Management of Perth's coastal waters and beaches: an ecosystem approach

R J Pearce, MLA,
Minister for the Environment
77 St Georges Terrace
PERTH WA 6000

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Abstract

The Environmental Protection Authority (EPA) has the responsibility of controlling industrial and domestic waste inputs to state waters. With continued industrial development and urban expansion to the north and south of Perth, pollutant loadings to nearshore marine environments will inevitably rise as a result of increases in industrial and domestic waste discharge, urban drainage and groundwater inflow. These increased loadings will inevitably cause additional stresses on the nearshore marine ecosystems of Perth.

The EPA has adopted the concept of "assimilative capacity" as a philosophical approach to maintain the biological integrity of nearshore coastal ecosystems in Western Australia. This approach is based on the assumption that the receiving environment has some capacity, albeit limited, to disperse, dilute and absorb certain types of pollutants without incurring long-term damage to the biological functioning of the marine communities in question.

This approach will be outlined using case studies. In the first case-study Cockburn Sound, a marine embayment adjacent to the southern metropolitan waters of Perth, will be used to explain how this approach can be used to 'rehabilitate' formerly severely polluted waters. In the second case-study the EPA's approach to controlling nutrient enrichment of the nearshore waters of the Perth region (which includes the Marmion Marine Park) will be used to demonstrate how the principle of the "assimilative capacity" approach is being utilised to prevent deterioration of "pristine" ecosystems.

Introduction

The Western Australian coast (Figure 1) is long and exposed. Its nearshore waters are strewn with submerged limestone reefs, and local maritime history tells of the many vessels which foundered in these treacherous waters. Safe, sheltered anchorages, available in only a few partially enclosed embayments and sounds, were highly prized. These naturally-sheltered locations became focal points for early European settlement and for subsequent population growth and development.

For example, Perth, now the state capital of Western Australia, was established in 1829, with ships anchoring in Cockburn Sound, a sheltered embayment to the south of Perth (Figure 1). The development of Perth has been slow until the last four decades, when the population growth rapidly accelerated. The population was 303,000 in 1947, 703,200 in 1971, and at present, stands at about 1,160,000. It is projected that by the year 2021, the population will have reached 2,000,000. This recent rapid growth has been spurred by industrial development, and has led to urban expansion. Perth is now a modern city whose people have expectations both of material well-being and of high environmental quality. Given the long, hot summers and mild winters experienced in Perth, its people are particularly geared to a wide range of beach and water-based recreational pursuits, including swimming, boating, diving and fishing. Thus the environmental quality of the coastal waters, which also support productive commercial fisheries, is of high priority. In the past, these twin ideals (of prosperity and environmental quality) have been largely met. As the population increases, however, improved management systems will need to be employed to avoid or resolve conflicting uses of the coastal waters, and to preserve them for multiple community uses and for future generations.

Western Australia is fortunate in that most of its marine ecosystems are presently in good condition. The basis of the Western Australian approach to management of its coastal waters is therefore long-term maintenance of the marine biological communities. Both international and local experience points to the need for ongoing, effective environmental management to avoid long-term environmental damage.

Offshore waters

The marine waters off Western Australia have several special characteristics. The Leeuwin Current flows southward in winter and brings warm tropical water down along the edge of the western continental shelf and around Cape Leeuwin into the Great Australian Bight (Cresswell and Golding, 1980; Hollaway and Nye, 1985). This is the only western coast in the southern,hemisphere with a southward moving oceanic current. The planktonic larvae of many tropical species are swept southward by this warm current (Cresswell and Golding, 1980), explaining the unusual southerly occurrence of species such as corals and fish that would otherwise not appear at these temperate latitudes. The existence of this current also helps to explain the apparent lack of significant upwelling of nutrient rich water along the coast. (In contrast, nutrient upwelling is an important feature off the west coasts of Africa and South America, and this supports major pelagic fisheries, eg anchovies). These exposed offshore waters off Western Australia show little or no effect of human influence.

Inshore waters

There is little input of riverine sediments and nutrients along most of the metropolitan coastline, and hence these inshore waters typically have very low nutrient content and high water clarity. Nearshore water movement is principally wind-driven (tidal currents are insignificant), and average current speeds are low, in the range of 0.05 - 0.1 m/s (Hearn, 1983).

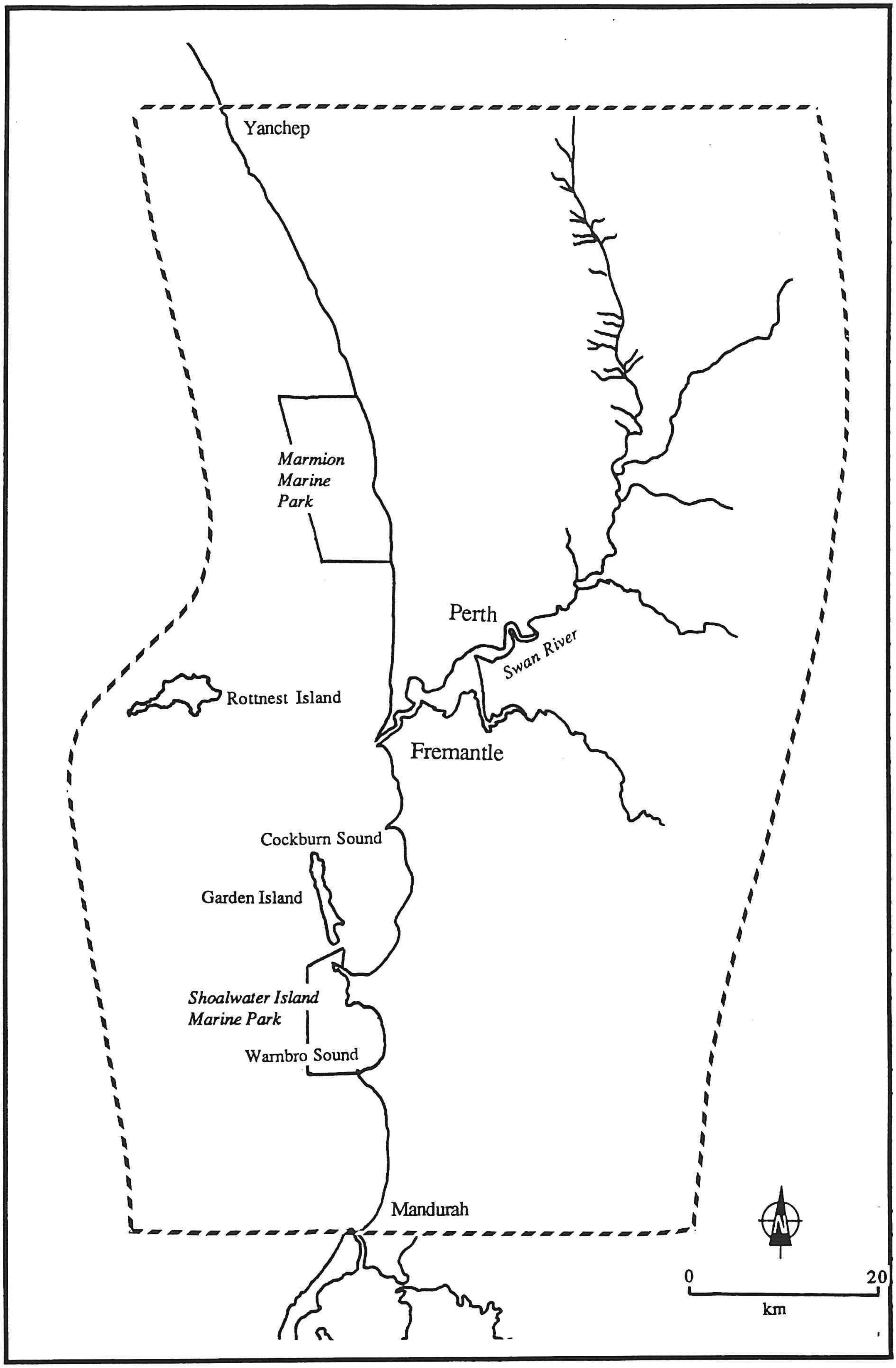

Figure 1. Coastline showing study area.

A feature of the inshore waters off metropolitan Perth is the extensive system of marine limestone reefs, approximately parallel to and within a few kilometres of the shore. Garden Island, to the south of Perth, is formed on this line of reefs, and protects Cockburn Sound, one of only two sheltered marine embayments near Perth. Further north, broken lines of reefs protect the coast from the full force of Indian Ocean swells and create partially sheltered inshore lagoons (Figure 1). These lagoons contain chains of nearshore reefs, and provide an attractive underwater panorama, with spectacular cave fauna, diverse communities of fish, crustaceans, sponges, molluscs and algae. In 1987, the Government set aside much of this area as a Marine Park for recreation, conservation, education, scientific research and fishing.

The limestone reefs are surrounded by sand and seagrass communities. Although these seagrasses are not as visually attractive as the reefs, it is becoming increasingly apparent that these meadows are at the base of the food chain, and provide nursery grounds and shelter for the juveniles and adults of many fish, crustaceans and other marine animals, including a large number of commercial species (Bell and Pollard, 1989). Furthermore, the extensive root and rhizome systems of these seagrass meadows stabilise nearshore sediments and sand banks (Scoffin, 1971), which in turn enhances coastal water clarity.

Posidonia seagrass meadows occupy approximately 20,000 square kilometres of the shallow seafloor off Western Australia (Kirkman and Walker, 1989), and are considered to be the most extensive meadows in the world. Eight of the nine known species of the genus *Posidonia* are endemic to Western Australia (Kuo and McComb, 1989). These species have evolved in response to the clear, nutrient-poor waters found along this coast. Although seagrass meadows are rarely destroyed by natural catastrophes such as storms, large-scale devastation can be caused by direct disturbance and by indirect disturbance, particularly nutrient-enrichment. Nutrient-enrichment causes the excessive growth of various types of algae. These algae can occur as unattached benthic macroalgae infesting the meadows, as epiphytes attached to seagrass leaves, or as microscopic phytoplankton drifting in the water column. All three types of algae have the same ultimate effect, in that they shade the seagrasses and starve them of light.

Evidence shows that *Posidonia* seagrass meadows which may be lost in months to years, may never return, even in decades to centuries (Clarke and Kirkman, 1989). Hence, the effects of excessive nutrient-enrichment on seagrass meadows are virtually irreversible.

Historical problems in the marine environment of Western Australia, particularly Cockburn Sound and the Albany harbours (Anon., 1979; Simpson and Masini, 1990) and the predicted magnitude and nature of future waste discharges into Perth's coastal environment suggest that nutrient enrichment is likely to be the major threat to our protected nearshore marine ecosystems. Thus, the aim of the Government of Western Australia in regards to the management of Perth's marine environment is to prevent irreversible damage to the major primary producers, particularly the seagrasses, from the detrimental effects of excessive nutrient loading. The catastrophic loss of seagrasses as a result of excessive nutrient loading is exactly what occurred in Cockburn Sound.

Cockburn Sound

As described previously, Cockburn Sound is one of the very few sheltered, navigable waterways along the south-west coast of Western Australia. It is about 30 km from the central business district of Perth, and is now surrounded by suburbs.

Development of Cockburn Sound as the outer harbour for the Perth-Fremantle area really began in the 1950s. Then the relatively shallow banks surrounding the deep central basin of the Sound were covered by healthy seagrass meadows (Figure 2a).

The first major unit of an industrial complex, built on the eastern shore of the Sound, was an oil refinery which opened in 1955. This was followed by the development of other major and ancillary industries, including iron, steel, alumina, and nickel refining or processing, and chemical and fertiliser production factories. Wastewaters from several of these industries and from a domestic wastewater treatment plant were discharged directly into Cockburn Sound. There was a steady growth of urban population in surrounding areas during this period, and Cockburn Sound proved important to the community for a wide range of non-industrial uses, including recreation (swimming, fishing and boating), commercial fishing, and mariculture (mussel farming).

By 1976, about 80 % of the once extensive seagrass meadows had been lost (Figure 2b). How was this allowed to happen?

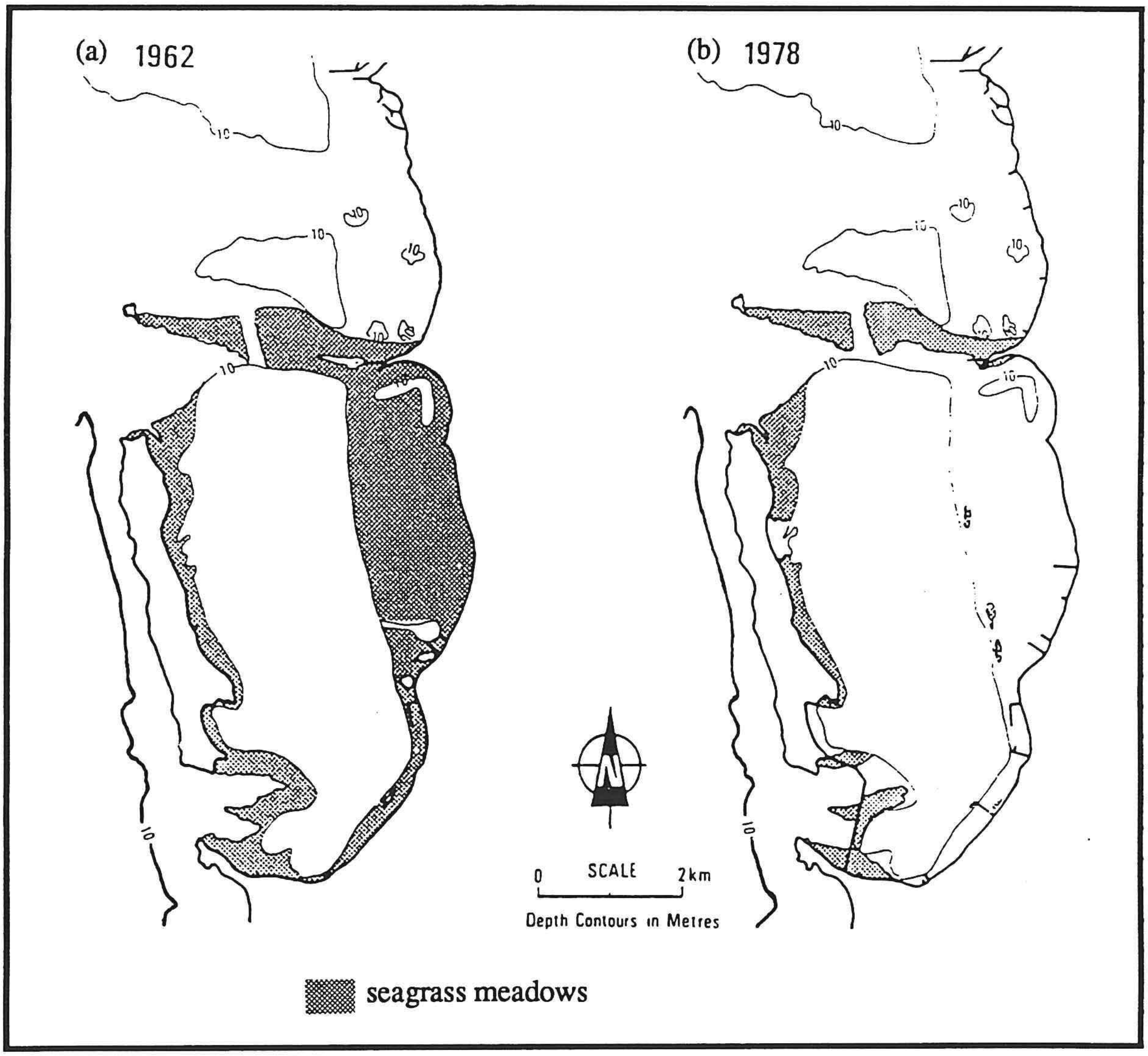

Figure 2. Distribution of seagrasses in Cockburn Sound a) 1962, b) 1978.

Early industrial developments were sited in Cockburn Sound to take advantage of the safe anchorage, land availability, proximity to Perth, and the apparently unlimited ability of "the ocean" to accept wastes. Little consideration was given at that stage to the short- or long-term effects that these discharges could have on the marine environment. However, from the early 1970s onwards, the community became increasingly concerned over emerging environmental problems.

Prior to passing the Environmental Protection Act, 1971, there was no single responsible body for environmental protection. However once this legislation was established, the Government commissioned several investigations, which led to the comprehensive three year Cockburn Sound Environmental Study (1976-1979), the object of which was to obtain the information necessary to manage the Sound for multi-purpose community use. These studies confirmed that the Sound is quite poorly flushed, and that the biological systems had been adversely affected by pollution. Since then, negotiations have proceeded between government and industry to develop pollution control measures to ameliorate the situation. It was not until the passage of the Environmental Protection Act, 1986, however, that legally enforceable licence conditions on marine discharges were provided for. Licence conditions for individual industries can only be effective if they are part of an overall, unifying strategy of environmental management, based on a total ecosystem perspective. Cumulatively, all licensed discharges must not exceed the capacity of the ecosystem to assimilate these wastes.

Any discharge of a polluting substance will cause some change in the receiving environment. The change will depend on the nature of the receiving environment and the type and amount of pollutant discharged. A primary decision has to be made on whether any change is acceptable. If it is not, no discharge should occur. If change is acceptable, the acceptable level of ecological change must then be set.

Pollutants can be broadly divided into toxic and biostimulant categories. In Western Australia, toxic substances, such as heavy metals, pesticides, etc are not widespread in the marine environment, but contamination has occurred in localised areas. Once contamination has been detected, and a source determined, the Government has acted to remove or contain these sources. Although these substances may pose a threat to public health, in Western Australian marine waters they are not generally considered to pose a threat to entire ecosystems. However, biostimulants (ie nutrients), although non-toxic in normal concentrations, may still pose a very real threat to the ecological balance of entire ecosystems. For instance, excessive inputs of nutrients may cause the disruption of food webs, the loss of many plant and animal communities, and a deterioration in water quality to the extent that recreational activities such as swimming and fishing are adversely affected. In order to maintain the ecological health of a system, we need first to understand how it functions. Although we can never hope to unravel all of the intricacies and obtain the perfect ecological model of an ecosystem, we can look to understand the key physical and biological components and processes controlling that system.

For example, the EPA has been conducting bi-annual studies of water quality in Cockburn Sound (eight sites monitored weekly for 14 week periods during summer) since the late 1970s. Long-term averaging of system-wide data derived from these types of studies eliminates much of the 'noise' typical of short-term studies, and highlights general trends and relationships within the data. This long-term monitoring of Cockburn Sound has shown that an increase in phytoplankton biomass in the waters of the Sound (measured as chlorophyll *a*) causes a decrease in water clarity (light attenuation coefficient) (Figure 3a). Seagrasses can only survive down to a certain water depth. At greater depths there is insufficient light to sustain these plants. If water clarity decreases (for example, due to increased phytoplankton in the water column) seagrasses at their depth limits are starved of light, and die. Phytoplankton biomass (which affects water clarity) has been shown to increase as nitrogen loads in industrial discharges increase (Figure 3b). Using these relationships together with recent information on the light requirements of seagrasses (Masini *et al.*, 1990), it is possible to relate seagrass depth limits in Cockburn Sound to discharged nitrogen loads (Figure 3c).

Seagrasses were formerly found to a maximum depth of about 9 metres, whereas now they only remain in water depths of about 4 metres or less. From the relationship described above (Figure 3c), we can calculate the maximum acceptable nitrogen load to the Sound to return water clarity to levels consistent with the re-establishment of seagrass meadows. This value is about 500 kg/day, about one third of current industrial nitrogen loadings to the Sound.

Although there is no evidence to suggest that the original *Posidonia* species will return, different species of *Posidonia*, or other faster growing genera are likely to colonise the area once water clarity improves. This provides a simple, but ecologically based model from which to set licence conditions for nitrogen discharge into Cockburn Sound.

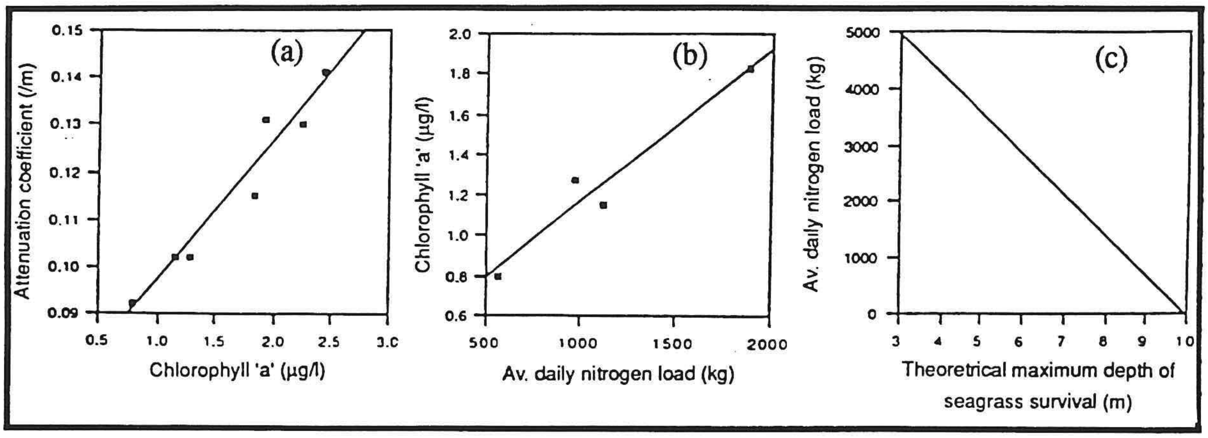

Figure 3. Relationships derived from long-term averages of system-wide data collected in Cockburn Sound during summer:
(a) Relationship between mean chlorophyll 'a' and light attenuation coefficient,
(b) Relationship between average daily industrial nitrogen load and chlorophyll 'a',
(c) Derived relationship to set nitrogen load limit from the required maximum depth of seagrass survival.

Environmental management from a regional perspective

The example I have just given is one of a relatively simple ecosystem with a clearly defined cause and effect pathway. This system has been degraded because its nutrient assimilative capacity has been exceeded for many years. This is really an exercise in environmental rehabilitation. However, the real challenge that we face is to determine the maximum nutrient load (from domestic wastewater outfalls, groundwater discharge and urban runoff) that can be assimilated by the nearshore marine environment off the Perth metropolitan area while still maintaining its biological quality and integrity. As previously discussed, this northern region is more exposed to the ocean and better flushed and is therefore likely to have a greater capacity to assimilate nutrients than the more protected Cockburn Sound; and much of this area is a Marine Park with a diversity of habitats, and that therefore, the community's and the government's expectations are for continued high environmental quality.

Estimates by the Western Australian Water Authority indicate that, by the year 2000, approximately 350 million litres of mainly secondary treated domestic wastewater will be discharged daily, from a series of outfalls, into the nearshore waters off metropolitan Perth. This corresponds to total daily nutrient loads of about 18 tonnes of total nitrogen and 4 tonnes of total phosphorus. At this rate it would take only 8 years to discharge a total nutrient load equivalent to the total load discharged over the past sixty odd years since ocean disposal of domestic wastewater first commenced in 1927.

The scale of this increase raises several important environmental issues. Normally, environmental impacts of proposed wastewater outfalls are assessed individually. But, are the effects of each of these outfalls sufficiently localised to be considered independently as a series of point sources, or should these outfalls be considered collectively as a diffuse source affecting part or all of a much larger system? A potential exists for the environmental effects of adjacent outfalls to overlap. The waters off metropolitan Perth have a finite capacity to assimilate waste without deterioration of the local marine communities. At present the physical and biological processes which control the assimilative capacity at a regional scale are being investigated.

The assimilative capacity should be known well before environmental impacts occur. In this way, the suitability of ocean discharge as a long-term solution to domestic wastewater disposal can be assessed, and at a time scale appropriate to the consideration, and possible implementation of alternatives. The full consideration of regional assimilative capacity will also take into account nutrient loads resulting from groundwater flux, industrial effluent discharge, surface runoff, and even atmospheric inputs. With this in mind, the Government has required a study into the likely environmental impacts of the total wastewater discharges into the coastal waters off metropolitan Perth, projected for the next 50 years. In this way the Government is promoting sound planning and management of the marine environment, using an ecosystem approach. The vast majority of our coastline is in a 'pristine' state, and with this long-term management view of our nearshore waters, we intend to keep it that way.

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