Impact From the Ocean/Land Interface

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1 OVERVIEW OF IMPACTS

Activities at the ocean/land interface impact significantly on the marine environment. Habitats and biological communities in the South-east Marine Region are affected primarily by urban and agricultural run-off, industrial and sewage effluent discharges and coastal development. Water quality is degraded in many areas by high nutrient and sediment loads, heavy metals, chemical pollutants, faecal bacteria and organic wastes, and periodically does not comply with guidelines for protection of aquatic ecosystems. The largest impacts have been caused by elevated nutrient levels and sedimentation, and include widespread loss of seagrass beds and eutrophication of coastal waters. Parallel losses in invertebrates and fish have been linked to declines in coastal fisheries, while algal blooms include toxic species that have contaminated shellfish and pose human health threats. Saltmarsh and mangroves have also suffered incremental declines in coverage due to habitat loss and smothering, further reducing nursery areas for coastal fish.

Heavy metals and other persistent chemicals are bio-accumulated in a range of marine species, while fish kills and disease have occurred due to oxygen depletion, chemical contaminants and acidic run-off. Organic pollution has also had major impacts on benthic communities near pollution sources, leading to reduced biodiversity. Extensive habitat loss and modification has resulted from drainage and reclamation, port and marina construction, dredging, flow alterations and urban development. Impacts have included loss of seagrass and wetlands flora, local extinctions of fish populations, destruction of natural spawning and nursery grounds and loss of benthic communities.

There have been a number of improvements in approaches to water quality and habitat management at the ocean/land interface, particularly over the past ten years. However, continued losses of seagrass and poorly degraded water resources indicate that the marine environment remains highly disturbed. The impacts on various types of marine biota in the South-east Marine Region are summarised in Table 1.

2 PRIMARY AREAS IMPACTED

The most impacted areas occur adjacent to major coastal cities, where pollutants enter the sea via a wide range of point and diffuse sources and habitats have been highly modified through urban and industrial development. Localities most affected in the South-east Marine Region are Port Phillip Bay, incorporating Corio Bay and bordered by Melbourne and Geelong, the Port River Estuary and Gulf St Vincent coastline at Adelaide, and the Tamar and Derwent estuaries at Launceston and Hobart respectively.

Other areas that are heavily impacted due to industrial discharges and run-off include the northern Spencer Gulf in South Australia, Westernport in Victoria, and the north west coast and Macquarie Harbour in Tasmania. A number of coastal lakes have also become highly degraded through nutrient enrichment or flow modification, with areas most affected including the Gippsland Lakes in Victoria, the Coorong in South Australia, and a number of small lakes along the southern New South Wales coastline.

In general, the types of environments that have been most severely impacted are river estuaries, coastal lagoons and sheltered marine embayments, since these areas are less readily flushed than exposed coastlines, are generally most affected by catchment run-off and also act as foci for human activity and pollution.

3 IMPACT OF LAND BASED SOURCES OF POLLUTION

3.1 Industrial Discharge

3.1.1 Heavy metal emissions

Heavy metals enter estuarine and marine environments via a range of point and diffuse sources, however primary sources of emissions are industrial, sewage and stormwater discharges and mining operations near coastal rivers. Heavy metal concentrations in the Derwent Estuary, Tasmania, remain amongst the highest in Australia (Coughanowr 1997), while studies suggest that up to 600km^2 of marine seabed has been contaminated with heavy metals in Spencer Gulf in South Australia (Edyvane 1995). The metals of most concern in the South-east Marine Region are mercury, copper, cadmium, lead and zinc (Edgar 2001), with concentrations frequently exceeding the water and sediment quality guidelines prescribed by ANZECC (2000) and the Australian Food Standards Code of the NHMRC (1996) (e.g. Ward *et al.*1986, Carpenter *et al.*1991, Garland and Statham 1991).

Species that occupy the seabed or filter particles from the water column are most impacted and accumulate high concentrations of heavy metals in their tissues. The effects of this are lethal in some cases, as demonstrated by alterations in species compositions and reduced biodiversity near sources of heavy metal emissions (e.g. Ward and Young 1982, Newell *et al.* 1987). However, many species experience sub-lethal or non-lethal effects at certain concentrations and are commonly used as bio-indicators for heavy metal pollution (Nicholson *et al.*1992a, Dineen and Noller 1995).

Fish may also accumulate high levels of metals in their tissues, and food safety guidelines are periodically exceeded for some species (de Blas 1994, Nicholson *et al.* 1992b). In severe cases of contamination, fish kills have resulted from metals accumulating in gill tissue and interfering with oxygen uptake (e.g. DEP 1990). Elevated concentrations of metals such as mercury and cadmium can also occur in the flesh of large and wide ranging predatory fishes, seabirds and dolphins due to the effects of bio-accumulation and bio-magnification (Howarth *et al.* 1982, Kemper *et al.* 1994, Edgar 2001).

3.1.2 Other chemical emissions

Additional chemical emissions in the South-east Marine Region include wastes from pulp, paper and woodchip mills, food processing works, salt and chemical plants and oil refineries. In many cases, industrial wastes are discharged to municipal sewage treatment plants (Winstanley 1995, Crawford *et al.* 2000), where they are combined and treated with sewage wastes, while chemical toxicants also enter estuarine and marine environments via urban and agricultural run-off (see Sections 3.2 and 3.3). The range of industrial chemicals released is extensive, but includes dioxins, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, resin acids and organic halogens (e.g. Fabris *et al.* 1992, Richardson *et al.* 1995, Australian Paper 2001). The effects of many of these chemicals on marine life are not well understood, however toxic effects on fish and other aquatic biota have been identified (Walden 1976, Edgar 2001) and bio-accumulation in seabirds and marine mammals has been linked to reduced breeding success (Gorman 1993).

Industrial discharges are also commonly characterised by elevated levels of suspended solids (SS), biological oxygen demand (BOD; a measure of organic content), nutrients and, in the case of timber and paper mills, woodchip fibre (Davies and Kalish 1994, Coughanowr 1997). While these components of emissions are essentially non-toxic, they have significant impacts on estuarine and marine biota in the South-east Marine Region through habitat alteration and degradation of water quality.

The impacts of pulp and paper mill contaminants on biota are specific to mill technologies used, treatment processes, effluent types and the nature of the receiving environment (Keough and Mapstone 1995). In estuarine environments, direct impacts have included accumulation of wood fibre sludge, degradation of water quality and impoverished benthic faunas (Horwitz and Blake 1992, Davies and Kalish 1994). In addition, impacts on fish have been reflected by avoidance responses to pulp mill effluent, fin damage, and fish kills during mobilisation of sludge masses by flood events (Davies *et al.* 1989, Garland and Statham 1992). Impacts are less severe at open coastal sites, however reductions in diversity of intertidal fauna, growth of nuisance algae and modification of subtidal communities have been documented (CEE 1989, 1994).

Chemicals such as PAHs and PCBs exhibit high degrees of bio-accumulation in marine food chains and have been recorded at elevated levels in fish within the South-east Marine Region (Nicholson *et al.* 1991, Fabris *et al.* 1992). Impacts on fish health, such as lesions, eye damage and high external parasite loads, have also been documented (Gibbs *et al.* 1986).

3.1.3 Thermal discharges

Thermal waters are discharged from a number of power stations, as well as from a wide range of industrial sites (Miller 1982, Winstanley 1995). Areas most impacted include the Port River Estuary and northern Spencer Gulf in South Australia and Port Phillip Bay in Victoria. The Tamar Estuary in northern Tasmania will also receive very large and on-going thermal discharges following the conversion of the Bell Bay power station to gas (Wood and Associates 2001).

Thermal discharges result in plumes of heated water in nearshore coastal and estuarine environments. Most severe biological impacts are likely to occur within 100m of the discharge (Aquenal 2001a), however changes in community structure may occur over several kilometres (Thomas *et al.* 1986). Sessile species, such as seagrasses and a range of benthic (bottom-dwelling) invertebrate species, are most impacted by thermal plumes. Invertebrate communities exhibit changes typifying environmental stress, with a small number of highly tolerant, opportunistic fauna becoming abundant, replacing more diverse communities (Thomas *et al.* 1986).

In addition to altering temperature regimes, thermal discharges result in alterations of the sedimentary environment and water clarity and frequently lead to increased growth of microalgae, epiphytic algae and other nuisance flora. All of these factors affect seagrass beds, although impacts are not always severe where the effluent temperature is within the tolerance range of the species present (Ainslie *et al.* 1994). Severe die-back of seagrass beds during unusually warm conditions in parts of Victoria and South Australia (Jenkins *et al*. 1992, Seddon *et al.* 2000) indicates that tolerances could be exceeded as a result of some thermal effluents.

Thermal pollution has a significant impact on the distribution and abundance of native fish species in estuarine and coastal systems. While fish have the mobility to escape lethal effects of thermal waters, they are affected through behavioural changes. A number of species exhibit avoidance responses to the discharges, with reduced fish diversity recorded near thermal outfalls (e.g. Jones *et al.* 1996). The implications of this behaviour may include reduced breeding success through preventing migration to spawning sites. At certain times of the year, some species of fish are attracted to thermal outfalls (Jones *et al.* 1996, Aquenal 2001b), at which time they are highly exposed to any toxic contaminants contained in the discharge.

3.2 Urban Run-off

Stormwater discharges and diffuse run-off are significant sources of pollution in estuaries and coastal environments in the South-east Marine Region. Urban run-off is characterised by high sediment loads and nutrient levels (Williams 1980, Edgar *et al.*1999), and contains a wide range of pollutants, including domestic wastes and litter, pesticides, heavy metals, faecal bacteria, hydrocarbons, PCBs and organic matter (CEPA 1993, Green 1997).

Impacts in receiving estuarine and coastal waters include nutrient enrichment and eutrophication, bacterial contamination, oxygen depletion, elevated turbidity, siltation and acute and chronic toxicity to biota (Scott 1996). Nutrients from stormwater have been linked to nuisance growth of green macroalgae such as sea lettuce (*Ulva* sp.), *Gracilaria* sp. and *Giffordia* sp off metrapolitan Adelaide and other urban centres. Under certain conditions, these algal growths can accumulate in beach areas, forming large decomposing drifts, and smothering benthic habitats (Edyvane 1995). Stormwater discharges have also been implicated in seagrass loss and degradation, mangrove and saltmarsh dieback and the increasing frequency of ‘red tides’ formed by blooms of microalgae (Macdonald 1995, SA EPA 1998a). These impacts occur as a result of reduced light attenuation associated with turbid waters and smothering of the seabed and tidal flats with sediments and algal growth.

Plastic litter discharged from stormwater outlets may also impact on biota, since debris entering the coastal environment harms fish, marine mammals and seabirds through ingestion and entanglement (Winstanley 1995).

3.3 Agricultural Run-off

Land clearance for agriculture and other rural industries, such as forestry, results in significant increases in catchment run-off. This run-off contains a combination of animal wastes, fertilisers, pesticides, agricultural chemicals and soil, and is a major source of elevated sediment and nutrient loadings in estuaries and coastal waters (NSW Fisheries 1999, Edgar *et al.*1999).

High levels of dissolved solids and nutrients in agricultural run-off result in degradation of water quality and sedimentary habitats, and have been implicated in loss of seagrass cover (Rees 1994, Edgar 2001). Associated nutrient enrichment may also trigger algal blooms, which are periodically severe in parts of the South-east Marine Region. While blooms are a natural phenomenon, they appear to have increased in frequency and extent as a result of increased nutrients from agricultural areas and may cause considerable environmental damage. In the Gippsland Lakes, for example, oxygen depletion caused by eutrophic conditions has resulted in mortality of fish and other aquatic life (Winstanley 1995). In addition, while the elevated nutrient inputs stimulate the growth of microalgae and other nuisance flora, some important native algae, such as the giant kelp *Macrocystis pyrifera*, are detrimentally impacted by sedimentation caused by catchment run-off (Sanderson 1999).

While pesticide and herbicide chemicals are frequently contained in urban run-off and industrial discharges, agricultural run-off contributes significantly to their concentrations in coastal watercourses (NSW Fisheries 1999). The organochlorine pesticides pose greatest risks to marine and estuarine biota, since these chemicals are persistent in the environment and magnify along food chains (ANZECC 2000). Evidence of bio-concentration of organochlorines in the South-east Marine Region has been collected for numerous invertebrate species and fish (Steen 1970, Mann and Ajani 1991, Nicholson *et al.* 1991), while birds and marine mammals may also be impacted lethally or sub-lethally (Gorman 1993, Water Report 1995).

3.4 Sewage Discharges

More than 100 sewage treatment plants discharge wastes into coastal, estuarine and embayment waters in the South-east Marine Region (based on; Parks and Wildlife Service 1995, Winstanley 1995, SA EPA 1998b, NSW EPA 2000). Secondary or tertiary treatment techniques are used at the majority of STPs, although primary treated or untreated wastes are still commonly discharged at ocean outfalls, including an outfall at Macquarie Island, due to the higher dispersion and dilution forces at these sites (NSW EPA 2000). Raw sewage discharges during heavy rainfalls remain a problem in many areas of the South-east Marine Region due to overloading of treatment plants and illegal stormwater connections (Edyvane 1995, Coughanowr 1997).

As a result of integrated waste treatment systems, efluents discharged at sewage outfalls frequently contain a range of industrial and domestic pollutants in addition to large quantities of diluted faecal matter (Edgar 2001). Sewage effluent is very high in organic matter and nutrients and therefore causes water quality degradation primarily through eutrophication, oxygen depletion and elevated turbidities (Coughanowr 1995, Zann 1995). Discharges result in large growths of nuisance algae, which sometimes extend a number of kilometres from the outfall and lead to species loss and reduced diversity among natural algal communities (Connolly 1986, Brown *et al.* 1990). Blooms of cyanobacteria and toxic microalgae have also been triggered by the high nutrient loads and subsequently contaminate and, in extreme cases, cause mortality of shellfish (Parry *et al.* 1989, Cannon 1990, Hallegraeff 1995)

Sewage discharges have also been directly linked to widespread seagrass loss and mangrove dieback. For example, the disappearance of more than 4000 ha of seagrass and

68 ha of mangroves in Gulf St Vincent near Adelaide has been primarily attributed to excessive nutrient levels and turbidities caused by sewage (Neverauskas 1987, Bayard 1992, SA EPA 1998a). Impacts on seagrass occur via reduced light attenuation in the water column and epiphytic algal growth on leaves, while algal growth responding to nutrients smothers and chokes mangrove seedlings and established trees. The disappearance of the productive seagrass and mangrove communities has significant ramifications for commercial and recreational fishes (Jones 1984).

Sewage discharges lead to modifications in benthic invertebrate communities, with sediments near outfalls dominated by scavengers and deposit-feeding species, a reflection of high organic fractions and nutrient levels (Poore and Kudenov 1976, Poore and Kudenov 1978a). The communities are typically low in diversity and are dominated by a small number of pollution tolerant species, such as capitellid worms (Edgar 2001).

4 IMPACT OF HUMAN CHANGES ON THE COASTAL ZONE

4.1 Dredging

Many estuarine and coastal environments in the South-east Marine Region, particularly near commercial ports, have a long history of capital and maintenance dredging. The largest dredging programs have been performed in Port Phillip Bay, where more than 200 million cubic metres of sediments have been removed since the nineteenth century to maintain port access and navigation channels (Currie *et al.* 1998, Coleman *et al* 1999). Spoil from dredging activities, which sometimes contains high concentrations of heavy metals and other contaminants, is deposited in specified spoil dumping grounds generally located in deep water, although tidal flats have also been used for spoil dumping (Pirzl and Coughanowr 1997).

Dredging activities impact on the marine environment by smothering benthic biota and habitats and degrading water quality through elevated turbidites and bioavailability of pollutants. In addition, alterations in seabed morphology and bathymetry, and consequently to wave energy and water circulation, result in modified patterns of littoral drift (NSW Fisheries 1999, Watchorn 2000). The effects of this can include progressive accretion of sediments on some parts of the coast, and erosion in other areas (Winstanley 1995).

Biota are obliterated during dredge removal and may take months or years to recover (Coleman *et al.* 1999). Species directly affected include invertebrates, fish and seagrass, although mangrove and saltmarsh communities are indirectly affected through altered water flows within estuaries (Edgar 2001). Dredging has been implicated in the disappearance of some invertebrates from port environments, such as a number of hydroid species that have not been recorded in Hobsons Bay, Victoria, since the advent of dredging programs (J.E. Watson, pers. comm., cited in Poore and Kudenov 1978b). Studies elsewhere have shown that the long-term influences of dredging on benthic infauna occur through permanent modification of the sedimentary environment (Jones and Candy 1981).

4.2 Altered River Flows

Impoundment and diversion of freshwater flows for hydroelectricity generation, irrigation of agricultural lands, domestic or industrial water supply and flood mitigation works have affected many estuarine and coastal waters in the South-east Marine Region (Crawford *et al.* 2000). Dams, weirs and other man-made barriers impact on these waters via reduced and unseasonal flows, lower flood frequencies, habitat modification, barriers to fish migration and reduced water quality (Harris 1984, Davies and Kalish 1989, Edgar *et al.*1999).

The modified flows result in altered patterns of sedimentation and erosion in downstream environments, leading to habitat modification and reduced productivity as, for example, expressed by slower growth in commercial shellfish (Crawford *et al.* 2001). In addition, water quality frequently deteriorates as a result of low flows, since periodically high flood levels are often important for maintaining the health of estuaries (Davies and Kalish 1989).

Freshwater flows also provide the stimulus for breeding or migration in many marine and estuarine species (Longergan *et al.* 1989). Restrictions to frequency and amplitude of flows therefore have major repercussions for the ecology and breeding success of migratory fish species (Edgar *et al.* 1999, NSW Fisheries 1999). Freshwater impoundments also provide a barrier to migration of fish between freshwater and marine waters. Harris (1984) estimated that fish passage in approximately one half of the aquatic habitat of mainland Australia's south-eastern coastal drainages had been obstructed by dams, wiers and other artificial structures. Impacts on migratory fish range from extinction of local populations to reduced breeding success and modified distribution patterns.

Water quality changes caused by impoundments may also create subtle barriers to fish migration and cause fish kills in extreme cases. Retained floodwaters are generally cold and deoxygenated and can contain compounds such as hydrogen sulphide (Adam *et al.*1992). Sudden release of this water results in disease and mortality of fish, marine vegetation and invertebrate species.

Reduced riverine flows also indirectly impact species such as mangroves and salt marshes within estuaries, since increases in salinity cause stress in marsh plants and loss of mangroves through fungal infections (Macdonald 1995, Edgar 2001).

4.3 Altered Tidal flows

Changes in tidal flows are commonly linked to modifications of riverine flows, for example where flow restrictions in upper catchments result in periodic closing of estuary mouths, preventing tidal excursions and fish migration (Edyvane 1995). In addition, where estuary mouths are not obstructed, reduced riverine discharges cause deeper penetration of tidal waters into some rivers. This alters the distribution of invertebrates and fish, dependent upon their salinity tolerances, and may also lead to death of aquatic vegetation (NSW Fisheries 1999).

Additional constructions in estuaries and coastal regions directly influence tidal flows independently of modifications in upper catchments. Williams and Watford (1997) identified various structures that may reduce tidal flows, including bridges, causeways, culverts, floodgates, fords and weirs. The impacts of these barriers include prevention of fish migration, altered water quality and associated changes to distributions of invertebrates, fish and aquatic flora.

Environmental problems have been caused by artificial closures of coastal lakes and lagoons. Prevention of tidal flushing results in build up of nutrients, eutrophication and signficiant reductions in salinity. This in turn leads to loss of seagrass, excessive algal growth, blooms of toxic algal species, oxygen depletion and declines in the diversity of fish and other aquatic life. These impacts were documented, for example, at Orielton Lagoon in Tasmania prior to remediation works that restored an adequate level of tidal flushing (Brett 1992, Jones *et al.* 1994). Artificial measures to open waterways that are generally closed to tidal flows under natural conditions can also lead to environmental problems. Toxic algal blooms in the Gippsland Lakes have been attributed to an interaction between nutrient releases and water stratification, conditions created by the artificial opening at Lakes Entrance (Bremner 1988). The blooms have resulted in reduced dissolved oxygen levels, leading to mortality of fish and other aquatic life (Winstanley 1995).

4.4 Reclamation

Most large urban centres on coasts and estuaries in the South-east Marine Region have been highly modified through reclamation. Reclamation has occurred for the purposes of industrial, residential and port development, establishment of refuse disposal sites and construction of roads and other public utilities (Watchorn 2000).

Impacts on marine and estuarine habitats are greatest at major ports and industrial complexes, where there has been extensive loss and modification of foreshore environments (Winstanley 1995). Habitat and biological productivity are permanently lost by the removal of intertidal and nearshore sections of the seabed. Land reclamation is therefore a significant contributing factor to declines in estuarine resources, particularly seagrass beds, and is also one of the most obvious causes of mangrove and salt marsh declines (Burton 1982, Shepherd *et al.* 1989). This is exemplified by an 80% loss of original saltmarshes in the Adelaide metropolitan and northern beaches area through land reclamation for salt pans and industrial development (Edyvane 1995).

Coastal wetlands are particularly vulnerable to damage and yet have frequently been reclaimed for industrial and agricultural activities, and to be used as disposal sites (Coughanowr 1997). This results in loss of habitat for aquatic species and wetland birds and degradation of water quality through leaching of pollutants from dumped wastes, acid drainage in prone areas and increased erosion and sedimentation (Macdonald 1995, Watchorn 2000).

4.5 Erosion

The pressure of human activity, combined with natural processes of wind and water, has accentuated coastal erosion in the South-east Marine Region, where the majority of beaches are retreating (Brass 1984). Retreat of dunes and beaches is a natural phenomenon, and has been associated with sea level rises (Zann 1995), however human interference, such as residential development, recreational access, grazing and engineering works, has altered and accelerated the process of erosion (Bird 1985).

A major factor contributing to erosion problems is removal or damage to dune vegetation, since this results in exposure of sands to high coastal winds and wave action, causing dune blowouts and sand drifts. Construction of buildings, such as shack sites and other coastal settlements, too close to beaches and fore-dunes is commonly associated with loss of protective vegetation cover and consequent erosion (Dobson and Williams 1978, Crawford *et al.* 2000).

The construction of seawalls, groynes and breakwaters has been used widely to protect property on frontal dunes and other coastal areas subject to erosion. However, through reflecting eroding waves, these structures disrupt longshore sand drift and may cause aggravated scouring of adjacent beaches (Goldin 1987). Beach scour has necessitated artificial replacment of sand in areas such as Port Phillip Bay, where Bird (1985) dcoumented 11 sites at which sands were being replaced to aid coastal stabilisation and restore recreational resources.

Direct impacts of coastal erosion on marine biota are not well studied, however loss and modification of intertidal and neashore habitats is likely to impact on seagrass beds, fish nursery habitats and invertebrate communities. In addition, local losses of saltmarsh and mangrove have been attributed to erosion caused by seawall construction (Zann 1995). Erosion and other disturbances in the coastal zone also have significant impacts on seabirds, such as the threatened hooded plover (*Thinornis rubricollis*), that nest in beach and dune environments (Buick and Paton 1989).

4.6 Port and Marina Construction

Construction of port facilities involves considerable modification of estuarine and coastal habitats through reclamation, physical alteration of the shoreline, dredging and disposal of spoil (Zann 1995). Environmental impacts include destruction of aquatic habitats, loss of seagrass beds, saltmarshes and mangroves and sedimentation or erosion caused by altered bathymetry and water circulation patterns (Edyvane 1995, Edgar *et al.* 1999).

Permanent loss of habitat and biological productivity occurs where structures occupy the foreshore or seabed, or where major dredging works are performed to establish harbours and shipping channels (Coleman *et al*. 1999). In addition, studies elsewhere indicate that shading caused by wharves may reduce the long-term sustainability of seagrass and algal beds through reduced light attenutation (Fitzpatrick and Kirkman 1995, Burdick and Short 1999). Changes in benthic communities also result from the replacement of native habitats with artificial structures. These artificial substrates attract exotic fouling communities that may subsequently invade other habitats in the port environment, resulting in reduced diversity of native communities (Hewitt *et al.* 1999) (see Chapter 1).

Sediment transport processes are altered at coastal ports both through reflection of waves from port structures and hydrographical modifications caused by dredging. This has lead to changes in seabed habitats and marine communities in areas such as Portland Harbour in Victoria, where protective works are now required to prevent ongoing erosion of the adjacent coast (Winstanley 1995).

Construction of marinas has similar impacts to those outlined for port development, although generally at a smaller and more localised scale. However, the increasing number of marinas and associated structures, such as jetties and boat ramps, along the South-east

Marine Region coast suggests that the cumulative impacts are significant (Zann 1995). In some areas, such as the Gippsland Lakes in Victoria, the proliferation of marinas and related facilities has grossly altered the nature of the shoreline and inshore habitats (Winstanley 1995). Marina construction results in a reduction in benthic habitat, altered sediment transport processes and local losses of seagrass through similar mechanisms to those at major ports. Due to their shallower bathymetry, marinas can be more susceptible to reduced flushing and anoxia (Edgar *et al.* 1999), and frequently act as collection points for large quantities of beach wrack, leading to smothering of intertidal habitats and biota. Vessel activities at both ports and marinas result in water quality degradation through discharges of wastes and contamination with other pollutants (refer to Chapter 2).

4.7 Acid-sulphate Soils

Acid-sulphate soils typically occur in low-lying areas such as wetlands, estuaries, tidal flats, mangrove swamps and saltmarsh habitats, and remain inert (i.e. 'potential' acid-sulphate soils) while waterlogged. However, when exposed to air, they react with oxygen to form sulphuric acid, a compound that has potentially lethal effects on aquatic species (Cook *et al.* 2000). Activities near the coast that drain or disturb waterlogged habitats, such as reclamation works, grazing, mining and urban development, can facilitate this chemical conversion, leading to acid sulphate run-off. This run-off often contains very high concentrations of heavy metals, which, together with the elevated acidity, form a lethal cocktail (Hyne and Wilson 1997, Corfield 2000). Run-off is accentuated during high rainfalls, when large areas of estuaries may become acidic, causing disease and mortality of fish, loss of diversity in benthic communities and long-term habitat degradation (NSW Fisheries 1999, Cook *et al*. 2000).

In general, the problems of acid-sulphate soils are more severe in northern New South Wales and Queensland (Zann 1995), than in the South-east Marine Region. However, acidic soils have been recorded near Adelaide, Westernport Bay in Victoria, north western Tasmania and various other localities in south eastern Australia (DEST 1997). Acid mine drainge, where acid sulphate soils have been distrubed through mining excavation, is prevalent in areas such as Macquarie Habour in Tasmania. Acidic run-off into this harbour, combined with high metal concentrations, has caused mortalities in fish during high rainfall events (DEP 1990).

4.8 Altered Water Quality

Water quality at the ocean/land interface has been impacted by the various forms of environmental degradation described in earlier sections of this chapter. Chemical contaminants, thermal discharges, pathogens, nutrients, suspended solids and organic matter enter the marine environment, either directly or via catchment run-off, and have markedly altered water quality in many areas of the South-east Marine Region. The cumulative effect of these inputs is that water quality conditions frequently do not meet recommended criteria for protection of aquatic ecosystems (Rozenbilds 1991, Coughanowr 1997). Natural parameters affected include water temperature, salinity, turbidity (clarity), dissolved oxygen, pH (acidity) and chlorophyll concentration, all of which are important in the survival of marine fauna and flora (ANZECC 2000, Edgar 2001). Biotoxins in shellfish and faecal bacteria are primary concerns for human health and necessitate detailed water and shellfish quality monitoring programs in many areas (e.g. SA EPA 1997, Callan *et al.* 1993).

Biota that are most directly impacted by reduced water quality are sessile plants and animals, such as seagrass and benthic infauna, since they are most persistently exposed to pollutants and degraded conditions. However, due to trophic and other ecological links between these and more mobile species, impacts have extended to many parts of the marine ecosystem (Jenkins *et al.* 1992).

Table 1 Impacts of the ocean/land interface on marine biota in the South-east Marine Region.

Source of Impact	Biota Impacted	Nature of Impact
Heavy metal emissions	Shellfish	High rates of bio-accumulation; contamination of commercial species.
	Benthic invertebrates	Lethal and sub-lethal effects resulting in alterations to species diversity and composition.
	Fish	Bio-accumulation and kills in severe cases of contamination.
	Sea birds and marine mammals	Bio-accumulation in tissues.
Other chemical emissions	Shellfish	High rates of bio-accumulation and mortality through toxic effects.
	Benthic invertebrates	Lethal and sub-lethal effects resulting in alterations to species diversity and composition; loss of communities in severe cases of contamination due to toxic effects and smothering.
	Fish	Bio-accumulation and kills in severe cases of contamination; disease such as fin erosion and other lesions; avoidance responses and changes in distribution patterns.
	Sea birds and marine mammals	Bio-accumulation in tissues.
	Seagrass	Localised reduction in cover due to light reduction associated with colour of some chemical plumes.
	Algae	Reduced diversity of natural communities through competition from nuisance algae.
Thermal discharges	Benthic invertebrates	Lethal and sub-lethal effects resulting in alterations to species diversity and composition.
	Fish	Avoidance and attraction response, depending on season; attraction responses may increase exposure to associated chemical contaminants, avoidance responses may impact on reproductive success through altered migration patterns.
	Seagrass	Localised loss and stunting through increased temperature, microalgal blooms and growth of epiphytic algae.
	Algae	Reduced diversity of natural communities through competition from nuisance algae; alteration of species composition and abundance of microalgal communities.
Urban run-off	Shellfish	Bio-accumulation of contaminants; potential contamination with microalgal biotoxins during bloom events caused by increased nutrient levels; mortality in extreme cases of water contamination.
	Benthic invertebrates	Loss and reduced diversity through smothering and bio-accumulation of chemical

Source of Impact	Biota Impacted	Nature of Impact
		pollutants.
	Fish	Bio-accumulation of contaminants; impacts of debris through ingestion or entanglement.
	Sea birds and marine mammals	Impacts of debris through ingestion or entanglement; bio-accumulation of chemical contaminants.
	Seagrass	Loss or reduction in coverage through siltation, elevated turbidity and epiphytic algae and microalgal blooms caused by nutrient inputs.
	Algae	Smothering through growth of nuisance algae, alterations of species composition and abundance of microalgal communities during blooms.
	Mangroves and saltmarsh	Potential die-back caused by sediment loads in run-off.
Agricultural run-off	Shellfish	Bio-accumulation of contaminants; toxic affects of organochlorine pesticides and other agricultural chemicals; potential contamination with microalgal biotoxins during bloom events caused by elevated nutrient levels.
	Benthic invertebrates	Loss or reduced diversity through smothering of benthic habitats; bio-accumulation and toxic affects of organochlorine pesticides and other agricultural chemicals.
	Fish	Bio-accumulation of contaminants; fish kills due to microalgal blooms and potentially through organochlorine contamination.
	Sea birds and marine mammals	Organochlorine contamination through the processes of bio-accumulation and bio-magnification.
	Seagrass	Loss or reduction in coverage through siltation, elevated turbidity and growth of epiphytic algae and microalgae.
	Algae	Smothering through growth of nuisance algae; alteration of species composition and abundance of microalgal communities; declines in distribution and density of native macroalgae, such as the giant kelp (*Macrocystis pyifera*).
	Mangroves and saltmarsh	Potential die-back due to sediment loads carried by run-off.
Sewage discharges	Shellfish	Contamination with faecal bacteria; potential contamination with microalgal biotoxins during bloom events caused by elevated nutrient levels.
	Benthic invertebrates	Loss or reduced diversity through smothering of benthic habitats and through oxygen depletion and hydrogen sulphide production during bacterial decomposition of organic matter; community domination by a small number of pollution indicator species, such as capitellid worms and other scavengers and deposit-feeding species.
	Fish	Impacts little studied, but impacts at other organically enriched sites include

Source of Impact	Biota Impacted	Nature of Impact
		avoidance responses, changes in distribution patterns and reduced habitat through anoxia and elevated hydrogen sulphide concentrations.
	Seagrass	Loss or reduction in coverage due to growth of epiphytic algae and microalgal blooms.
	Algae	Smothering through growth of nuisance algae, resulting in reduced diversity and loss of some native species; altered species composition and abundance of microalgae due to blooms.
	Mangroves and saltmarsh	Extensive mangrove die-back caused by excessive algal growth that prevents or retards the establishment and growth of mangrove seedlings and kills aerial roots.
Dredging	Benthic invertebrates	Loss of communities and species; long-term impacts through habitat modification.
	Fish	Loss of spawning and nursery habitat through removal of sediments and seagrass.
	Seagrass	Loss or reduced coverage of seagrass beds through disturbance of the seabed, elevated turbidity and erosion resulting from altered flows.
	Mangroves and saltmarsh	Indirect effects through altered water circulation.
Altered river flows	Shellfish	Retarded growth rates in some areas due to reduced productivity; in other areas, potential contamination with microalgal biotoxins during bloom events caused by poor flushing.
	Benthic invertebrates	Alterations in distributions of communities due to changes in salinity and other water quality variables.
	Fish	Loss of habitat through anoxic conditions; loss of environmental triggers for breeding and migration events; prevention of migration due to artificial barriers. Effects range from local population extinction to reduced breeding success and modified distributions.
	Algae	Alterations in algal communities caused by microalgal blooms and excessive nuisance algal growth in poorly flushed conditions.
	Mangroves and saltmarsh	Potential impacts through changes in salinity, other water quality variables and the sedimentary environment.
Altered tidal flows	Shellfish	Potential contamination with microalgal biotoxins during bloom events caused by poor flushing.
	Benthic invertebrates	Alterations in distributions of communities due to changes in salinity and other water quality variables; loss of species where tidal flows are prevented.
	Fish	Loss of habitat through anoxic conditions; prevention of migration due to artificial

Source of Impact	Biota Impacted	Nature of Impact
		barriers. Effects range from local population extinction to reduced breeding success and modified distributions.
	Seagrass	Loss of seagrass where tidal flows are prevented or reduced.
	Algae	Alterations in algal communities caused by microalgal blooms, as a consequence of either reduced or increased tidal incursion; loss of algal diversity through excessive growth of nuisance species in poorly flushed conditions.
	Mangroves and saltmarsh	Potential impacts through changes in salinity, other water quality variables and the sedimentary environment.
Reclamation	Benthic invertebrates	Loss of communities through permanent removal of habitat.
	Fish	Potential loss of nursery and spawning habitat.
	Seabirds	Potential interference with seabird (and wetland bird) breeding sites and reduction in nesting habitat.
	Seagrass	Loss of seagrass beds and habitat; further reduction in beds caused by altered water flows and habitat.
	Mangroves and saltmarsh	Extensive declines through loss of habitat.
Erosion	Benthic invertebrates	Potential loss or alteration of communities through habitat modification.
	Fish	Potential loss of nursery and spawning areas through habitat modification.
	Seabirds	Impacts on breeding success of species nesting in beach and dune habitats.
	Seagrass	Potential loss of seagass through habitat modification and turbidity.
	Mangroves and saltmarsh	Local losses through erosion caused by adjacent seawall construction.
Port and marina construction	Benthic invertebrates	Loss of communities through permanent removal of habitat; altered communities through habitat modification; smothering near structures that act as accumulation points for wrack and sediments.
	Fish	Loss of nursery and spawning habitat; potential impacts on migratory behaviour during construction due to acoustic disturbance in the water column and elevated turbidity.
	Seabirds and marine mammals	Potential interference with seabird breeding sites and reduction in nesting habitat; potential impacts on marine mammal behaviour during construction through acoustic disturbance in the water column.
	Seagrass	Removal of seagrass beds and habitat; reduction in beds caused by altered water flows and habitats; impacts through shading effects of wharf facilities.

Source of Impact	Biota Impacted	Nature of Impact
	Algae	Modification or loss of algal habitat; impacts through shading effects of wharf facilities.
	Mangroves and saltmarsh	Loss through removal of habitat; possible declines through altered water flows and sedimentation.
Acid-sulphate soils	Benthic invertebrates	Loss or reduced diversity of benthic communities.
	Fish	Disease and mortality during periods of high run-off.
	Seagrass	Potential reductions of beds through habitat degradation.
Altered water quality	All biota	A wide range of impacts, encompassing the effects described above for specific impacting activities that influence water quality.

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