and the extent of contamination from hazardous wastes into groundwater systems, waterways and the coastal receiving waters is not known. The pollution risk to coastal waters from these sources requires research. The site at Lauderdale fails to meet the majority of DELM requirements, and windblow plastic waste and ground water contamination is a pollution risk to adjacent coastal areas.

Run-off
Urban and agricultural run-off are sources of nutrient enrichment, and other forms of pollution in numerous estuaries and coastal water bodies around the State. Examples include the Derwent estuary, Tamar River, North West Bay, Duck Bay, Georges Bay, Pittwater, and numerous smaller sites.

Most piggeries, chicken farms and feed lots have no discharge into coastal waters, but the State's largest piggery at Penguin discharges its effluent directly into the sea and carries a ministerial exemption. Many rivers and ultimately the coastal waters of the north-west receive effluent from dairy farms and processors in the area, and fertiliser and pesticide run-off from intensive commercial vegetable growing. The overall extent and impact of this run-off is largely unresearched, although remedial action is being taken with some dairy farms (see 'Existing and planned marine environment monitoring programs, Dept of Primary Industry', this paper) (J. Wood, DELM, pers. comm.). An example is the statewide survey of dairy sheds and intensive piggeries, and improved effluent control practices.

Sewage
Statewide, 45 STPs discharge directly into coastal, estuarine or bay receiving waters. Of these, 13 have ministerial exemptions covering effluent levels, including 4 that discharge directly into the Derwent river. The exemptions are due to cease by the 30th June 1994, although the lack of progress in the city of Hobart suggests that compliance with regulations may not be achieved in that time. State regulations for sewage discharge into receiving waters are listed in Table 1.

Upgrading of STPs has concentrated on installing secondary treatment stages to existing plant. Some community groups argue that no discharges should be permitted into rivers and coastal waters, and that a valuable resource is being wasted that simultaneously degrades the State's waters. It is now, however, becoming generally accepted that recycling and waste minimisation is the preferred approach, including reuse of the effluent. Some councils (e.g. Riverside and Scamander) are now investigating these options and guidelines have been released.

Marine accidents and spillages of hazardous materials

Disaster/contingency plans for oil spills
All oil products imported into Tasmania are in their refined state. Tank ships visit three ports on the north coast (Burnie, Devonport and Georgetown), and Hobart in the south. King and Flinders Islands also receive occasional deliveries of oil products. Hobart also services Macquarie Island and the Antarctic bases with oil products. The movements of tank ships in Tasmanian waters is relatively light compared to some large mainland ports. Average annual tank ship visits for each port are Hobart (20), Georgetown (12), Devonport (12), Burnie (18), Lady Barron (Flinders) (nil), Naracoopa (King Island) (1), and Port Latta (1).

Although considered a low risk, a major marine oil spill is always a possibility in Tasmanian waters. This could occur through collision at sea, collision or grounding close to the coast, minor collisions or spills in port, or illegal discharge of bilge water or tank washings. Under the Tasmanian Supplement to the National Plan to Combat Pollution of the Sea by Oil, coastal features at risk have been identified, and the State Marine Pollution Control Committee has contingency plans for all local port and harbour authorities in the event of maritime accidents, particularly oil spills. However, Tasmania does not have the facilities to cope with more than a minor spill, and plans for a major spill assume considerable assistance from other States as provided for under the National Plan. The Tasmanian Pollution of Waters by Oil and Noxious Substances Act 1987 provides for the management of marine oil pollution by shipping in the State.

Table 1: Ambient quality for water receiving sewage discharge

Receiving waters	BOD (mg/L)	NFR (mg/L)	Faecal Coliforms (/100 ml)	Grease & Oil	Dissolved oxygen
Bays & estuarine	20	30	1000	visually free	not reduced below 50%
Coastal	no limit	200	no limit	visually free	not reduced below 50%

BOD - Biochemical oxygen demand
NFR - Nonfilterable residues

Oil exploration
There is currently no oil exploration in Tasmanian waters, although a production well for oil and gas is likely to be installed in the near future in the Yolla field 140 km north of Burnie. There is a further possibility of drilling on the continental shelf off the west coast near Strahan in the future. Possible exploration of oil bearing formations in the south Bruny Island area are unlikely to involve offshore drilling.

Tar deposits found on west coast beaches have been chemically linked to exposed oil-bearing formations in Indonesian waters, and are a natural phenomenon.

MARPOL
The International Convention for the Prevention of Pollution from Ships (MARPOL) annexes I (oil), II (noxious liquid substances) and V (garbage) are in force in Tasmania as throughout Australia. To date there have been no successful prosecutions in the State. This may be attributed to the complexity of Commonwealth/State administrative arrangements associated with MARPOL, a lack of resources to regulate the MARPOL system, and the need to provide better information about the Convention and its requirements.

Activities exploiting living resources - Fisheries

Some fisheries (e.g. shark, scallop, rock lobster and barracouta) are in decline, with a reduction in fishing effort recognised as being needed, while most others are being fished at rates that present knowledge cannot guarantee are ecologically sustainable. Where catch levels have been maintained it is usually due to increased effort and improved technology. The causes of decline include at least one of the following: heavy or over-exploitation, degradation of food sources, loss of breeding and nursery grounds, pollution, habitat degradation, and natural fluctuations. Also, the consequences of the by-catches of some practices on marine ecosystems is little understood. At present no allowances are made for possible long-term consequences of environmental change, even though, for example, the decline of the macroalga *Macrocystis pyrifera* in Tasmania is thought to be due in part to ocean warming (Sanderson 1987) (see 'Ecological impacts, Habitat degradation/modification, *Macrocystis pyrifera* - string kelp', this paper).

In general, despite considerable research into individual fisheries in Tasmanian waters and the acceptance of the need for an holistic ecosystems approach to fisheries management, it is still not possible to predict ecologically sustainable levels of exploitation. Both commercial and recreational sectors of the industry tend to lobby decision makers to maintain the status quo until research proves that reductions are essential. The ever increasing list of over-exploited species indicates that a more cautious approach is necessary for the ecological sustainability of our marine ecosystems.

Regulation and policing of recreational and commercial fishing are problems due to lack of resources, and the perception by the fishers that penalties are small even if apprehended. Recently, penalties have significantly increased with a maximum fine from $2000 up to $500 000. The courts have also been given the option of jailing, for up to 2 years, repeat serious offenders.

General issues and commercial fisheries

Examples of fisheries where an accurate assessment of fish populations is lacking include crayfish, abalone, jack mackerel, orange roughy, and the inshore trawl fishery. Some species show a short- or long-term variability that may be environmentally induced, e.g. barracouta and jack mackerel. Others have almost certainly been over-fished. For example, the serious decline in school and gummy shark populations is leading to severe restrictions on further exploitation and the increased protection of nursery areas. Similarly, the scallop fishery has been closed since 1987 due to the collapse of the population through over-exploitation. At present there is little sign of any recovery. As part of the development of a new legislative basis for fisheries management in Tasmania, the management of all fisheries within Tasmanian fishing waters is being reviewed. This is being done through the development of individual fisheries management plans that will specifically consider the environmental impact of the activities managed under the plan. Management measures contained in the plans will additionally undergo a period of public comment before their introduction.

Jack mackerel
Jack mackerel have been fished industrially off the east coast since 1985. In 1991-92 the total allowable catch was set at 42 000 tonnes. In the previous year the catch was of 27 300 tonnes. The impact that the jack mackerel fishery has on the marine ecology is little understood, although it is known that the species is an important food source for some marine mammals, seabirds and other fish species.

Rock lobster (Jasus edwardsii)
The Tasmanian rock lobster fishery harvests the crayfish *Jasus edwardsii*. In the commercial fishery 10 532 pots are distributed amongst 340 vessels, with an additional 10 000 amateur licences issued annually. Current yields are considered unsustainable, with catch rates declining and the residual biomass of legal sized fish falling. Size limits must also be reviewed, as females in the north of the State do not become sexually mature before they reach the legally fishable size. A Rock Lobster Task Force has been established to study future options for the fishery (DPIF 1993) and a reduction in the fishing season has now been implemented by the Department of Primary Industry and Fisheries.

Scallop dredging and demersal trawling
Anecdotal information suggests that commercial scallop dredging in D'Entrecasteaux Channel severely degraded the substratum by exposing anoxic muds that were previously covered by sand and shell material, and that the lack of commercial scallop recruitment in recent decades is due to the altered habitat rather than overfishing itself. Whether true or not, the use of dredges which dig into the seabed clearly has the potential to cause sustained ecological damage off the eastern and northern coasts of Tasmania. This problem has only recently begun to be properly investigated in Victoria and New South Wales.

The effect of demersal trawling on the substratum, and the flora and fauna found there, is of concern both within the fishing industry and in general. The extent and impact of any effects are unknown, however, and both DPIF and the CSIRO have begun a research program into this issue.

Cockles
Some sediment dwelling bivalves, collectively referred to as Cockles, are presently being targeted for recreational and semicommercial exploitation. The harvesting of cockles can lead to the disturbance of large areas of tidal flats, where the underlying anoxic sediment is brought to the surface. This can have significant impacts on the flora and fauna of the tidal flats and the estuaries as a whole. Popular sites are Ansons Bay, Georges Bay and Recherche Bay. Commercial harvesting of clams and cockles has been banned except via limited (3) exploratory licences.

Reefs
Reef communities are targeted at all trophic levels by both recreational and commercial fishing. Examples of target species include algae, abalones, wrasses and other fish, urchins and crayfish. There is little data on interspecific interactions in reef communities.

Recreational fishing
Recreational fishing by line, net or collection is a popular pastime in Tasmania with the high level of boat and beachside shack ownership. Because of the lack of any economic restraints on recreational fishing activity, and loyalty to 'traditional' fishing spots, the depletion of local fish populations may be severe, and taking undersized fish is not uncommon. Additionally, some operators can be said to fish semicommercially, with large boats and sophisticated fish location technology. The area of greatest concern is the recreational gill net fishery.

Recreational fishing using gill nets is comparatively unregulated in Tasmania, a situation the government is now trying to change, as this practice has been recognised as decimating reef fish stocks and is banned or heavily controlled in all other States and Territories in Australia. Gill netting is permitted without a licence, with three nets allowed per person, and no lower age limit on gill net ownership. There are also no controls over the length of time a net is set, or requirements for nets to be tended. Any number of nets may be set from one boat, provided the required ratio of people is present. The Division of Sea Fisheries estimates net numbers at between 15 000 and 45 000, each up to 50 m long. The maximum length of deployable net in the State may therefore be 2250 km.

The Division of Sea Fisheries is concerned at the lack of data on this practice. There is currently a draft management plan under public discussion (DPIF 1992). Gill net use has the potential to deplete reef fish communities. If poorly set or left untended they can catch indiscriminately, causing large bycatches, or if lost can 'ghost fish' indefinitely. The impacts of, and practices used in, gill net fisheries, both commercial and recreational, on the reef fish communities around Tasmania are of concern. These issues are being addressed through the development of fisheries management plans and codes of practice for commercial and recreational gill net fishing.

Aquaculture
The aquaculture industry is based on the farming of finfish and shellfish. These operations generally occupy leases in sheltered coastal waterways and intertidal areas principally in the south-east of the State (see Figure 2).

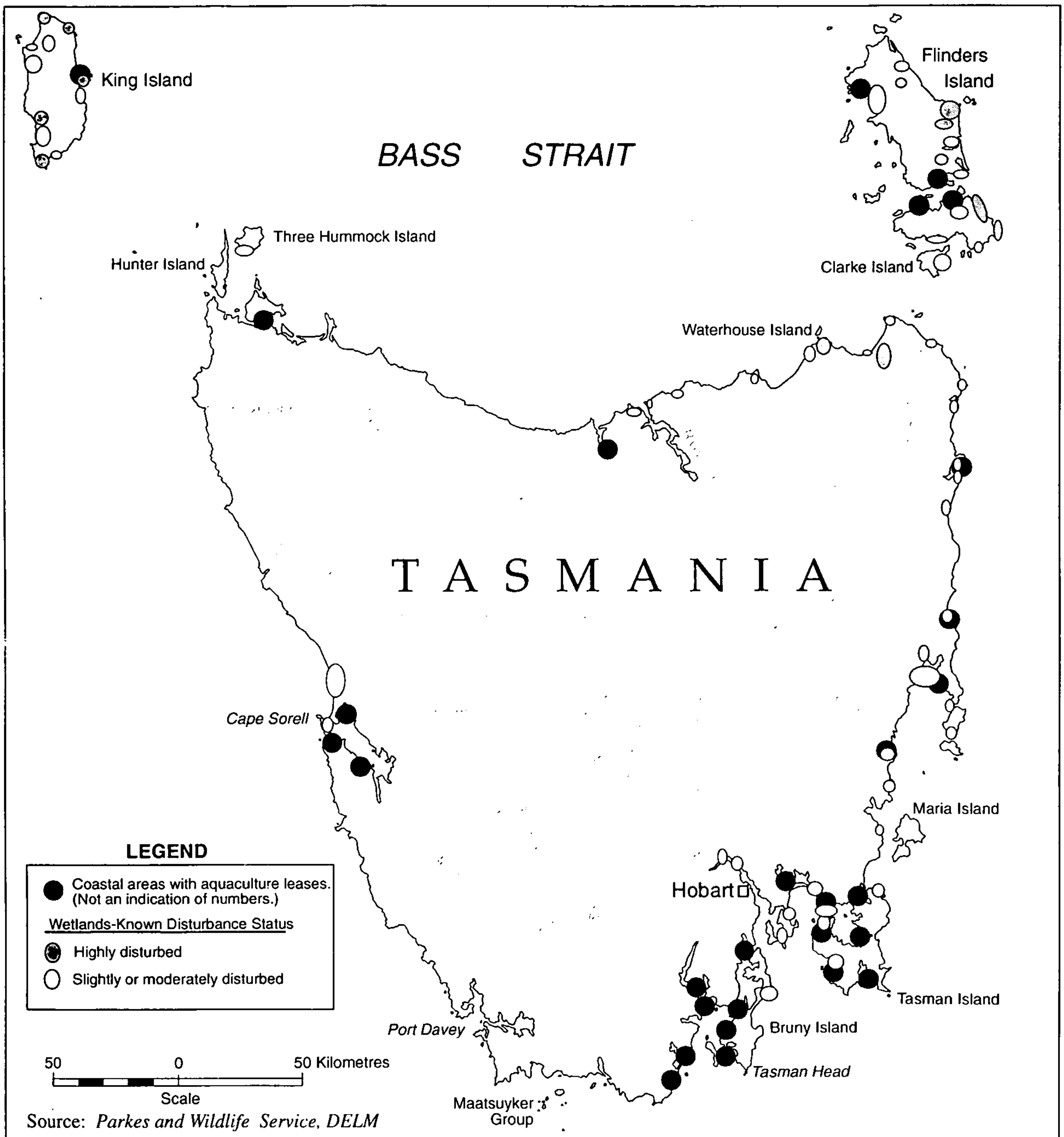

Figure 2: State map showing locations of principal aquaculture development, and disturbed wetland areas.

This Industry is one of the fastest growing areas of primary industry and has further potential to expand, providing new jobs and economic growth. In recognition of the benefits of aquaculture, the Department of Primary Industry and Fisheries is undertaking a major program to produce Aquaculture Development Plans (or planning schemes) that introduce a zoning system for all marine farm growing regions. Special planning legislation has been developed to support these schemes. Plans will be completed for the major growing areas in south-east Tasmania (e.g. Huon River/D'Entrecasteaux Channel) by the end of 1994. Key environmental factors are being taken into account in the delineation of aquaculture zones. Environmental management plans for each aquaculture zone and Codes of Practice to guide the operations of farms are also being introduced.

Finfish farming

Salmonid species have been farmed in Tasmania since 1984. The industry has evolved structurally and technically after an initial rush of speculative capital in the early years, and competition for suitable lease sites. These were granted in many otherwise undeveloped inshore waterways. Atlantic salmon and sea-run rainbow trout are the species farmed, with research into farming Striped Trumpeter in progress. The current state of knowledge in relation to potential environmental impacts include:

(1) adverse interactions with wildlife, with small numbers of seals and seabirds being shot. This is now very rare due to improved netting and cage design;
(2) some sea bed degradation and localised high nutrient loadings due to faecal waste: the routine rotation of cages to leave sites fallow, and minor adjustment of leases to improve natural flushing have lessened this problem. Woodward et al. (1992) in a two year study found that salmon farming was having no detectable impact on algal blooms and nutrient cycling in the Huon estuary. Localised loss of benthic biodiversity may be an issue with some groups, however, this loss is not viewed as irreversible.
(3) their visual impact in otherwise unobstructed waterways. Visual pollution, noise and loss of amenity have been common objections to the expansion of existing farms or the granting of new leases, and the alienation of the adjacent foreshore by the building of facilities is a problem in some areas;
(4) some reliance on the Jack Mackerel fishery off Tasmania's east coast for feed stock (see 'Activities exploiting living resources, General issues, Jack mackerel', this paper), in addition to imported feed stocks;
(5) the impact on coastal marine ecosystems of feral fish. Some anecdotal evidence suggests that feral salmon and trout consume many juvenile native fish and other organisms, however, there is no scientific support for this view. Unpublished inspections of gut contents of many salmon specimens indicates that escaped salmon are more likely to starve, perhaps due to their habituation to pelletised food (N. Barrett, pers comm.).

There have been 36 finfish leases granted (DPI 1992), although not all these are operational. A moratorium on new salmon leases is due for review in November 1993. Some operators are presently seeking enlargements of existing leases. However, most future growth in the industry will tend to use offshore deepwater sites where there will be less impact on inshore ecosystems.

Shellfish farming

Shellfish farming includes oysters, mussels and, on a small scale, abalone. There are 91 leases granted for Pacific and/or flat oysters, though not all are occupied (DPI 1992). Shellfish farms are usually less obtrusive than finfish farms, the major points of conflict with the human community being the loss of navigable water, visual impact and noise from harvesting operations. Impacts on the coastal marine ecology are less clear. Locally there may be a loss of food for other plankton feeders, and a decline in seagrasses in the immediate vicinity of intertidal racks due to algal growth, shading and turbidity caused by boat activity. However, there is no clear scientific evidence to date in relation to these possible impacts. There is also some suggestion that seagrasses are coming back in some areas where there are oyster farms , for example Little Swanport and Moulting Bay.

Coastal and catchment management and development activities

In the postwar decades there has been considerable development of the coastal zone in many parts of the State. This includes urban and industrial development, wetland drainage, forest clearance, road building, and holiday shack development often on fragile shore land such as dune systems. Many municipal authorities have permitted coastal subdivisions in response to the demand for waterfront holiday properties. Planning and administrative problems in the coastal zone have been discussed in detail in State and Commonwealth government reports (DELM 1991; RAC 1993), and a newly established coastal policy unit within the Department of Environment and Land Management is focussed on developing an integrated coastal policy for the State. Two development issues affecting the coastal marine environment are briefly considered here.

Manipulation of hydrological cycles

The majority of the State's rivers in all regions have been dammed or modified for the production of hydro-electricity, irrigation, or domestic and industrial water supply. On the north-west coast almost all rivers are intercepted by farm irrigation dams; the west coast rivers are dominated by hydroelectric schemes, as is the Derwent flowing to the south-east; the Coal River has been dammed for a major irrigation scheme in the south-east; some east coast rivers, such as the Meredith, Prosser and Scamander, are dammed for town water supplies; and the South Esk and Tamar system supports irrigation, town water supplies and a hydroelectric scheme.

These modifications have tended to alter natural seasonal flow patterns, reduce total discharges, cause deeper penetration of saline water into some rivers, and subject some rivers to unseasonal releases of fresh water. The ecological impacts on the coastal marine environment are largely unresearched, but may result in loss of habitat, altered sedimentation patterns, and disruption to natural breeding and migratory patterns.

Port and jetty development and operations

Potential port development problems include the modification of the environment by landfill, construction and maintenance works, and the disposal of dredge spoil. These activities are usually in areas already highly modified such as Burnie, Port Dalrymple, and Hobart, but may prevent the recovery of habitat. On a small scale there are many new jetties and boat ramps added to the shoreline annually, often related to aquaculture activities or holiday shack development. Each has only a small and very local impact, but in total amount to a significant intrusion into inshore waters. An incremental loss of habitat and additional point sources of debris are possible results.

Lighthouse destaffing and implications

Under cost-cutting measures by the federal administrating body AMSA, Tasmania's lighthouses have been progressively destaffed over recent years, and replaced with automatic beacons. In many sites, particularly on the Tasmanian mainland and close to human habitation there has been no decline in safety due to the improved navigation technology of shipping. However, there are other important functions in having a human presence in remote areas that are not fulfilled by an automatic beacon.

The lighthouse on Maatsuyker Island off the south coast provides the only administrative presence in a dangerous and remote area frequented by many fishing vessels and recreational craft. Up to the minute weather reports and prognoses are obtainable from the lighthouse staff, and relief coordination in the event of mishaps at sea. Additionally, the fragile flora of nearby islands and the adjacent coastline of the World Heritage Area of south-west Tasmania has been subject to numerous deliberate fires, and local seal colonies have been regularly harassed. The official presence on Maatsuyker Island provides a significant deterrent to these illegal activities. Similar issues apply to the lighthouse on Deal Island in Bass Strait. AMSA plans to destaff and automate both these sites.

Ecological impacts

Habitat degradation/modification

Other activities discussed elsewhere contribute to degradation and modification of habitats. Described here are specific examples of ecological change.

Seagrasses

Seagrass beds in Tasmania have declined significantly in a number of areas close to large human population centres (Rees 1993). Five species of seagrass occur in Tasmanian coastal waters. In the Furneaux Group on the north coast, particularly among the islands of the north-west, there are extensive areas of *Posidonia australis*, and smaller areas of *Amphibolis antarctica* and *Heterozostera tasmanica*. On the east coast and in the south-east of the State, seagrasses are confined to sheltered bays and estuaries, and tend to be dominated by *H. tasmanica*, but include *Halophila australis* and *Zostera muelleri*.

In many cases these water bodies have been receiving waters for urban, industrial and agricultural waste, which have added nutrients and suspended solids to the water column. These have been identified as causes of seagrass decline in other parts of Australia (Larkum et al. 1989). Recent research has shown significant losses in the Hobart and D'Entrecasteaux region, Triabunna and St. Helens on the east coast, and the Tamar, Port Sorell, and Duck Bay near Smithton on the north-west coast. A strong relationship between seagrass decline in these coastal areas and the presence and abundance of algal epiphytes on seagrass beds has been demonstrated (Rees 1993).

Macrocystis pyrifera - String kelp

Macrocystis pyrifera is a brown alga and the largest of the kelps, forming dense stands offshore along suitable rocky coastlines. Plants may grow up to 30 m long, forming an upper canopy over smaller native species They thus increase both habitat complexity and refuge for fish and invertebrate species, including larval lobster and abalone. Urchin divers claim their best catches come from within *Macrocystis* beds.

Macrocystis is also highly productive. A company was established in the 1960s to harvest this alga on the east coast, on the basis of earlier estimates of the growth rate and standing biomass by Cribb

(1954). Harvesting in most areas realised a single crop per year rather than the three anticipated, and the largest annual yield was 9000 tons. With a decline in the amount of alga, the enterprise became unviable and closed in 1972. Another proposal to harvest *Macrocystis* was rejected by the Division of Sea Fisheries in 1986. A survey had estimated a biomass of 10-12 000 tonnes. Since then *Macrocystis* has continued a dramatic decrease.

This decline over recent decades has corresponded with a rise in mean annual seawater temperatures (Sanderson 1987), although other factors have been suggested as possibly being implicated. These include:

(1) extra run-off and siltation from forestry activities affecting recruitment;
(2) earlier scallop dredging silting up inshore reefs;
(3) frond damage from boat traffic;
(4) competition from the introduced alga *Undaria pinnatifida* which occupies a similar ecological niche; and
(5) fishing pressure on rock lobsters, a predator of sea urchins may have lead to an ecological imbalance where the populations of sea urchins have increased, thereby impacting on the *Macrocystis*, one of their foods. There is no evidence, however, of a significant increase in sea urchin numbers or that they are eating out the *Macrocystis*.

Introduction of exotic organisms

As in the terrestrial environment, the marine ecology of Tasmanian coastal waters is being rapidly modified by the introduction of exotic species. Some of these are having serious long-term impacts on the biota, out-competing indigenous species with little prospect for control of their spread.

Some species, noted below, have been introduced by the discharge of ballast water from visiting bulk carriers in Tasmanian ports.

Gymnodinium catenatum - toxic dinoflagellate

Vessels collecting woodchips from terminals at Long Reach in the Tamar, Triabunna on the east coast and Port Huon in the south are the likely source of the toxic dinoflagellate *Gymnodinium catenatum*. These first appeared in 1971, soon after the first woodchip exports from the area. Blooms of these organisms threaten shellfish farms in the Huon. In 1986, 15 farms were closed for 6 months, leading to financial hardship. The situation is monitored by the Department of Community and Health Services through a $120 000 per annum program that also samples the bacterium *Escherchia coli* and other organisms in shellfish (G. Hallegraeff, pers. comm.). The Government has recently set up a 'The Harmful Algal Bloom Task Force' which will report in July 1994 and make recommendations on the management and research options needed to deal with harmful algal blooms and the requirements for environmental monitoring.

Undaria pinnatifida - Japanese Kelp

In 1988, the first plants of the exotic seaweed *Undaria pinnatifida* were found at Rheban on Tasmania's east coast (Sanderson 1990), although it may have been introduced in ballast water as early as 1982 (Sanderson & Barrett 1989). In New Zealand, plants have been found attached to ships hulls and as a consequence transported to other harbours around the country (Hay 1990). This alga is a member of the Laminariales or 'kelps'. It is an annual and can grow to 2 m in height. It can attach to a variety of substrates to depths of 15+ m, and will out-compete a number of native algal species important to the abalone and urchin fisheries. In some areas it shades 100% of the ocean floor, having profound effects on the inshore marine ecology. Temperature tolerances of critical phases of the plant's life cycle indicate its potential to spread from Woolongong (NSW) to Cape Leeuwin (WA).

So far, in Tasmania, the distribution of the alga has been confined to an area of coast from Triabunna to the southern tip of Maria Island, a distance of approximately 25 km. *Undaria* cannot be eradicated, but some control may be possible through commercial harvesting programs, since the species is an important mariculture crop plant in Japan. Local and Japanese markets could be established taking advantage of Tasmania's pollution-free image.

Predatory starfish

Another likely ballast water introduction, now well established in south-east Tasmanian waters is the Northern Pacific Seastar, *Asterias amurensis*. A predator of scallops, mussels, oysters, crabs, barnacles, and some gastropods including juvenile abalone, *Asterias* poses a serious threat to the marine ecology in the State. In Japan, *Asterias* is a serious pest to commercial scallop growers, and is a threat to the trawl fishing industry. The female seastars breed prolifically, and can produce up to 25 million eggs annually. They can live at depths from 1 to 200 m.

While a majority of the farms in the south are affected by the seastars, these infestations are being controlled by physical means. *Asterias* has no known predators, though the gonads are eaten by some Japanese communities. Harvesting is the most suitable management option and the University of Tasmania is investigating ways of using seastars as compost. However, toxins remain in seastar bodies and this may prevent the development of a fertiliser market.

The Tasmanian and Commonwealth Governments have recognised the potential impact of the Northern Pacific Seastar and have established and funded the National Seastar Task Force. The Task Force is to develop a national approach to the seastar problem and to fund research into various control measures.

A second large predatory starfish that is common on exposed reefs on the eastern, southern and western coasts, *Astrostole scabra*, has also probably been introduced to the state, as it was first recognised in Tasmania in the later 1960s but is abundant in New Zealand. A major prey of this species is abalone.

Spread of Pacific oysters

The Pacific oyster, *Crassostrea gigas*, was introduced to Tasmania in the 1950s, and is now extensively cultured in the State. The oysters have now become established in the wild, and encrust some rocky shorelines in the south-east and Tamar regions. Rocky intertidal habitats are considerably altered by the oysters, with an unknown impact on intertidal communities.

Maoricolpus gunnii - Gunn's screw shell

Gunn's screw shell is believed to have been introduced into the state from New Zealand amongst live oysters imported by boat in the 1920s.

Since its arrival, this gastropod has gradually spread in massive numbers up the east coast and has now reached southern New South Wales. In many areas, including the D'Entrecasteaux Channel, it has completely altered the structure of the benthos because the substrate is now covered with a carpet of live and dead shells in contrast to the former sand or mud. A variety of other New Zealand species were probably also introduced at the same time, including the crab *Cancer novaezelandiae* and *Petrolistes elongatus*, the chiton *Amaurochiton glaucus* and the seastar *Patiriella regularis*. The effects of none of these species on the local biota is known.

Impacts on wildlife

Marine debris

Tasmanian coasts are increasingly polluted with debris from oceanic sources, implicating activities such as fishing, boating and shipping. A large proportion of this debris is potentially harmful to wildlife. Australian fur seals have an entanglement rate of 1.7%, approximately 500 seals at any one time. Other vulnerable species include other marine mammals, fairy penguins, gannets and other seabirds.

A statewide survey conducted at a representative geographic sample of 88 coastal sites between January 1990 and June 1991 assessed the composition and source of the debris (Slater 1991). Plastics made up 65% of all debris, of which 40% was related to fishing and aquaculture (rope, nets, line, bait straps, oyster spat bags, buoys and floats). Green mesh trawl net has only been used in recent years, yet forms a major component of the fishing net debris found (71%). Some 59% of debris was potentially harmful to wildlife. The proportion of fishing debris on Tasmanian beaches appears to be significantly higher than elsewhere in the world.

Educational programs are concurrently aimed at the fishing industry, the recreational fishing and boating community, and schools who play a major role in beach surveys. The development and marketing of a strapless bait box in Tasmania is helping to reduce the number of potentially lethal straps discarded by fishing vessels.

Seals

Ten species of seals inhabit or visit Tasmania's coast. These are all protected by law, but are still threatened by illegal shooting, entanglement and ingestion of marine debris, and reductions in prey species through fishing. Conflicts with fish farms have now been greatly reduced by improved cage and protective net design (DELM 1991) following earlier research (Pemberton 1989).

Some haulout sites are subject to disturbance in the breeding season by tourist boats and illegal shooters.

Seabirds

Seabird populations in Tasmania have generally declined. Pressures include the impact of feral animals, destruction or disturbance to nesting sites by development, off-road vehicles, pets and walkers, ingestion or entanglement with marine debris, and direct poisoning or loss of food sources by pollution (Woehler 1989, and pers. comm. 1993)

Wildlife interactions with fisheries
There is a high mortality of sea birds and mammals from longline fishing within the 200 nautical mile zone (i.e. as close as 20 nm offshore). Albatrosses, gannets and seals are particularly vulnerable. Entanglement in marine debris is another cause of mortality (see 'Activities exploiting living resources, General issues' this paper), and competition for commercial fish is a likely, though unquantified source of pressure on sea birds and mammals (see 'Activities exploiting living resources, General issues, Jack mackerel' this paper). Gill nets in the Pacific are also a cause of seabird mortality. Estimates suggest that as many as 280 000 short tailed shearwaters leaving Tasmania are drowned in Japanese gill nets each year. The northern Pacific squid fisheries also kill unknown numbers.

Gannets are a favourite bait for crayfishers, and their population on Cat Island in Bass Strait has dropped from 10 000 pairs to less than 10 as a result of this activity (Woehler 1989). Fairy penguins are also in decline statewide due to killing for cray bait, nesting habitat destruction, and competition with fisheries for food.

Climate change
During the past 30 years there has been a general increase of about 1.5°C in mean water temperature in the Tasmanian region (Harris et al. 1987). Because of the retraction of the subtropical convergence to higher latitudes, there has been a substantial decrease in nutrient levels and plant productivity associated with the temperature increase. Major consequences of this change seem to include a reduction in the productivity of pelagic systems including a decline in jack mackerel stocks, loss of *Macrocystis* beds (see above) and perhaps the extinction of other algal species (e.g. *Adenocystis utricalis*, which has not been recorded in Tasmania for several decades). Any further increase in global water temperatures will presumably have a greater effect on Tasmanian than other Australian marine communities because of the formerly high productivity in this area and the lack of a refuge further south into which cool water species can move.

Areas containing chronically disturbed zones

Some regions of the State have a concentration of human activities whose effects over time have compounded to seriously degrade what was, only 200 years ago, a pristine marine environment. The most evident of these are discussed below (for locations see Figure 1).

D'Entrecasteaux Channel and North West Bay
The population of this area has increased by 33.7% between 1971 and 1991, putting increased pressure on the marine environment, already considerably altered since European occupation due to activity on land and in the waterways. Marine living resources have been depleted through overfishing, resulting, for example in the collapse and closure of the D'Entrecasteaux scallop industry. Increased sedimentation from land clearance and forestry, agricultural run-off, and effluent from urban and industrial development all continue to impact on marine vegetation such as seagrass beds and macroalgae, degrading coastal marine habitats. Some coastal wetlands have been degraded, used as illegal waste disposal sites or reclaimed for development (see Figure 2).

Water quality is of prime importance to the increasing mariculture of salmonids and shellfish in the region. An aquaculture management plan and water quality monitoring program do not yet exist for the area.

Derwent River
The Hobart area has a population of only 172 000 people and only three major industries discharging effluent into the Derwent River, yet the river was described in 1973 as one of the most polluted rivers in Australia (Bloom 1973). Studies on the biota have indicated that shellfish throughout the estuary are unfit for human consumption, while finfish are within standards but to be treated with caution due to heavy metal accumulation.

Principal contaminants in the river include treated and untreated sewage, nutrients, food wastes, wood processing by-products, resin acids, sulphides, chlorine, chlorinated organic compounds, dyes, contaminants from urban run-off and wastewater, and heavy metals (zinc, manganese, arsenic, cadmium, mercury, copper, and lead) both in the water column and in sediments. These have reduced water quality especially in shallow bays and in the upper estuary, have affected the aquatic biota, diminished recreational and commercial use of the estuary and contributed to long-term environmental degradation. Bloom (1975) found mercury levels in sediments near Pasminco EZ works (1130 µg/g) were at the time exceeded only by Minimata Bay in Japan. This study has now been repeated (see 'Existing and planned marine environment monitoring programs, DELM Environmental Management Division', this paper), and published results indicate a significant improvement since that time.

The results of government monitoring programs have been published in DOE (later DELM) annual reports which were tabled in parliament. The earlier broadwater sampling strategies by the DOE have now been abandoned in some cases in favour of more comprehensive studies of heavy metals and organic contaminants using biological indicators such as mussels and oysters (*Mytilus edulis* and *Ostrea angasi*).

In general, however, surveys have been too narrowly based. The result is that the environmental systems of the Derwent have been poorly understood, and cause/effect influences and pathways have not been mapped. Even now, effective development, planning and pollution control strategies have yet to be put in place (Chapman 1992).

Of the 14 sewage treatment plants discharging into the estuary 4 still have exemptions. All are required to provide full secondary treatment with disinfection by 1994, although it has been argued that the haste required in meeting this timetable may be detrimental to producing the most desirable outcome. Bacterial levels in the river are often high, and most popular swimming beaches have had to be closed from time to time, and activities restricted at others.

Major industries on the river have greatly reduced discharges in compliance with the lifting of ministerial exemptions in 1994. ANM has greatly reduced its effluent (see 'Polluting activities, Other major industries, Pulp and paper mills', this paper), and Pasminco EZ has similarly been reducing the metal load in its effluent so that the current ministerial exemption will not be required. Prior to the construction of an effluent treatment system significant quantities of zinc and cadmium were discharged into the river. In future these metals in wastewater will be recovered.

In general, the direction of State and local government and industry has been to reduce the levels of pollutants to within 'acceptable' limits. Community groups on the other hand are calling for zero discharges of all pollutants into the Derwent (Friends of the Derwent, Greenpeace). The DELM Discussion Paper on the review of the Environment Protection Act: Future Directions for Regulations and Standards noted that: 'Tasmania should seek to move in that direction - zero discharge as a long-term goal, particularly for persistent bio-accumulative toxicants' (DELM 1991).

Macquarie Harbour

The Mount Lyell mine in Queenstown, owned by Renison Goldfields Consolidated, began releasing tailings into the Queen River in 1922 with the introduction of flotation technology to preconcentrate the ore. This discharge has continued to the present. In December 1974 the mine was granted a pollution exemption with no specified limits. Currently, 1.5 million tonnes of mine tailings and an undocumented quantity of acid mine drainage is discharged annually into the Queen River.

The highly alkaline tailings (pH 10.1) pass from the Queen River into the King River and out into Macquarie Harbour where heavier particles drop out of suspension. A 250 ha delta has formed. Finer particles remain in suspension for some months as a plume on the harbour. The tailings and acid drainage contain a cocktail of heavy metals including manganese, cadmium, nickel, copper and zinc. Much of this is in particulate phase and is deposited in the delta. At present the alkalinity of the tailings neutralises the acid mine drainage. There is concern that when the mine ceases operation in June 1995, the un-neutralised acid drainage will liberate the heavy metals in the delta into the environment for an indefinite period.

Dissolved heavy metals have been irregularly monitored in the King River by the DOE and DEP since 1974, and in 1975 a DOE study looked at heavy metals in mine residues (DOE 1975). Recently metal levels have been studied for the first time in fish (de Blas 1992). Copper in oysters from the harbour have shown 5 times the NH&MRC standard of 70 µg/g. De Blas found mercury levels in some fish species 2 to 3 times NH&MRC standards (brown trout and dogfish respectively). As a result of these findings, in April 1993 the Department of Health advised the public not to eat some species of fish from Macquarie Harbour more than once per fortnight. Although the mining company dispute that they are the source of this contamination, figures cited in DOE (and DEP) annual reports indicate that copper and mercury levels in the Queen River rise dramatically below the tailings outfall.

A CSIRO report (Carpenter et al. 1991) found the concentration of dissolved heavy metals in the harbour to be 100 times that of coastal of seawater. The total concentration of manganese, cadmium, nickel and zinc were found to be two orders of magnitude higher, and copper three orders of magnitude higher in the lower King River than in the Gordon River which also drains into Macquarie Harbour.

In February 1993, a steering committee was formed to coordinate a 3 year scientific investigation of pollution in Macquarie Harbour.

This included representatives from the Division of Environmental Management, the Division of Sea Fisheries, the Hydro Electric Commission, and the Mt. Lyell Mining and Railway Company Ltd. The Macquarie Harbour Study is designed to examine the fate of sediment and metal dispersion in Macquarie Harbour, particularly in relation to the King River. It will assess the possible impacts of future changes to activities in the King River Catchment, including alterations to inputs from the Mt Lyell Mine and the operation of the King River Power Station. As part of the study, there will be an assessment of metal contamination of fish caught in the harbour.

Stage I will incorporate technical investigations into the physical and geochemical processes controlling sediment and metal dispersion in the freshwater and estuarine environments, and the status of sediments throughout the Harbour. The information obtained from Stage I will provide the technical basis for future environmental policy directions in Macquarie Harbour. Stage II should commence in the first half of 1994 and will examine the broader environmental management issues relating to the Harbour, together with broader community concerns. Analysis of farmed fish shows no evidence of elevated metal levels.

North-west coast - Burnie and surrounds

In the region of Burnie on the north-west coast of Tasmania a number of industries impact on the marine environment. A polluted zone extends from Table Cape in the west to Point Sorell in the east (Tasmanian Department of Environment and Land Management annual reports). Pollutants include chemical contaminants, nutrients, and suspended solids which may significantly increase turbidity.

Australian Pulp and Paper Manufacturers (APPM) commenced production in Burnie in 1938. The effluent of this plant is released directly into the sea. Other sources of pollution in the area include:

(1) acid-iron waste from Tioxide Australia Pty. Ltd. dispersed through a pipeline off Heybridge (see Newell 1986; Ritz et al. 1985);
(2) residual contamination from the Emu Bay ocean dumping site of North West Acid Pty. Ltd. prior to their 1979 closure, and;
(3) partially-treated sewage, urban run-off, quarry washings, and spills and discharges from harbour and shipping activity.

There are also towns to both the east and west of Burnie, plus light industry, agricultural run-off and the effluent from the Wesley Vale pulp mill situated about 55 kilometres to the east.

Some aspects of the impact of human activity on the littoral, benthic and marine biological communities of this coastline have been documented in various reports (Ritz et al. 1985; AEC 1982; DOE 1981, 1978, 1974). There remains a need for studies into the synergistic effects on the marine environment of combined effluents in Bass Strait, particularly in the Burnie area.

Orielton Lagoon

Orielton lagoon was created in 1953 by construction of a causeway which divided it off from Pittwater. Tidal exchange with Pittwater was limited. The northern section of the lagoon is an internationally recognised wetland, important for migratory wading birds.

The introduction of primary treated sewage in 1969 exacerbated an increasingly eutrophic environment previously dominated by extensive seagrass beds. The lagoon is now devoid of seagrasses, and has become dominated by phytoplankton and the rapid growth and die-off of a few species of macroalgae; in 1993 there was a toxic blue-green algal bloom. The visual impact and odours produced by decomposing algae affect the local residents in Midway Point and Sorell, and cause frequent complaints.

A remediation program is following the recommendations of a consultant's report, as a component of an integrated catchment study commenced by the State government and the local council. Solutions to the problem include land disposal of the effluent, increasing the tidal exchange, and a range of catchment management practices. A comprehensive monitoring program has been initiated to ensure no detrimental impact to Pittwater and the valuable oyster industry there.

Tamar River

There is only limited knowledge of the state of the environment of the Tamar River valley. The river is the site of major urban, industrial and agricultural development, with attendant pollution problems from each of these sectors. A dam above Launceston forms Lake Trevallyn which reduces freshwater flow. Some 13 sewage treatment plants discharge into the Tamar and its tributaries. Industries in the Bell Bay/George Town area include the COMALCO aluminium smelter, the Southern Aluminium wheel foundry, the BHP-TEMCO ferrous smelter, an oil-fired power station, two wood chip mills and wharfs at Bell Bay and Beauty Point, and the Sea Cat terminal at George Town.

Pollution also enters the river from urban run-off and trade wastes from Launceston, old mine workings at Beaconsfield and on the South Esk river, a tributary of the Tamar, and also silt and other contaminants from agricultural run-off. The South Esk receives effluent from a variety of sources, including a 3000 cattle feed lot, a sewage plant and dairy at Fingal, and sewage ponds at Longford. There is also drainage into the South Esk River from tailings at the now abandoned mining operations in the catchment.

DELM is currently coordinating an environmental baseline program for the lower Tamar in the Bell Bay region. This will identify many of the environmental parameters that at present remain unquantified.

Existing and planned marine environment monitoring programs

Monitoring programs are listed here under the State or Commonwealth agency responsible. (ref: RAC 1993).

Department of Environment and Land Management, Parks and Wildlife Service

The Division has data bases relating to recreational facilities, flora and fauna, and is establishing a GIS covering its activities. Specific marine programs include:

(1) Muttonbird and Seal Monitoring Program;
(2) Marine Debris and Pollution Program;
(3) Environmentally Friendly Fishing and Boating Campaign;
(4) Marine Reserves Program (baseline monitoring under Ocean Rescue 2000);
(5) Introduced Marine Invertebrate Study (with Tasmanian Museum);
(6) capture/relocation of seals for fish farm protection;
(7) recording of whale sightings, and sampling of stranded pods for heavy metals and other data, and;
(8) monitoring of seabird colonies and populations.

Department of Environment and Land Management, Environmental Management Division

This Division is responsible for licensing polluting industries and installations under the Environmental Protection Act 1973, including STPs, landfills, factories and food processing operations discharging into rivers and coastal waters. The most polluting of these generally carry exemptions granted under the provisions of the Act. Monitoring programs are gradually moving towards testing ambient levels and biological indicators rather than point discharges, although a comprehensive program of indicator monitoring proposed for Victoria (VIMS 1991) has not been developed in Tasmania.

Several air and water monitoring programs are conducted by the Division, including:

(1) West Coast Monitoring Program, a continuation of the Pieman River study sampling 36 sites in the catchment for heavy metal levels;
(2) Derwent River Monitoring Program, repeating Bloom's 1975 study of metals in fish and shellfish (now complete);
(3) Derwent River Nutrient Study, a 12 month program looking at nutrients in water and sediments;
(4) ongoing sampling of bacteria and faecal coliforms in the Derwent River;
(5) involvement in a current program in Macquarie Harbour looking at the distribution of mine tailings and the consequences of mine closure;
(6) various air monitoring programs, including the Launceston Air Study, air fallout at some major industrial sites, and monitoring lead in air, and;
(7) incident response monitoring of spills and other polluting accidents.

The Industrial Operations Branch run no specific monitoring programs but receive data from a range of industries that have monitoring obligations under their licensing conditions. These include Tioxide, APPM, ANM, COMALCO, TEMCO and EZ. Similarly, the Waste Management Branch requires industries and local authorities to conduct monitoring regimes and submit data to the agency. The emphasis is thus on increasing the auditing role of the agency rather than running costly monitoring programs itself, although these are undertaken randomly as a safeguard. A database is held of environmental monitoring results. The Bell Bay Environmental Baseline Program is similarly coordinated by the Division, but is contracted out.

In recent years the Division has developed comprehensive solid and hazardous waste management strategies. These have an emphasis on waste minimisation, reuse and recycling, and appropriate treatment and disposal practices.

Department of Primary Industry, Division of Sea Fisheries (DSF)

Evaluation and monitoring are central to fisheries management, and include:

(1) collection and analysis of catch statistics;
(2) baseline research and monitoring in Marine Reserves (with DPWH);
(3) research relating to commercially and recreationally fished species;
(4) environmental monitoring of marine farms;
(5) algal bloom monitoring and biotoxin levels in shellfish.

Department of Primary Industry, Water Resources Division

The Division has overall responsibility for the State's water resources under the Water Act 1957, but no powers over tidal waters. However it has powers to control water pollution in rivers (in cooperation with local government) and may affect the marine environment through irrigation works, river management and drainage, and foreshore protection works. Of importance is the Dairy Effluent Project, initiated in 1991 to reduce the levels of dairy effluent entering rivers in the north west of the State (see 'Polluting activities, Agricultural and urban pollution, Run-off', this paper) (due however to high *Escherichia coli* levels in shellfish farms in Duck Bay rather than a wider environmental concern).

Department of Health

The Department has extensive powers over many areas of human activity with its overall mission to 'promote, protect and maintain the health of the people of Tasmania'. It has overriding control over development and health issues, and delegates many of these powers to local government.

The Department's activities include:

(1) management of the Tasmanian Shellfish Quality Assurance Program;
(2) administration of the Food Standards Code (including seafoods) which sets maximum permissible levels of harmful substances;
(3) monitoring recreational water quality, including swimming beaches;
(4) setting standards for on-site wastewater disposal, and prescribing effluent quality criteria.

CSIRO

CSIRO does not conduct ongoing monitoring programs as such, but carries out specific research projects that may be self-initiated or requested by DASET, usually in the context of licensing agreements for particular industries. Research projects are sometimes undertaken cooperatively with industry, and the results are often confidential. The organisation sees its role as an impartial research body, yet despite this is reluctant to make available its findings in the public domain for fear of being drawn into controversial political issues.

In Tasmania, CSIRO research has been conducted into Bass Strait water movements off Wesley Vale as part of the National Pulp Mill Program, Derwent and Storm Bay pollution studies, offshore Jarosite dumping, research on the south-eastern trawl fishery, and heavy metal studies in Macquarie Harbour.

Inadequate knowledge, research and community awareness

Community interest and response to issues relating to the marine environment has increased greatly in recent years. The majority of the State's population live on or near the coast. Many own or have access to a boat or beachside shack, and perhaps enjoy fishing or other water-based activities. Public education programs have aimed at minimising the impact of some of these uses of the coastal zone, but have also encouraged many people to participate in ongoing monitoring and impact reduction campaigns. Examples of this include:

(1) Adopt-a-beach, where communities, schools and organisations collect litter and marine debris, and conduct some monitoring (particularly of wildlife) on a chosen beach. This ties in with;
(2) marine debris surveys, which have gained considerable community support and have provided data enabling some sources of debris to be identified and addressed;
(3) fishing education campaigns, using booklet distribution in schools and the community, aimed at reducing undersized catches, overfishing, illegal fishing, littering and other damage, and improving safety;
(4) cleanup campaigns, such as the Derwent, organised by nongovernment organisations and community groups who also play a lobbying role against polluters;

(5) work with the fishing and aquaculture industry on seal and seabird issues. The questions of illegal shooting of seals and seabirds and gun control on boats will need to be addressed.

Although these are generally limited programs, each has required skill and resources to establish and maintain, and has served to increase overall public interest and awareness. Their ongoing funding is, however, uncertain.

The introduction of marine reserves also has reinforced the concept that the marine environment can be protected and not just exploited. The current reserves are arguably too small to play a significant role in the conservation of marine ecosystems, but with funding for improved interpretation material and education campaigns the community may support additional marine reserves. The baseline biological monitoring of the existing reserves is an essential part of this process and deserves ongoing financial and logistical support.

Other ecological issues discussed in the text requiring urgent research include:

(1) *Undaria pinnatifida* - Japanese Kelp;
(2) *Asterias amurensis* - Pacific seastar;
(3) *Macrocystis pyrifera* - String kelp;
(4) environmental impacts of marine farming;
(5) loss of seagrass beds in specific areas, and;
(6) comprehensive monitoring of environmental indicators.

A comprehensive range of physical and biological indicators derived from the Tasmanian marine environment needs to be adopted along the lines of the Victorian program (VIMS 1991). A commitment to funding the regular monitoring of these indicators should be a priority. The State Policies and Projects Act 1993 establishes a legislative requirement for State of the Environment Reports to be prepared for Tasmania.

Data management in the State also needs addressing. Much data has been gathered independently by many agencies, consultants, academics and independent researchers, and concern a wide range of issues relating to the marine environment . However, there is currently no strategic plan to produce an integrated marine database. To build such a database would require agreement on standardisation of data storage and the free exchange of information between organisations. The result would enhance the value of present knowledge, enable limited research funds to be more effectively allocated, and improve the quality of management decisions by all relevant agencies.
Whilst the importance of raising awareness of marine environment issues through properly resourced public education campaigns is acknowledged, sanctions are also required to deter those who would flout regulations. These must adequately reflect the serious damage to the marine environment that some actions can cause. Such regulations relate to fisheries, effluent discharges, attacks on wildlife, and dumping of debris. However, there is not yet the community perception that regulations will be enforced in the courts. Therefore, legal sanctions need to be reviewed and policed with an allocation of resources that reflects the economic, cultural and ecological importance of Tasmania's marine environment.

Many polluting operations, both publicly and privately owned, have in recent decades been allowed to exceed regulations through the granting of exemptions by ministers of the day. The repeated renewal of these ministerial exemptions reflects poorly on the priorities of these past decision makers. These exemptions are now being phased out, but the environmental legacy of some of these operations remains at odds with a growing national and international perception that Tasmania has a clean and pristine environment.

Increased public awareness and debate of marine environmental issues is a desirable outcome of access to information, with the community enabled to make quality decisions over its relationship to the marine environment. The commencement of a State of the Environment Reporting program in Tasmania by the Department of Environment and Land Management will support public awareness and understanding of the issues.

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The technical paper by Mr C. Rees was reviewed by Dr G. Edgar, Zoology Department, University of Tasmania.

Issues in the Northern Territory marine environment

Russell Hanley

Northern Territory Museum of Arts and Sciences
Darwin, Northern Territory

Introduction

The Northern Territory has an area of 1 347 519 km^2 and a mainland coastline of about 7200 km which lies entirely within the monsoon tropics. It is subject to strong south-easterly winds during the dry season (May to October) and north-westerly winds during the wet season (November to April). Rainfall is correlated with latitude (Figure 1) and is generally reliable, although considerable variation in onset and duration of rainfall occurs between years.

The coastline is predominantly macrotidal, with the maximum range of about 8 m occurring in the west and gradually diminishing eastwards to less than 1 m in parts of the Gulf of Carpentaria. Much of the coastline consists of gently sloping muddy shorelines lined by mangroves and washed by shallow, warm, turbid waters. Some rocky reef and sandy foreshores are present, usually on shorelines exposed to strong seasonal winds, and reef coral development is generally poor. Sea temperatures range from 23 to 33°C.

The coast features several large ria systems (wedge-shaped indentations in the coastline), notably Darwin and Bynoe Harbours, and large embayments such as Arnhem, Buckingham and Melville Bays. The hinterland is largely monsoonal lowland, dissected by large rivers with broad seasonal flood plains. The low gradients of these plains and high tidal ranges result in tidal influence up to 100 km upstream. Most of these large tidal rivers and their flood plains show signs of recent ecological change (Woodroffe & Mulrennen 1991).

The population of the Northern Territory is about 157 000 and on the coast, the two largest population centres are Darwin (73 300) and Nhulunbuy (3500). Alyangula on Groote Eylandt has a population of 1200, but other coastal settlements are small (200-300 people), isolated, and their populations are mainly Aboriginal Australian (Gardner 1991). Most of the coastline is therefore largely unpopulated, and remains remote and often inaccessible during the wet season. Access to the coast is further restricted by the designation of 72% of the coastline as aboriginal land (Figure 1), with entry governed by permits issued by Land Councils.

The majority of the population and associated service industries and infrastructure are located in and around Darwin which is the seat of government. Unlike Nhulunbuy or Alyangula where current population levels are entirely dependent on single mining operations (Nabalco and Gemco, respectively), Darwin appears poised for substantial industrial development and population growth. Proximity to Asian markets, improved transport links with the rest of Australia, and the growth of offshore mining for oil, gas and minerals in the Timor and Arafura Seas suggest Darwin will attract large scale projects. Apart from mining and its support industries, aquaculture, agriculture and tourism also offer the potential for growth. The 1991 Darwin Regional Structure Plan identifies substantial industrial development and concomitant population growth as both likely and desirable and suggests the Darwin region will eventually achieve a population of 1 million.

Irrespective of the desirability or likelihood of population growth of that magnitude, current stresses on the coastal marine environment might be expected in proximity to the three largest coastal centres. Darwin is a small city by Australian standards, but its population does have an impact on nearby marine environments. The mining operations at Nhulunbuy and Alyangula might also be expected to have some level of impact upon the marine environment.

The marine environment near each of these population and mining centres is discussed in greater detail separately and the existing and potential impacts are identified. Locations mentioned in the text are shown in Figure 1.

Melville Bay

The Nabalco bauxite mine at Nhulunbuy lies inland and the ore is transported by conveyor to

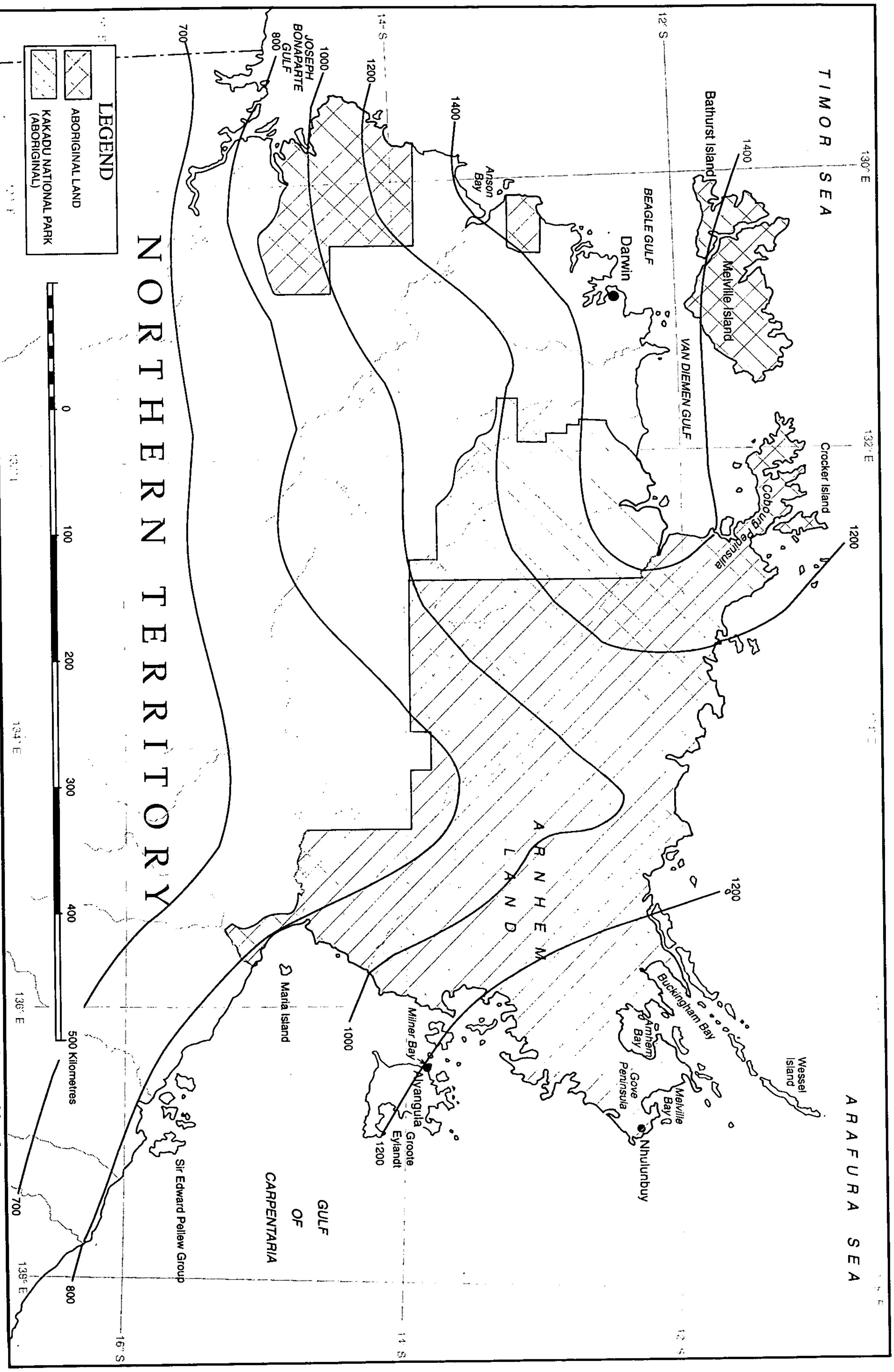

Figure 1: Territory map showing locations mentioned in the text, rainfall isohyets and Aborginal owned coastal land.

the alumina refinery on Gove peninsula. The town of Nhulunbuy lies about 10 km east of the refinery. Gove peninsula runs in a westerly direction along the northern side of a large embayment known as Melville Bay.

Melville Bay is approximately 170 km^2 in area, and is fringed by mangroves, with several coarse sandy beaches and some rocky shores. There are small rocky islands and headlands in the northern part of the bay. The water in the Bay is shallow, rarely more than 15 m in depth and mostly less than 10 m. Water temperature data is available for July 1991 (23.9 -26.2°C) and March 1992 (30.6 - 32.6°C). The tidal range is 4 m and on most low spring tides some of the shallow arms of the Bay dry out. Studies of tidal movements and subsequent impact on the distribution of sediments in Melville Bay are presented by Foster et. al. (1968). The substrate over most of the Bay is fine mud and silts, typically anoxic, and seagrasses are present but patchy in distribution. Seagrasses are largely *Halophila* spp. although several other species are reported.

There have been a number of reports (Noller 1991; Peerzada et al. 1990b; Peerzada & Dickinson 1989) examining Nabalco's operations and potential environmental impacts on the region. Concerns have included the level of sulphur emissions from the Steam Power Station stacks, the discharge of heated seawater into the Bay, occasional spills of caustic soda into the Bay (Noller 1991), and heavy metal contamination of oysters in Melville Bay.

Peerzada et al. (1990a) found high zinc levels in oysters in Melville Bay at a site close to the bauxite treatment plant. They also found the level of other heavy metals to be higher near Nabalco's bauxite treatment plant. Elevated copper levels in oysters (27.9 ppm wet weight) at one site in Gove Harbour were attributed to the presence of red mud settlement ponds that discharge supernatant liquor straight into the Bay (Peerzada et al. 1990a). This assertion that the elevated level of copper is due to Nabalco's operations in Drimmie Arm is unsubstantiated. Noller (1991) found quite different results to Peerzada et al. (1990a), and suggests that zinc contamination in oysters is probably due to the presence of boats and habitation.

Nabalco has recently undertaken an extensive study (water, sediment, heavy metals, benthic biota) of Melville Bay. Results suggest that although there is no evidence to indicate that effluent from the Nabalco refinery is contributing directly to the heavy metal load in Melville Bay, it is possible that metal levels in the north-western corner of the harbour may be slightly elevated due to discharges from Nabalco (McConchie 1991). Hanley (1993a) reported on the benthic fauna of Melville Bay collected by grab sampler at more than 100 sites during the survey. The results of the survey cannot be discussed here as Nabalco has not yet responded to the information contained within the report.

Apart from the impact of Nabalco operations on the Bay there are several other sources of concern. A barge landing facility and a fuel depot for prawn trawlers are located on the southern side of a low, narrow peninsula dividing Melville Bay from the sea. Further east along this peninsula lies the recreational yacht club in Inverell Bay. The sediments of the small embayments on the southern side of the peninsula are fine mud and silts and are highly anoxic. This is a depositional environment with poor circulation, particularly since the construction of a causeway during World War II has halted movement of seawater through the northern end of Drimmie Arm. The yacht club and small ships facilities are therefore sited in areas where flushing and dilution of effluent is poor. The regulation of activities along this foreshore is virtually nonexistent, and consequently there are small spills and leakages of diesel fuel, paints, and petroleum based products almost daily. Yachts anchored in the eastern part of the bay regularly discharge raw sewage into the bay.

The scale of these problems must be kept in perspective. The population is small, and therefore the volumes of effluent and spillages are also small, and at present there are no contaminants present in concentrations high enough to be of immediate concern. However, the poor circulation in the north-eastern area of Melville Bay suggests that cumulative problems may emerge as fine anoxic sediments act as sinks for contaminants. No information is available on the rate of exchange of seawater between this sheltered area of Melville Bay and the sea north of the peninsula. Observations made during the recent Melville Bay Survey suggest the level of daily exchange is small, and therefore if nutrient loadings to the sheltered north-eastern area increases then eutrophication is possible.

If the population of the region and/or industrial development were to increase substantially then this area of Melville Bay would be increasingly at risk. The current situation in this area requires careful assessment and the development of a management plan.

Milner Bay

The township of Alyangula is located on the north-western tip of Groote Eylandt, on the shores of Milner Bay, where manganese ore mined further south at Angurugu is loaded onto bulk carriers. The manganese mine has been operated by Gemco since 1965.

Milner Bay is sheltered during the dry season when prevailing winds are from the south-east, but is exposed to the north-west monsoon. Consequently the bay has a relatively steep floor rising to sandy intertidal flats backed by sand beaches and rocky outcrops. The tidal range in the bay is 2 m, and no creeks of any size discharge into the bay. Rainfall at Alyangula averages 963 mm per year. Some data on water temperatures has recently been collected by Gemco (Klein, pers. comm.). The bay appears to be well flushed by natural tidal and wind generated processes. The National Tide Authority has recently installed a monitoring station at Alyangula.

Johnston (1990) has reported on manganese and other heavy metal levels in marine sediments, seawater and marine organisms (oysters, fish) from samples collected in Milner Bay, a control site on the north side of the island and the two largest rivers on the island. In general, concentrations of heavy metals were found to be within the range of background levels recorded elsewhere in the Northern Territory. The exception was manganese in marine sediments, which was reported at higher than typical levels at several locations.

Alyangula is unlikely to experience any substantial increase in population or industrial activity in the future. The current manganese extraction and shipment operations appear to have had little impact on the marine environment in Milner Bay.

Darwin Harbour

Darwin Harbour or Port Darwin is a large ria system of about 1000 km^2 formed by postglacial marine flooding of a dissected plateau. The shoreline of the outer, northern section of the Harbour is predominantly coarse sands and rocky cliffs, and the estuarine shoreline of the inner, southern section of the Harbour is dominated by fine silts and mangroves. Dames and Moore (1985) estimated the volume of seawater in the Harbour at high tide is about 2.5 million m^3 and about one third of this amount is exchanged with seawater north of the harbour on every spring tidal cycle.

The three major arms of the harbour receive substantial inputs of fresh water during the wet season but negligible amounts in the dry season. Semidiurnal tides with a maximum range of 8 m ensure rapid mixing of the fresh water (Michie 1987). Salinities in the broad reaches of the harbour range from 30.5 ppt in March to 35.5 ppt in September and records for the upper estuarine sections of the Elizabeth River show a seasonal range of 6-41 ppt. Water temperatures range from 23.4° C in July to 31.0°C in December (Dames & Moore 1985).

Much of the harbour is shallow, under 10 m in depth and exposed at spring low tides. The three arms of the harbour are 10-20 m deep and the main channel of the harbour where it passes through the constriction between East and West Points reaches 36 m depth. The distribution of sediment types in Darwin Harbour has been documented by Michie (1987), but data are incomplete for subtidal areas in Middle and West Arms. A major survey of subtidal sediments and benthic biota is currently in progress and results should be available by December, 1994. The geomorphology and floristics of the intertidal zone of estuarine Darwin Harbour has been described by (Ecosystems 1993; Woodroffe et. al. 1988; Semeniuk 1985). Useful reviews of marine fauna of the harbour can be found in Larson et al (1988), and Hanley (1993b) provides a comprehensive summary of mangrove invertebrate fauna.

The city of Darwin lies on the north-eastern side of the harbour. The majority of environmental impacts on the harbour are concentrated on the area around Darwin city and the East Arm of the harbour. Although Darwin is a capital city it does not have any heavy industry. Some light industrial developments are present, such as slipways, chemical/explosives operations, cement works, fuel storage and a tannery.

Within the Darwin region the major impacts on coastal and marine habitats are the clearing of mangroves and reclamation of intertidal land (Hanley & Couriel 1992). Vehicular and pedestrian traffic on stretches of beach in the northern section of the harbour has also caused coastal dune and vegetation erosion (Kraatz 1992). Other potential problems are the discharge of sewage effluent and stormwater run-off into harbour waters.

Reclamation of intertidal land

The coastline in the Darwin region is almost entirely inaccessible as it consists of broad intertidal mudflats, dense mangroves and saltpans. The large tidal range, the presence of biting midges and mosquitos, and deep, unstable mud are significant barriers to development. However, development is proceeding and large areas of mangrove are being cleared, with landfill in the intertidal zone encouraged for a variety of land use proposals such as port facilities, mooring basins, shipyards and slipways, marinas, housing estates, refineries (oil and gas), aquaculture farms and industrial estates.

Many proposed developments have the potential to affect large areas of the intertidal zone adjacent to them. For example, the proposed hazardous and offensive chemical industrial zone on the Middle Arm peninsula would require large scale clearing of mangroves and at least some of the industries will present a threat to the surrounding mangrove flora and fauna in the event of spillages. Housing estates and marinas also have the potential to precipitate widespread destruction of mangroves. After the removal of mangroves on the construction site, there will be pressure from residents of at least some of these developments for removal of surrounding mangroves because of biting insect problems. Guidelines which suggest that no housing construction should take place within 1.6 km (Whelan 1988) of mangroves are consistently ignored.

The mangroves of Darwin Harbour (some 20 000 hectares) are one of the largest single stands of mangroves in the country and as such are nationally important (Hanley 1992a). Any mangrove loss should be accompanied by attempts to maintain productivity levels and a range of all mangrove habitat types. However, no mangrove management plan currently exists, although a management plan to be developed for Darwin Harbour may address the issue of maintenance of productivity. In the meantime, clearing of mangroves and associated landfill continues, with the proposed Darwin South development set to remove some 8-10% of the harbour mangroves if it proceeds (Ecosystems 1993). There is a very real danger that the current mosaic of development will lead to a significant loss of mangrove productivity and habitat similar to that seen elsewhere in Australia.

Sewage and stormwater effluent

The majority of sewage from Darwin is treated to secondary stage in oxidation ponds at a number of sites around the city. The two other forms of treatment/disposal are chemical precipitation, at Ludmilla, and an ocean outfall of untreated sewage, at Larrakeyah. All the oxidation ponds are sited adjacent to mangroves into which effluent is released directly. The volume of effluent released varies considerably, with the greatest volumes discharged during the wet season. Several of the smaller ponds may not release any effluent during the dry season because daily evaporation meets or exceeds the volume of water entering the ponds.

The impact of effluent on mangrove flora has been examined by Clough et al. (1983) who suggest that inputs of heavy metals, nutrients and pesticides will not be harmful to mangroves themselves, and that mangroves can act very effectively as sinks, trapping nutrients, heavy metals and pesticides that would otherwise be released into estuarine waters. Saenger et al. (1990) provide supporting evidence for this role with data showing mangroves between the Wynnum refuse tip and Moreton Bay in Queensland have trapped heavy metals, nutrients and pesticides.

Evidence from ambient water quality studies show the harbour waters are high in dissolved oxygen with low nutrient and chlorophyll a concentrations indicating little nutrient enrichment (Wrigley et al. 1990). Clough et al. (1983) presented evidence of nutrient enrichment of mangrove sediments near a sewage effluent discharge in Darwin and suggest that nutrient enrichment may be directly beneficial to mangrove flora. This is a view supported by work at several effluent discharge sites (Hanley & Couriel 1992), although the substantial fresh water input from effluent discharge is also important during the protracted dry season when growth of mangrove flora is usually negligible (Woodroffe et al. 1988).

The impact of sewerage effluent on mangrove fauna has been poorly studied in the Darwin region, although the large tidal range and strong tidal currents are thought to have an ameliorating effect through rapid dilution. However some effluent outfalls are located high enough in the intertidal zone to discharge undiluted effluent for several hours each day directly into mangroves. Hanley and Couriel (1992) compared the number of species of benthic invertebrate fauna in the effluent plume near a treated sewage outfall at Bleesers Creek (Darwin Harbour), with numbers of species from three nearby control sites. The number of species differed significantly between three of the four sites, but was not due to sewage effluent. In addition the species composition of the invertebrate fauna at all four sites was similar and representative of the mangrove fauna usually associated with the mangrove flora at that level on the shore. Presumably, the relatively low volume of effluent discharge has not yet produced conditions which lie outside the range of acceptable conditions for typical mangrove invertebrate fauna. However, any increase in the volume of discharge might produce changes.

The results of this study are not easily extrapolated to the other sewage outfall sites in the Darwin region. Although each outfall discharges into mangroves, the outfalls are located at different heights, carry different effluent volumes and are sited in different mangrove habitats. The largest outfall discharges effluent from Leanyer treatment ponds straight into Buffalo Creek and some evidence suggests effluent is shunted up and down the creek by the ebb and flow of the tides, without significant mixing.

Heavy metals and other pollutants

Seawater

The relatively low levels of industrial infrastructure and maritime activity, and the large, semidiurnal tidal range suggest the low levels of anthropogenic contaminants entering the waters of the harbour are subjected to a rapid and substantial dilution. Ambient water quality surveys of Darwin Harbour have consistently reported low levels of heavy metals, pesticides, PCBs and hydrocarbons and the harbour waters are considered pristine (Dames & Moore 1993; Wrigley et al. 1990; Currey 1988; Peerzada 1988).

Sediments

Analysis of harbour sediments for concentrations of various heavy metals and other contaminants has never been undertaken in a comprehensive fashion and the available results tend to reflect both the nature of the sediment and its position relative to sources of pollution. In a study of 8 sites around Darwin Harbour, Peerzada (1988), and Peerzada and Ryan (1987) found the highest levels of copper, lead and zinc in sediments around the Darwin wharf precinct. In November 1990 the Conservation Commission of the Northern Territory (CCNT) analysed sediments from three wharves in the Darwin Port area; Fort Hill, Stokes Hill (abandoned) and the Iron Ore Wharf. The study found high levels of trace metals below the Iron Ore Wharf. Copper, lead, zinc, cadmium and arsenic were found to exceed the National Health and Medical Research Council (NH&MRC) limits. All results except that for arsenic from Fort Hill and Stokes Hill were less than NH&MRC limits. Subsequent testing by the CCNT (in January, 1991) of sediments below the Iron Ore Wharf revealed levels in excess of NH&MRC limits for copper, zinc, lead and arsenic. Levels were generally much higher in the upper layers of sediment. The elevated metal levels were all found below or near a conveyor belt used to load metal ores onto cargo vessels. (Warren, pers. comm.). Currey (1988) recorded elevated levels of cadmium near the Stokes Hill wharf which he suggested was the result of localised shipping activity.

By contrast, surveys of heavy metals, hydrocarbons and pesticides from four nearby tidal creeks and a control area on the other side of the harbour has shown low levels of most metals and other contaminants. For chromium and arsenic, concentrations were slightly higher than NH&MRC guideline concentrations for contaminated soils. The spatial pattern of these samples with slightly elevated concentrations does not indicate any source of contamination and probably reflects natural occurrence (Dames & Moore 1993).

Within Darwin Harbour, levels of some metals such as chromium, zinc and arsenic in some sediments appear consistently high. This might be the result of leachate from old dump sites, or the result of recent mining of ore containing high concentrations of zinc in the catchment of the Elizabeth River. A large amount of material was dumped in and near intertidal areas around the harbour after the bombing of Darwin in 1942 and after cyclone Tracey in 1975. The exact location of most dumping grounds is only vaguely known and their contents are unknown. At least some are likely to contain significant amounts of a range of heavy metals. Perhaps some of the elevated levels of various heavy metals recorded in the studies discussed above may be due to leaching from these dumps. High background levels of some heavy metals in sediments may also be due to natural fluvial input from weathered ore bodies in Northern Territory coastal waters.

The results of the few small surveys of metals in sediments suggest some variability in concentrations between sites and sediment types. A recent survey of heavy metals and sediment types at some 200 sites in the harbour should produce a clearer pattern of distribution than is currently available.

Very little data on TBT levels are available. There is currently no regular monitoring of areas adjacent to slipways in Frances Bay (Darwin Harbour) for heavy metal (including TBT) contamination, although spot monitoring of the mud in front of the slipways has revealed TBT contamination (M. Vincent, QDEH, pers. comm.). Analysis of nearby sediments from Sadgroves Creek shows no contamination (Dames & Moore 1993), suggesting the area of impact is small. The use of TBTs on small boats in the Northern Territory is still legal although it is now illegal in most other Australian states.

Organisms

Very few organisms have been examined for heavy metal and other contaminant levels in Northern Territory waters. The records are patchy, and there is little consistency in the range of contaminants tested. Most of the data are heavy metal concentrations, and these results show that in general, all metals examined were found to be below NH&MRC limits.

During the survey of metals in sediments near the Darwin Port, two species of sessile fauna were tested (a bivalve, *Chama* sp. and ascidians) below the Iron Ore wharf and both were below the NH&MRC limit for all metals except lead (Warren pers comm.). Peerzada and Kozllk (1992), Peerzada (1988) and Peerzada and Dickinson (1988) reported on a range of heavy metals concentrations in oysters from sites in Darwin Harbour and concluded that all were fit for consumption as they had heavy metal concentrations well below NH&MRC guidelines. The exception was a sample from Nightcliff, where oysters had lead levels close to or above the maximum recommended level.

Much of the research on heavy metal levels in organisms has concentrated on mangrove-associated molluscs. The mudwhelks *Telescopium telescopium*, *Terebralia palustris* and *Terebralia sulcata* are widely eaten by local Aboriginal people, and there is evidence to suggest that some of these organisms may not be fit for consumption. As detritivores, *T. telescopium* are likely to accumulate some heavy metals, but caution is needed in interpretation of the available data, since no background heavy metal data exist for *T. telescopium* from Darwin Harbour.

Urban run-off and sewage effluent discharge in populated areas are potential sources of heavy metals. Peerzada et al. (1990a), recorded high lead levels in T. *telescopium* at Frances Bay (8.14 ppm) and Rapid Creek (8.99 ppm), and 'high' concentrations of cadmium (1.26 ppm), zinc (199.47 ppm) and copper (72.05 ppm) in T. *telescopium* at Ludmilla (Racecourse) Creek,. They remarked that the creek receives treated sewage effluent, but reported no attempt to determine if a gradient in concentrations from the effluent source was present. Recent assessment of heavy metal levels in the potamid molluscs *Telescopium telescopium* and *Terebralia palustris* from Ludmilla Creek showed levels of heavy metals were below the limits of concentrations acceptable for human consumption (Hanley 1992b). High cadmium concentrations in T. *telescopium* were also detected at Elizabeth River, where according to Peerzada et al. (1990a), samples were taken in the vicinity of boat ramps, landfill sites and sewage outlets. However, from the information provided it appears that samples were taken some kilometres distant from some of the proposed sources of pollution.

In the absence of any evidence of a gradient in concentrations of heavy metals between the sample site and the proposed point sources of pollution, or any evidence of the background concentrations of the heavy metals under scrutiny, the attribution of a 'high' concentration of any heavy metal to anthropogenic sources is of dubious value. For example, Peerzada and Dickinson (1989) found extremely high concentrations of cadmium in oysters from the Arnhem Land coast, which is sparsely populated and has no anthropogenic source of cadmium. All oysters tested exceeded NH&MRC limits for cadmium. Naturally high concentrations of cadmium have also been reported at Shark Bay, Western Australia (McConchie et al. 1988). Noller and Outridge (1987) reported on the concentrations of heavy metals and arsenic in several species of estuarine shellfish from the mouth of the East Alligator River, and found that cadmium, copper, mercury, lead, and zinc were all below the recommended dietary limits. Arsenic concentrations in several species were at the dietary limits, although it was unlikely all the arsenic was present in inorganic form. The concentrations of selenium in oysters was found to exceed the dietary limit. These studies underline the need for caution in extrapolating the results of localised surveys to other areas of the Northern Territory coastline.

Summary

The Northern Territory is in an enviable position. The available evidence supports the view of a largely pristine marine environment. No large scale chronic or acute pollution stresses have been identified. However, for much of the coastline no baseline data exist.

Significant industrial development and population growth is expected in at least the

Darwin region during the next few decades. There will be impacts on the marine environment should this occur, and it is imperative that a coordinated program of baseline data collection is implemented during the next decade to allow the development of sound management plans.

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Acronyms

AAS	Atomic Absorption Spectrometry
AMD	Acid Mine Drainage
ANCA	Australian Nature Conservation Agency
ANZEC	Australian and New Zealand Environment Council
ANZECC	Australian and New Zealand Environment and Conservation Council
AOX	Adsorbable Organic Halogen (Edyvane)
AOX	Adsorbable Organic Halide (Richardson)
APM	Australian Paper Manufacturers
APM	Australian Paper Mills (Rees)
APPM	Australian Pulp and Paper Manufacturers
ASV	Anode Stripping Voltammetry
BHAS	Broken Hill Associated Smelters
BHP	Broken Hill Proprietry
BOD	Biochemical Oxygen Demand
CCNT	Conservation Commission of the Northern Territory
CEPA	Commonwealth Environmental Protection Agency
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DASET	Department of Arts, Sport, Environment and Territories
DBIRD	Department of Business, Industry and Regional Development
DELM	Department of Environment and Land Management
DENR	Department of Environment and Natural Resources
DEP	Department of Environment and Planning
DEST	Department of Environment, Sport and Territories
DOE	Department of Environment
DPI	Department of Primary Industries
DSP	Diarrhetic Shellfish Poisoning
EAC	East Australian Current
EDTA	Ethylenediamine tetraacetic acid
EMP	Environmental Monitoring Program
EOX	Extractable Organic Halogen
EPA	Environment Protection Authority
EPCSA	Environment Protection Council of South Australia
ESD	Ecologically Sustainable Development
GBRMPA	Great Barrier Reef Marine Park Authority
GIS	Geographical Information Service
HCB	Hexaclorobenzene
ICPMS	Inductively Coupled Plasma Mass Spectrometry
ILZRO	International Lead Zinc Research Organisation
IUCN	International Union for the Conservation of Nature
MARPOL	International Convention for the Prevention of Pollution from Ships
MERP	Marine Environment Protection Agency
MRL	Maximum Residual Limits
NFR	Nonfilterable Residues
NH&MRC	National Health and Medical Research Council
NSW	New South Wales
NT	Northern Territory
OPUD	Office of Planning and Urban Development
PAH	Polyaromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PSP	Paralytic Shellfish Poisoning
QCFO	Queensland Commercial Fishing Organisation
QDEH	Queensland Department of Environment and Heritage
QDPI	Queensland Department of Primary Industries
Qld	Queensland
QTTC	Queensland Tourism and Travel Corporation
RAC	Resource Assessment Commission
SA	South Australia
SAAC	South Australian Aquaculture Committee
SAFIC	South Australian Fishing Industry Council
SARDI	South Australian Research and Development Institute
SCUBA	Self Contained Underwater Breathing Apparatus
SEMP	Shellfish Environmental Monitoring Program
SEPP	State Environment Protection Policy
SPCC	State Pollution Control Commission
STP	Sewage Treatment Plant
TAG	Technical Advisory Group
Tas.	Tasmania
TBT	Tributyltin
TCM	Total Catchment Management
TEMP	Tuna Environmental Monitoring Program
UNEP	United Nations Environment Program
USEPA	United States Environment Protection Agency
Vic.	Victoria
WA	Western Australia