Review of the State of Knowledge of the NSW Sapphire Coast Marine Environment

Prepared By Steven James Dalton

on Behalf of the

Eden Whale and Marine Discovery Centre

Funded By Coastcare Australia

Executive Summary:

The Bega Valley Shire, located on the far south coast of New South Wales is approximately 500km south of Sydney and has a coastal fringe that extends from Wallaga Lake to Cape Howe on the Victorian/NSW border. One hundred and one ocean beaches separate rocky headlands and 20 major coastal water bodies. This region has provided resources, spiritual guidance and shelter for traditional owners (Yuin nation) for over 6000 years, with colonisation by Europeans during the nineteenth century. The coastal fringe and associated marine ecosystem supports a growing population in the area with economic wealth provided by fisheries and tourism.

The Sapphire Coast region is important for its biogeographical significance as it delineates the boundary between warm temperate Peronian and warm/cool temperate Flindersian marine provinces. Many species of algae are at their most northern limits within this transitional region, with numerous subtropical and tropical marine species present when warmer waters extend down the coast.

Past research conducted along the Sapphire Coast relating to three distinct coastal and marine zones (intertidal, subtidal and estuarine) was reviewed and a discussion of the main findings outlined. Additionally, recommendations for monitoring programs that might be undertaken by voluntary organisations with support from government agencies and professional bodies have been presented.

Temperate intertidal zones are transitional areas between marine and terrestrial environments and have been relatively well studied in many parts of Australia, particularly near larger developed areas. Organisms associated with this area are affected by the variation in tidal movement and wave action. Rocky shore habitats are dominant along the far south coast, with small to large scale variation in assemblage composition evident along the Sapphire Coast. Seasonal differences are also evident, with different algal species dominating during warmer and cooler months. Algae species that occupy areas along the coast include *Corallina* spp. and foliose algae from the genus *Sargassum* and *Laurencia.* Large algae such as crayweed may also be abundant at the bottom of the shore. Additionally, zones of dominant sessile

invertebrates have been observed with cunjevoi, tubeworms, barnacles and mat-forming seaweeds dominating the lower zones.

With only three published research papers focusing on Sapphire Coast rocky shores, information presented is limited to small, mainly sheltered headlands and do not provide a comprehensive account of the fauna and flora associated with intertidal environments along the far south coast of NSW. Additional research is required that will provide base line information on assemblages associated with sheltered and exposed headlands and provide important data for comparison in the event of changing conditions due to anthropogenic impacts (i.e., climate change, impacts by tourism and regional development).

The implementation of a voluntary based monitoring program similar to the recently established Project AWARE 'on the rocks' would promote education, protection and conservation of the intertidal rocky shores and estuarine habitats along the Sapphire Coast, increase the knowledge of the local marine intertidal environment and encourage stewardship.

Temperate subtidal rocky shores are important for their high species diversity and endemism, yet little research has been conducted along the Sapphire Coast. Generally, eight habitats have been recognised within this zone (Fringe habitats, *Pyura* habitat, *Phyllospora* forest, Barrens habitat, *Ecklonia* forest, Turf habitat, *Durvillea* forest and Deep reef), all of which are present at varying proportions extending over 150m from the high tide mark at locations adjacent to rocky headlands. These zones are generally identified by the dominant epibenthic organisms. Patterns of habitat types tend to be determined by both physical (i.e. wave exposure, insulation, tidal movement and substrata type) and biological interactions (particularly predation and competition). Faunal species are generally associated with these different zones, with distinct fish and mobile invertebrates dominating different areas, especially the black sea urchins that maintain Barrens habitat. The interactions between algal assemblage dominance, predation by mobile fauna and competition tend to exclude some species whilst enabling the establishment of other animal species.

With limited research conducted in the subtidal zone along the far south coast it is difficult to correlate the presence of one habitat type with local characteristics. Further research is required in order to understand the relationship of different habitats and physical and biological processes. Additionally, a full understanding of subtidal habitats will provide informative data that may be sued in the future to evaluate the affects of increasing pressure on nearshore reefs due to anthropogenic stress.

Compared to subtidal areas, estuaries have been extensively studies in NSW due to their social, economical and ecological importance. Previous studies have mapped the habitat types (seagrass meadows, saltmarshes and mangrove forests) associated with estuarine environments, which has provided baseline information on their distribution and abundance along the far south coast. Previous studies have suggested that these habitats have declined in some of the estuaries close to urban development within the region, which may have resulted from terrigenous discharge ad other human disturbance. Further research is required to evaluate the present condition of these habitats which will enable comparison with past research and may indicate a decline in the health of local estuaries.

Recreational and commercial fisheries within the region are socially and economically important. Recently a number of the local estuaries have been closed to the majority of commercial fisheries; however, recreational fishing is concentrated within the estuarine and coastal environments and may be placing pressure on fish species in these areas. Over 300 marine species are exploited through commercial fisheries and the ports of Eden and Bermagui account for approximately 10% of the total NSW catch. Additionally, it has been estimated the recreational fishing along the far south coast has the highest participation rate for the state. There are active aquaculture businesses established along the coast with seven estuaries utilised for the production of Sydney Rock and Pacific oysters, with mussel farming occurring in Twofold Bay.

It has been suggested that many economically important fisheries are in decline, which may highlight the lack of conservation on fisheries management, and that better management practices are required in order to develop sustainable industries and reduce the pressure on the natural environment. Further research is required to understand the

effects of exploiting current fisheries on the ecosystem of which they are an integral component, both within the commercial and recreational sector.

The Sapphire Coast provides habitat for a number of threatened and endangered species including the Grey Nurse shark and the Weedy seadragon, with whale species frequenting the region during the migration season. Whale watching provides economic benefits within the region and recent increases in whale numbers through the protection of these large mammals highlights effective species management. Further research is required to ensure the survival of threatened and vulnerable marine populations with long-term monitoring programs necessary to ensure the survival of other protected species.

Threats to the Sapphire Coast marine environment include the introduction of marine pests, which have translocated through ballast water discharge and hull fouling. Previous research has identified seventeen introduced species occurring in the Twofold Bay area. There is a need for further research on these species in order to determine the impact they are having on the local native marine communities and the development of eradication programs that will control pest outbreaks. Additionally, baseline information on pest introductions is required throughout the Sapphire Coast, as the only pest research has previously been conducted in Twofold Bay.

In order to gain a comprehensive understanding of the coastal and marine environments along the Sapphire Coast, a collaborative approach is needed between local government, universities and voluntary organisations. Consultation between these groups would form the framework of future research priorities and provide the mechanism for capacity building, where community groups can become actively involved.

Baseline information that will determine the status of the Sapphire Coast marine and coastal environments is required in order to determine the significance of the region and provide management authorities with vital information that may be used to establish management strategies.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 INTRODUCTION

1.1 Sapphire Coast General description

The Bega Valley Shire located on the far south coast of New South Wales (NSW) is approximately 500km south of Sydney. The coastal fringe of the shire extends from Wallaga Lake (Bermagui) in the north to Cape Howe on the NSW/Victoria border in the south, encompassing approximately 225 kilometres of coastline (BVSC 2002). There are 101 picturesque ocean beaches distributed throughout the coast with extensive rocky headlands dominating the land to sea interface. Many of these beaches are in close proximately to coastal development and as such have experienced varying degrees of degradation. The beaches and coastal fringe abut a variety of tenures, with 49 adjoining National Parks, 50 adjacent to land managed by the Bega Valley Shire Council or public holdings with Fisheries Beach located in Twofold Bay bordering State Forest. Within the region there are 20 major coastal water bodies comprised of riverine estuaries, lakes and lagoons, most with small catchments. However, some estuaries (i.e. Bega River, Towamba River, Murrah River and Narira Creek/Wallaga Lake) have catchments stretching inland to the Great Dividing Range.

The Bega Valley Shire encompasses an area of 6,052 square kilometres extending from the coast to the Great Dividing Range to the West. The shire population of approximately 31,000 people (2001 Australian Bureau of Statistics census data), are generally concentrated along the coast, with six main residential areas and 12 smaller villages present. The main regional centre, Bega, is located approximately 20 kilometres from the coast adjacent to Bega River. Other centres (Bermagui, Tathra, Merimbula, Pambula, and Eden) are located close to the coast. Approximately 60% of the population live within the coastal zone and rely heavily on coastal resources (BVSC 2002).

The coastal range of the Bega Valley Shire (Sapphire Coast) provides many attractions for local residents and visiting tourists from Victoria, Canberra and overseas. Tourism throughout the shire is important for its economic benefit to the local community, providing revenue through accommodation, tour operations and retail. The main industry of the area is retail trade accounting for 17% of the labour workforce, with agriculture/forestry/fishing, accommodation, health and community services and

manufacturing employing 11%, 10%, 10% and 9% of the workforce, respectively (BVSC 2003a). The Sapphire Coast and associated marine and estuarine environment have been an important part of traditional culture and early European settlement and still provides social and economic benefits for local residents.

Located approximately 36º to 37º south of the equator, the marine environment of the Sapphire Coast may be described as a cool/warm temperate environment, with many endemic assemblages dominating the associated area. Generally, average maximum air temperature of the coast varies between 25ºC during summer, falling to 15ºC in winter with average minimum temperatures ranging between 16ºC and 5ºC (BVSC 2002). Seawater temperatures of the coast fluctuate seasonally and have been recorded to be as low as 9ºC during winter and as high as 23ºC when warmer currents from northern eddies reach the south coast (S. Dalton pers. obs.). This varied temperature regime provides a mosaic of habitats, which many temperate and subtropical organisms inhabit for short to long periods. This region is a unique area for its important biogeographical representation of marine fauna and flora, yet little or no research has been conducted within the marine environment and associated areas. Presented below is an account of past research that has been conducted along the Sapphire Coast, including areas such as the intertidal zone, subtidal zone and estuaries and rivers of the Bega Valley Shire. Additionally, gaps in knowledge of the marine environment will be presented with recommendations for monitoring programs that might be undertaken by voluntary organisations with the support of government agencies and professional bodies. Finally, a general review of marine uses and impacts will highlight the need for robust research strategies and programs to ensure that this relatively pristine coast remains sustainable now and into the future.

Whilst this review was limited by time and funding, the author believes that while not all reference material relevant to the Sapphire Coast and adjacent marine environment were included (due to logistical constraints to accessing unpublished material) the greater proportion of reviewed material has been presented. More time would have allowed for a comprehensive analysis of the literature available. However, what is presented here is a stepping-stone for subsequent reviews and provides an understanding of the current state of knowledge of marine and estuarine environment associated with the Sapphire Coast.

1.2 Historical perspective of the Sapphire Coast

1.2.1 Traditional Owners

Prior to colonisation of NSW, traditional inhabitants of the Sapphire Coast were communities within the Yuin nation. The main dissimilarity between groups occasioning the region was the distinction between different languages spoken. Two speaking groups were associated with Twofold Bay, the Thawa and the Daura or Thau-aira tribes with known distribution between Bega River in the North, the Monaro to the West and south to Genoa River. Further north, four language tribes (Jirringan, Thoorga, Thurumba and Tharawal) occupied traditional land within the now Bega Valley Shire (Wesson, 2001). Additionally, Ngarigu tribe from the Monaro were known to frequent coastal regions with overlapping territories with the above-described tribes (Graham Moore NPWS, pers. comm.).

The Aboriginal people have a special connection with the natural environment including; spiritual, visual and cultural landscape created by their ancestors. Transient Aboriginal tribes gathered along the Sapphire Coast for celebrations, ceremonies, trade and the exchange of marriage partners. Many significant sites are located along the east coast of NSW, including middens, burial grounds, gathering areas (fish traps) and other spiritual locations (e.g. Wallaga Lake). The coastal range provided food, shelter, material and spiritual guidance for the Yuin nation for over 6,000 years prior to European Settlement (BVSC 2003b), and the traditional land custodians still have an affiliation with the Bega Valley region.

1.2.2 European Settlement

Colonisation of the South Coast by Europeans occurred during the early nineteenth century, particularly at Twofold Bay and in the Bega area. Beef and dairy farming industry began in the 1830s, with the Imlay brothers settling in the area. Timber cutting and the collection of wattle bark supported farming activities, which were exported to Sydney and southern locations. Fishing, including whaling, became an important industry within Twofold Bay, and the discovery of gold (particularly in Bermagui) supported a growing population in the region.

Although the region was hampered by isolation to large cities during early settlement, the coastal towns (Bermagui, Tathra, Merimbula and Eden) became the growth areas during the early years. Following the Second World War and the development of land based transport infrastructure, the reliance on shipping ended. Subsequent to this period an economic decline in local produce and restriction in raw material resulted in the regression of many small communities throughout the Bega Valley. The development of industries such as fishing, timber, farming and tourism in recent times has lead to the development of a competitive economic platform in the Bega Valley Shire.

1.3 Biogeographical provinces within temperate Australia

The Sapphire Coast region has been described as an important area as it delineates the boundary of two major biogeographical provinces, the warmer temperate Peronian and warm/cool temperate Flindersian marine provinces (The Herman Slade Foundation 2004). Earlier work completed by Charles Hedley, a marine biologist of Sydney, divided the Australian coast into four distinct regions on the basis of mollusc species collected from many locations.

These regions were named and described as follows:

- The Dampierian, extending along the north coast from Cape York westward and then down the coast of Western Australia to Geraldton;
- The Solanderian, extending along the Great Barrier Reef region from Cape York to Wide Bay;
- The Peronian, stretching from Wide Bay along the coast of NSW and Victoria to some point in the Bass Strait; and
- The Adelaidean, now called the Flindersian region, which includes the coast of South Australia and South-western Australia (Dakin 1956).

Later work distinguished a further province called the Maugean region that included the southeast coast of Tasmania; a region dominated by cool temperate marine species. Plants and animals that are generally found in cool temperate waters, including along the Victorian coast, have previously been described (refer Bennet & Pope 1953). Dakin (1956) suggested that the area between Bermagui and Twofold Bay, NSW is a transition

zone between cool and warm temperate biogeographical regions, with the Maugean region extending from this location south to the Victorian/ South Australia border and including the coast of Tasmania, and the Peronian region to the north.

This delineation may be due to the effect of the major currents associated with the area. The East Australian Current (EAC) which flows south from the equator, extends along the coast to greater than 32°S (Mid North Coast) where the majority of the current tends to move offshore flowing towards Lord Howe Island (Zann, 1996, Fig.). The effect of the EAC can be felt as far south as Cape Howe with large eddies branching off from the main flow delivering warmer nutrient poor water to southern NSW. In contrast, the Flinders Current and the Antarctic Circumpolar Current affect cooler southern waters, which deliver cooler nutrient rich waters to the Tasmanian and Victorian coasts. The result of these opposing currents is that the coast of NSW, Victoria and Tasmania are subjected to differing oceanic systems.

Figure 1.1 Map of the Bega Valley Shire, located on the far south coast of NSW.

CHAPTER 2 COASTAL AND MARINE ENVIRONMENTS

Marine environments can be classified into distinct zones, where topography, salinity, hydrology and varying tidal movement, oceanic and land (i.e. flooding) and other physical processes shape the biological assemblages associated with different zones along the coast. Three temperate zones; intertidal, subtidal and estuarine, will be investigated within this review with distinction between each habitat provided, including an introduction into the physical and biological processes that shape these areas along the south coast.

2.1 Temperate intertidal zone (Rocky Shores)

Rocky shores are a transitional area between marine and terrestrial environments and because of their accessibility have been widely studied in many parts of the world. Within temperate Australian waters, William Dakin, Isobel Bennett and Elizabeth Pope during the 1940s and 1950s described patterns of zonation and assemblages associated with this habitat, including areas along the NSW coasts (refer Dakin 1956). More recently Tony Underwood and associates from the University of Sydney have investigated many ecological processes within this zone using manipulative experiments; however, much of the work has been focussed on rocky shores adjacent to Sydney and surrounding areas.

Environmental processes that influence organisms associated with rocky shores include the semi diurnal (twice daily) rise and fall of the tide and the variation in tide height during periods when the water variation is minimal between high and low tide, i.e. neap tides. Wave action is another important process that affects rocky shores assemblages. The variation in wave action over temporal and spatial scales influence the distribution of organisms up the rocky shore, with community composition varying according to the amount of physical disturbance caused at the interface of where water meets the shore. For example, at exposed sites, following large storm events, plants and animals may be removed from the substrata, creating space for colonisation. In contrast, areas that are sheltered maintain a relatively stable environment for fauna and flora, resulting in a

community composition that is well developed and sometimes extensive where shallow platforms are present (Smith 2002). The result of these two main influences (tides and waves) is that habitats on rocky shores vary from low to high on the shore and from sheltered to wave-exposed coastlines (Underwood & Chapman 1995).

Substratum formation associated with rocky shore is an important determinant of the type of community present. Rock platforms, vertical slopes, cracks and crevices, rock pools and boulder fields all found along the NSW coast provide different protection from desiccation and wave action, influencing the type of organisms associated with these rocky shores. Another factor that shapes the community composition of a rocky headland is rock type. For example, soft, sedimentary rocks are much less stable for attachment of sessile organisms than harder wearing, metamorphic rock types.

Interactions between physical and biological factors on rocky shores gives rise to a universal pattern of successive bands of organisms' distribution from the low water tidemark to the upper tidal limits. This is called zonation, and different generalised patterns have been used to associate different organisms at different heights on rocky shores (Dakin 1956; Underwood & Chapman 1995). Additionally, organism distribution varies according to the level of disturbance exposure (exposed vs. sheltered areas) and the gradient of the shoreline (platform vs. cliff face). Successive bands or zones are named after the organism that dominates the area. Dakin (1956) suggests that you only need to be familiar with only about eighteen different kinds of animals, and four or five seaweeds, to be able to recognise at a glance the zones of the rocky shores. Figure 2 indicates the basic zonation patterns of NSW shores, including variations between sheltered and exposed sites.

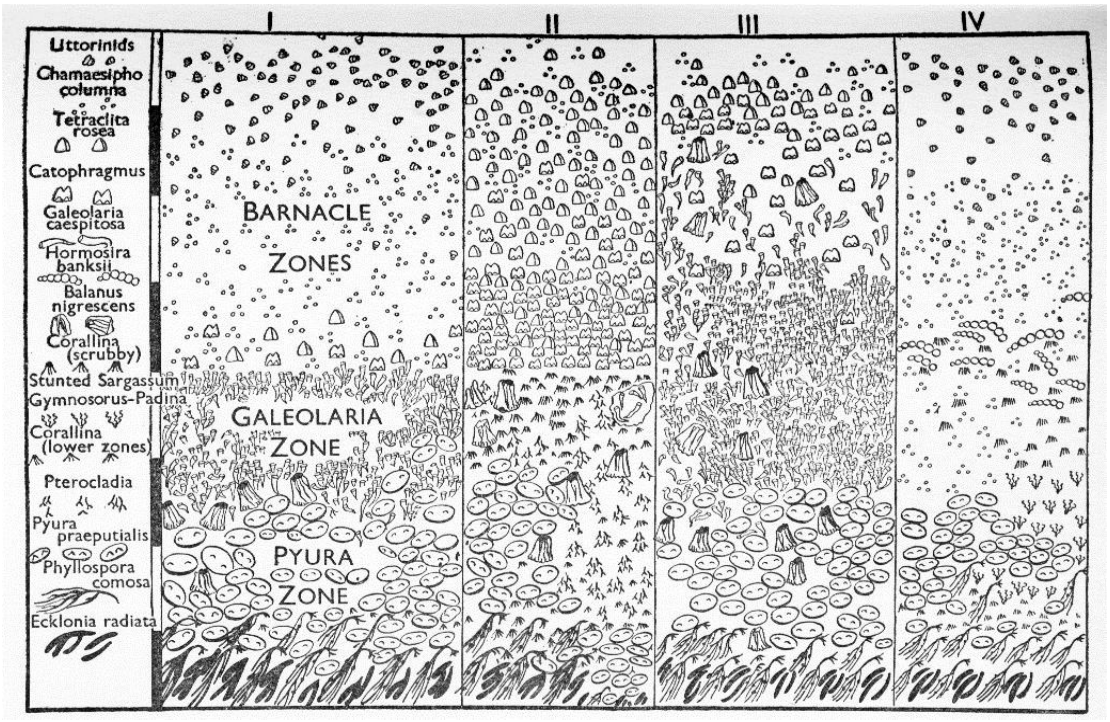

Figure 2.1 General zonation patterns of rocky shores in NSW, under different regimes of wave exposure. I = average conditions, reasonable shelter. II = high energy. III = very exposed conditions. IV = sheltered localities. (Source Dakin 1956)

These general patterns of organism distribution have been observed throughout NSW; however, with the majority of research focused on headlands adjacent to Sydney and surrounding areas (refer Underwood 1981; Underwood et al. 1983; Underwood & Jernakoff 1984), these patterns have not been tested in all regions of NSW. Previous work on rocky intertidal assemblages has been conducted within the Solitary Islands Marine Park (Smith 1995; Smith & James 1999), Byron Bay Marine Park (Smith & James 2003), Jervis Bay (Underwood & Chapman 1998a) and previously within Twofold Bay, Eden (Hutchings et al. 1989) and Merimbula (Day & Hutchings 1984). More recently, Chapman & Underwood (1998) and Underwood & Chapman (1998b) studied the algal assemblages associated with intertidal wave-exposed rocky shores of central and southern NSW.

2.1.1.1 *State of knowledge in the Sapphire Coast*

Rocky shores are a dominating habitat along the far south coast of NSW, yet little research has occurred within this region. Three published papers have focused on associated assemblages of rocky shores throughout the region (Hutchings et al. 1989; Chapman & Underwood 1998; Underwood & Chapman 1998b). However, these studies have been limited to small areas along the coast of southern NSW.

During studies of algal assemblages associated with lower intertidal rocky habitats Underwood & Chapman (1998b) examined large and small spatial and temporal patterns at five locations from central to southern NSW; however, only one location was evaluated in the area of interest. Results from this study highlighted considerable variation at all scales of the study, small within sites and large between sites and among shore variation. Chapman & Underwood (1998) indicated that algal assemblage at Tura Head was dominated by *Colallina* spp., with smaller amounts of foliose algae for the genus *Sargassum* and *Laurencia* present on lower intertidal reaches of the headland investigated.

Hutchings et al. (1989) investigated the assemblages associated with sheltered and exposed intertidal rocky shores at Twofold Bay, Eden. Zonation was not apparent at the sheltered site (Murrumbulga Point), which consisted of a rock platform with scattered rubble and boulders throughout. Interestingly, at the exposed site (Munganno Point) zonation was apparent on the rocky platform and sloping cliff face, with the lower zone dominated by cunjevoi (*Pyura stolonifera*) and mat-forming seaweed. Above this zone, the tubeworm *Galeolaria caespitose* and barnacles were present.

General patterns of zonation may provide an insight into the assemblages associated with southern rocky shores; however, as indicated by previous researchers, intertidal assemblages are variable over small and large spatial and temporal scales. This highlights the need to investigate the relationship between patterns of organism distribution and local physical and biological impacts, which may determine differences in community composition over these scales, providing a more accurate picture of assemblages associated with southern NSW rocky habitats.

Priorities for marine research and monitoring within the Sapphire Coast

As little research has occurred along the Sapphire Coast, important baseline information is required, which will enable comparison of marine flora and fauna associated with rocky shores between areas with high human use (i.e. Long Point, Merimbula) and regions regarded as pristine (i.e. headlands within Nadgee Wilderness). Furthermore, quantitative data collected from representative sites (exposed and sheltered sites) along the far south coast will provide mechanisms for long-term monitoring of changes in intertidal assemblages due to anthropogenic impacts.

Rocky shores are an area of high usage along the NSW coast and an emphasis on community education is required in order to reduce the loss of organisms due to collection and fishing along the far south coast. Locals and tourists frequent many headlands during peak summer holiday period and no information is available on the level of impact this amount of visitation has on the rocky shore assemblages.

Project AWARE "on the rocks", (refer EPA 2003) developed in 1995 by the Pittwater Council with the assistance from the Institute of Marine Ecology (University of Sydney) and other government organisations, is a community marine conservation programs, which focus on education, protection and conservation of the intertidal rocky shores and estuarine habitats. The outcomes of this program were to; stop the decline of flora and fauna of intertidal areas; build partnership between community groups, government agencies and scientific organisations; increase community awareness; and, encourage community conservation of intertidal zones (EPA 2003). At present this program has been extended into eleven other councils within the Sydney regions (Pittwater Council 2003) and would be an ideal program to implement at other locations along the NSW coast, including the Sapphire Coast. Results from this program would increase the knowledge of the local marine intertidal environment and encourage stewardship and conservation of this unique area.

2.2 Subtidal rocky shores

Australian temperate subtidal rocky shores have extremely high species diversity with a high proportion of endemic species, suggesting that marine assemblages are ecologically distinct from other temperate parts of the world (Zann 1996). Subtidal rocky habitats are abundant along the Sapphire Coast, with rocky platforms extending further than 150m from many rocky headlands (Andrews & O'Neill 2000). Rock platforms are not restricted to the coast and many midshelf reefs are present along the NSW coast. However, previous research has focused on the temperate subtidal reefs adjacent to headlands as they provide protection from prevailing sea conditions and are accessible using conventional self contained underwater breathing apparatus (SCUBA). Reef habitats along the far south coast are easily accessible to recreational, research and commercial divers with many diving operators located throughout the region.

Rocky reefs provide substrate for attachment of many sessile (non moving) organisms such as algae and marine invertebrates (sponges, ascidians, bryozoans to name a few). Patterns of habitat types vary according to many local characteristics of the region. Factors that determine these habitat types within a particular area include: the amount of insulation (light intensity and penetration); wave-action; tidal movement; composition, complexity and size of the substratum; siltation and abrasive action caused by suspended particles. Other factors that influence the community structure of a particular reef include modification to the area (i.e. development and construction of wharfs, barriers and marinas etc.), changes to adjacent land and estuaries and collection of important marine fisheries species (i.e. algae, and invertebrates such as crayfish and abalone). Additionally, inputs from sewerage discharge can affect the composition of dominant habitat forming organisms within coastal areas.

Biological factors also contribute to the composition of subtidal habitats. Interactions such as competition, predation, overgrowth and abrasion caused by other organisms may determine changes in dominant species over small and large temporal scales. For example, competition for space may lead to a loss of less dominant species, with more invasive organisms dominating. This is evident when top space competitors such as sponges, a modular organism (asexual reproducing animals) overgrow adjacent

organisms (refer to Underwood & Chapman 1995 (p.88)). Following the clearing of the substratum by either storm action or predation, successional changes are apparent with early colonisation determined by recruitment from the water column or asexual budding of adjacent organisms. Changes in benthic communities composition is dependant on many factors, which either favour or are disadvantageous to organism growth and dominance. Depending on factors such as time of the year (seasons) and available chemical cues of larvae settlement, early colonisation of free space will vary. Through time succession of species dominance will change with top sessile competitors dominating the reefs. However, as has been mentioned in literature, reef habitats don't achieve equilibrium and marine habitats can be characterized as a dynamic environment (Connell et al. 1997).

Benthic marine environments are continually affected by natural and anthropogenic factors at reefs adjacent to coastal development. For example, recent reports have described changes in benthic community structure or the modification of reef structure at locations adjacent to heavy development, such as cities (i.e. Sydney and Melbourne). Coastal development has occurred consistently over the past 200 years throughout the east coast of Australia, with the development of the far south coast of NSW increasing following the Second World War. This has given rise to increased stress on terrestrial, freshwater and marine environments, however, within the Bega Valley region coastal development has not kept pace with more north locations within NSW. The establishment of national parks along the coast within the region has reduced the impact on coastal ecosystems from urban and rural development.

The restriction of development may have lead to the preservation of the Sapphire Coast marine ecosystem, which could be an important reference for present and future studies. However, little research has been conducted within this area, and only generalization of habitat types have been described from broad scale surveys of the NSW subtidal environment (refer Underwood et al. 1991; Underwood & Chapman 1998b; Andrews & O'Neill 2000).

Previous studies into subtidal marine habitat assemblages have been restricted to headlands throughout the Sapphire Coast and at limited locations, which provide a general indication of habitat types at other locations. However, as outlined by Underwood & Chapman (1991) marine dominance varies at small and large temporal and spatial scales. It is therefore important to determine the distribution and dominance of different habitats at as many locations as possible; including exposed and sheltered areas, to fully understand the dynamics of marine ecosystems throughout this coastal region.

Zoning of the marine environment into habitat types is not a new method of describing general patterns through dominant species identification. Dakin et al. (1956) identified basic zonation of intertidal rocky shores. Characterisation of habitats provides a framework for studying the processes in which researchers are able to understand the association between marine organisms and their correlation with environment features such as depth and wave exposure.

Previous pioneering research work conducted in South Australia by Shepard and Womersley (1970, 1971, 1976, 1981) identified three zones to describe patterns of sub littoral habitats, the upper, mid and lower subtidal regions. These classifications were based on depth/exposure combinations, and were characterised by dominant algal groups present in each zone. Recent studies along the NSW coastline have identified distinct patterns between the association of species and habitat types (refer Underwood & Kennelly 1990 and Underwood et al. 1991). During broad scale benthic surveys conducted between South West Rocks in northern NSW and Merimbula to the south, Underwood et al. (1991) described seven habitat zones (Fringe, *Pyura*, *Phyllospora* forest, Barrens, *Ecklonia* forests, Turf and Deep reefs) present along the NSW coast. The distribution of these habitats varied between sites, which are generally related to physical (depth, wave exposure) and biological (particularly herbivory) processes (Underwood et al. 1991).

During more recent studies conducted by Andrews & O'Neill (2000) using aerial photographs and *in situ* ground truthing, an additional habitat type was described and present at locations south of Turingal Head (near Tathra; Fig. 1). *Durvillaea* forest was recognised in this study as a dense band of the bull kelp *Durvillaea potatorum* present in the low-shore and immediate subtidal zones (Andrews & O'Neill 2000). A description of each habitat type follows with reference to information on the Sapphire Coast presented.

2.2.1 Fringe habitats

Located in the shallowest waters (0-3m) this upper sub littoral area is dominated by foliose algae, particularly common alga *Ecklonia radiata* at more northern locations, with laminarian alga from the genera *Sargassum* and *Cystophora* spp. present. Further south of the NSW coast Crayweed (*Phyllospora comosa*) and Bull kelp (*Durvillaea potatorum*) are increasingly abundant (Dakin et al. 1956). Dakin et al. (1956) indicated that under the thick covering of *Pyllospora comosa* fronds, which may cover large areas of the upper sub littoral zone, smaller red and brown algae cover the available substrata. Andrews (1999) noted that whilst the community structure of Fringe habitats varies between latitudes, one important feature of this habitat that is consistent throughout NSW is that no single brown algae species dominate.

Sessile organisms are also a feature of this habitat with large solitary ascidians the Cunjevoi (*Pyura stolonifera*), present in varying percent cover. Additionally, turfing algae such as *Corallina* and *Amphiroa* spp. are present within the upper reaches of the sub littoral zone. Invertebrates are also present, however, in low abundance and species richness is limited to species able to withstand high wave energy such as chitons and limpets. Sea urchins (echinoids) may be abundant in areas of shallow depression and rock crevices.

State of Knowledge in the Sapphire Coast

Publications with reference to Fringe habitats within the Sapphire Coast region have been limited. Underwood and Chapman (1998) collected data from five wave-exposed rocky shores extending from Central to Southern NSW between 1980-1983; however, only one headland (Tura Head, Merimbula) was evaluated in the area of interest.

Results from this study indicated that the relatively steep rocky upper sub littoral zone was dominated by a homogeneous cover of foliose algae, principally *Corallina* spp. and other algae, including *Pterocladia lucida*, *Laurenca* spp. and *Ceramium* spp. present (Underwood & Chapman 1998). However, Underwood & Champan (1998) indicated that the methodology employed to determine algal assemblages (still photography) did not allow for the identification of many taxa present with only large and conspicuous species considered during this study.

During sub littoral surveys conducted in 1988, Underwood *et al*. (1991) determined the percentage cover of subtidal habitat extending 100m from the low tide mark. Results from sites surveyed on reefs adjacent to Long Point, Merimbula (a sheltered reef) indicated that Fringe habitat varied between less than 10% to greater than 20%. Their findings also indicated that there was variation in percent cover between sites surveyed and between seasons (summer v's winter). The dominant seaweeds observed at the two sites surveyed was turfing algae, with percent cover ranging between 65% and up to 90% for both sites surveyed, with cover increasing during winter (Underwood *et al*. 1991). Other algal assemblages present at Long Point included, filamentous algae, coralline algae and *Cystophora moniliformis*.

Fringe habitats are important to other organisms such as abalone (*Haliotis rubra*), which is commercially significant along the far south coast of NSW. Andrews & Underwood (1992) describe the distribution and association of *H. rubra* and *Centrostephanus rodgersii* at locations south of Eden. Results from this surveys indicated that there was high levels of variation in organism densities at small and large spatial scales, highlighting the heterogeneity of this type of habitat. There also appears to be a negative correlation between sea urchins and abalone densities at the small, within-habitat scale. Interestingly, abalone densities are generally greatest at shallower depths, with sea urchins dominant on deeper reefs (refer Andrews & Underwood 1992 and refs. within).

The most extensive study of the subtidal environment conducted along the Sapphire Coast in recent times was in 1996 and 1997, where aerial photographs were used to map reef sites extending 150m from the nearest point in the intertidal zone (refer Andrews & O'Neill 2000). Habitat maps were produced for reefs adjacent to Turingal Head, Haycock/Lennards Island, Eden, Disaster Bay, Nadgee and Cape Howe. Fringe habitats tended to increase with latitude, with greater than 60% of the reef at Cape Howe dominated by this classification. At locations south of Eden Fringe habitats represented over 20% of nearshore reefs (Andrews & O'Neill 2000).

2.2.2 *Pyura* habitats

When the Fringe habitat is completely dominated by monospecific stands of large solitary ascidians, commonly known to fishermen and generalists as Cunjevoi or sea-squirt (*Pyura stolonifera*), the *Pyura* habitat has been recognized. Complete dominance of the substrata has been observed at locations to the north of the state, particularly at nearshore reefs adjacent to South West Rocks and to a lesser degree at locations south of Eden. Cunjevoi can occupy all available substrate excluding all other sessile organisms including large brown algae.

Pyura habitats are limited to NSW in Australia; however, the same species are found in Chile and South Africa (Underwood & Chapman 1995). This may demonstrate that *Pyura* are an ancient species present prior to the division of the super continent Gondwana, when Australia was attached to South Africa and other continents.

Cunjevoi are filter feeders that can reach 20cm in height and approximately 10-12cm in diameter. They have a tough leathery outer layer and actively pump water through their mouth to filter plankton and other organic particles from the water column. This vertebrate species (Phylum Chordata) is able to close the inhalant and exhalant apertures, which reduces desiccation during periods when the tide is low.

Fauna generally associated with Cunjevoi include the large grazing chitons (*Plasipohora albida* and *Omithichiton quercinus*), which graze on algae attached to the Cunjevoi. There have been recent concerns that the removal of sea-squirts for fishing

bait may result in a decrease in abundance of associated species and a change in species composition at locations close to developed areas.

State of Knowledge in the Sapphire Coast

Pyura habitats on the far south coast of NSW generally cover small reefs of exposed sub littoral areas. Andrews & O'Neill (2000) describe patches of this habitat at locations adjacent to Turingal Head, with up to 57% cover of a small reef present at one site examined. However, anecdotal evidence suggests that *Pyura* habitats dominate many reefs between Nadgee and Disaster Bay to the south of Eden (Andrew's pers. obs. cited in Andrews & O'Neill 2000). Furthermore, this habitat has been observed to occur at exposed locations south of Merimbula, forming a dense cover extending into the intertidal zone on gently sloping headlands and occupying narrow margins of the upper sub littoral zone on vertical slopes (S. Dalton pers. obs.)

Studies conducted within Twofold bay in 1988 indicated that *Pyura stolonifera* was a dominant marine species of the lower intertidal zone of exposed rocky platforms adjacent to Munganno Point (Hutching *et al*. 1989). However, this habitat was not observed at Murrumbulga Point located within the bay, suggesting that *Pyura* habitats are located in areas of high energy.

2.2.3 *Phyllospora* forests

Dense forests of crayweed (*Phyllospora comosa*), a large brown algae, have been observed at nearshore reefs south of Wollongong (Andrews 1999). Characterised by the sawtooth-edged fronds that rise up from flat central axes and the spindle-shaped floats that are attached by small stalks, crayweed dominate exposed reefs of south-eastern Australia from the upper sub littoral zone to a depth of 20m (Edgar 2000). Generally, all kelp species are restricted to warm/cool temperate locations where adequate dissolved nitrogen is available for photosynthesis. The dominance of crayweed increases with increasing latitude, the most northern distribution recorded on the east coast of Australia limited to Port Macquarie, NSW (Edgar 2000).

Crayweed forests have a strong association with significantly important commercial fisheries in southern NSW, Victoria and Tasmania, including the black lip abalone

(*Haliotis rubra*) and the eastern rock lobster (*Jasus verreauxi*). However, an understanding of the ecology of these species is presently limited.

State of knowledge in the Sapphire Coast

Generally, the occurrence of *Phyllospora* habitats on the far south coast appears to be patchy in distribution on nearshore reefs. There is a clear increase in dominance of this habitat with increasing latitude, with a scattering of individuals observed at sites to the north of 36°S. Andrews & O'Neill (2000) noted that *Phyllospora* habitats were highest at Nadgee and Turingal Head with 40% and 62% cover, respectively. However, percentage cover was highly variable between Tura and the NSW/Victoria border. Underwood et al. (1991) observed variations in the abundance of *Phyllospora* forests at reefs adjacent to Tura Head, noting that this habitat was only present at one site investigated with approximately 10% cover recorded during winter surveys. This further highlights the patchy distribution of this habitat as well as the variation over small spatial (between sites within location) and temporal (between seasons).

2.2.4 Barrens habitat

As the term suggests, it might be assumed that there are little or no marine flora and fauna present in this environment, with only the abundance of the black sea urchin (*Centrostephanis rodgersii*) evident on first inspection. However, the boulder substratum is not barren with a thin covering of crustose red algae apparent. These algae, which appear as thin sheets on short tufts, give the reef a characteristic red/pink appearance. Producing calcium carbonate, which forms a large component of the algal structure, crustose algae are resistant to grazing from the sea urchins.

The substratum is composed of small to large boulders, where the cracks and crevices provide suitable locations for the dominant sea urchins to retreat to during the day, away from predatory fishers such as the blue groper (*Achoerodus viridis*) and sharks. In areas not heavily grazed upon such as vertical rock faces you will generally find sessile organisms such as sponges, ascidians and barnacles. The dominance of the black sea urchin determines the types of benthic organisms present in this habitat (Andrews 1999). Previous work, which compared the assemblage of boulder environments with and without the black sea urchin using cages or removal of this dominant species,

indicated that when there numbers of *C. rodgersii* is removed, turfing and large brown algae colonise the available substrata (Andrews 1993). Andrew & O'Neill (2000) suggested that if there is a decrease of urchins from barren habitats through fishing effort, the habitat may fragment with macroalgae and sessile invertebrates colonizing following the relief from grazing pressure. However, this may have a negative effect on other marine fauna such as grazing gastropod limpets, which rely on the urchin to provide suitable habitat. Limpets found within this habitat graze on diatoms and short-lived algae covering the crustose algae; if large macrophytes dominate the substrate then this may exclude encrusting algal forms.

State of Knowledge in the Sapphire Coast

Barren habitats are generally restricted to south of Newcastle, with only patches of nearshore reefs composed of this habitat to the north of the state (Andrews 1999). Andrews & O'Neill (2000) estimated that reefs south of Sydney composed greater than 50% Barrens habitat. Underwood *et al*. (1991) found that Barrens habitat dominated (< 60% cover) nearshore reefs adjacent to Merimbula. This dominance was also evident during further investigations conducted at exposed sites to the south of Merimbula. Barrens habitat tend to increase to a maximum between Eden and Disaster Bay with over 80% cover noted at latitudes greater than 37°S; however, this habitat were not present between Nadgee and Cape Howe (Andrews & O'Neill 2000).

2.2.5 *Ecklonia* Forests

Ecklonia radiata (common kelp) dominates the many reefs off the coast of NSW, with greatest densities recorded at central to northern locations (Underwood et al. 1991; Andrews & O'Neill 2000). *Ecklonia* forests can cover many hectares of hard substrata within estuaries, sheltered embayments and in deeper waters on exposed coasts (Andrews 1999). Characteristic of kelp is the attachment to rocky substrate via a holdfast that is connected to a single stipe, with fronds extending from both sides. *Ecklonia radiata* can be found in the shallowest of waters to a depth of 30m at exposed reefs, and provide a three dimensional habitat for thousands of animals and other algae, including epiphytes. Animals that are associated with this habitat include; lobsters, abalone, sea urchins, gastropods and fishes, many of which are significant fisheries resources. Additionally, many red and brown algae species are found interspersed

between the holdfasts. The kelp holdfasts provide a sheltered environment for a diverse macro fauna assemblage with the abundance of up to 1,500 individual and over 100 species noted (Smith et al. 1996). Additionally, *Ecklonia* forests are highly productive environments contributing organic material to a large range of fauna both within the forest, and in habitats to which organic material may be exported (e.g. sandy beaches).

State of Knowledge in the Sapphire Coast

Ecklonia forests are found throughout NSW coastal areas; however, Andrews & O'Neill (2000) indicated that there is a negative relationship between percent cover and latitude. *Ecklonia* forests dominate nearshore reefs adjacent to Port Stephens (35% cover) with no *Ecklonia* forests observed within Disaster Bay and Nadgee (Andrews & O'Neill 2000). Underwood et al. (1991) indicated that percent cover of this habitat vary seasonally at southern locations, with no *Ecklonia* forest reported during summer surveys at locations adjacent to Merimbula; however, *Ecklonia* forests were observed during winter assessments. Andrews (1999) indicates that *Ecklonia* forests are generally stable in their relative distribution; however, they undergo great variability in plant density over small temporal scales. For example, many plants may be lost from the substrata during storm events and recovery is determined by the time of the year the event occurred and the number of individuals lost. If the event occurred during summer, recovery of the population will be dependent on the level of recruitment to available space by other sessile organisms and the recruitment of *E. radiata* during the following winter when kelp reproduce. When a high percentage or all the population is removed then recovery may be reliant on recruitment from other locations.

Ecklonia forests are dynamic over small temporal scales, therefore one off studies into the distribution and abundance of this habitat type may not give a clear estimate of relative occurrence at locations in high energy environments, this highlights the need for seasonal and yearly assessment to account for natural physical and biological variability.

2.2.6 Turf Habitat

Underwood et al. (1991) defines Turf habitat as areas where there is an absence of animals (i.e. sessile organisms and sea urchins) and a dominance of turfing coralline and filamentous algae. Generally massive kelps (*Ecklonia*, *Phyllospora* and *Durvillaea*) are absent or patchy in distribution throughout this habitat. Other algae species are evident, with smaller brown algae, such as *Zonaria diesingiana* and *Dictyota dichotoma* and red algae *Delisea pulchra* and *Asparagopsis armata* dominating the substrata along the NSW coast.

Turfing habitat tend to dominate many nearshore reefs throughout NSW; however, there is considerable variability over small and large spatial scales. Andrews & O'Neill (2000) found that Turf habitat are composed off up to and greater than 20% of reefs extending from Port Stephens to Haycock Point, Eden in Southern NSW. There was considerable variability in the distribution of this habitat type and no significant difference in the representation of Turf habitat between locations examined. In contrast Underwood et al. (1991) determined that percent cover of Turf Habitats at representative nearshore reefs throughout southern NSW was generally less than 20%, with the exception of sites adjacent to Cape Banks and South West Rocks, where up to 50% of the reef sampled was Turf habitat.

Results from quantitative sampling of Turf habitats at South West Rocks and Seagull Point (Charlotte Head) indicated that filamentous algae covered approximately 60% of this habitat during summer, with turfing algae also present. In contrast, during winter surveys this trend was reversed with turfing algae dominant (Underwood et al. 1991).

State of Knowledge in the Sapphire Coast

Turfing habitats on the far south coast tend to be variable over small and large spatial scales with seasonal differences also apparent (Underwood et al. 1991; Andrews & O'Neill 2000). Generally this habitat tends to occupy less than 20% of nearshore reefs, with greatest percentage cover recorded at Tura Head and Haycock/Lennards Point. Percentage cover of Turf habitat is generally greatest during the warmer summer months, with filamentous algae increasing during this period, which might be due to increased insulation and supply of nutrients from localized upwelling events.

2.2.7 *Durvillaea* forest

During aerial mapping surveys of marine benthic habitats conducted between 1996 and 1997, Andrews & O'Neill recognized another habitat that was not previously identified by Underwood et al. (1991). The bull kelp (*Durvillaea potatorum*) formed dense bands in the lower intertidal and immediate subtidal zone of many reefs in the far south of the state, and this zone was appropriately called *Durvillaea* forest.

Durvillaea potatorum, known as a cool temperate kelp, has large fronds and is the dominant plant at and just below the low-tide level around the exposed Tasmanian and Victorian coast, with its most northern distribution recorded at Bermagui, NSW in the 1940s (The Herman Slade Foundation 2004). However, following recent surveys of macroalgal assemblages at locations between Twofold Bay and Montague Island, Tathra headland was the absolute northern limit of *D. potatorum* approximately 35km south of the previous reports (The Herman Slade Foundation 2004).

State of Knowledge in the Sapphire Coast

The distribution of *Durvillaea* forests within the Sapphire Coast is restricted to the south of Tathra and generally occurs as a narrow band in the immediate sub littoral zone. Additionally, *D. potatorum* were observed as scattered plants on the tops of ridges and associated with exposed headlands (Andrews & O'Neill 2000). *Durvillaea* forests were present at Turingal Head, Disaster Bay, Nadgee and Cape Howe, but only accounted for less than 2% of southern nearshore reefs examined by Andrews & O'Neill (2000), , during 1996 and 1997 surveys.

2.2.8 Deep reef

Sessile organisms, within the Deep reefs of temperate Australia, generally dominate regions where light becomes a limiting factor for photosynthetic organisms. Deep reefs tend to begin at depth of greater than 20m, although this isobath is determined by other physical factors such as location, exposure, sedimentation and water flow. The infralittoral zone, a shallow zone dominated by macroalgae that extends as deep as there is adequate light for photosynthesis, where the circalottoral zone is dominated by sessile and mobile invertebrates. Limited research has been completed within this light limiting region of nearshore reefs, with little or no work conducted at midshelf reefs

along the east coast of Australia. Preliminary research is currently being carried out by investigative teams from the CSIRO within South Australia, and other researchers at reefs adjacent to Sydney (Andrews 1999).

Deep reef habitats are dominated by sessile filter feeding organisms that are either modular encrusting organisms, more erect or branching and mobile animals. Although light is the limiting factor for many seaweeds at depths greater than 20m, encrusting red algae occupy large areas of Deep reefs in temperate waters (Underwood et al. 1991; Andrews 1999). With light intensity less than 1% surface level, only those species that can tolerate low-light conditions are found in this type of habitat. Other benthic organisms found within this habitat include, ascidians such as *Pyura spinifera*, sponges, soft corals and sedentary predatory black sea urchins.

State of Knowledge in the Sapphire Coast

Previous work conducted within the Sapphire Coast region, which describes the distribution of Deep reefs on nearshore reefs, is limited to one publication. Underwood et al. (1991) determined that this habitat accounted for less than 10% of nearshore reefs adjacent to Long Point, Merimbula. This report was limited to two sites at one location and it is difficult to form generalised patterns of habitat cover with limited quantitative data.

Anecdotal information indicates that Deep reefs form an important component of nearshore and midshelf habitats at locations within the region of interest. Many areas of frequented by recreational divers are located where sponge gardens are present. As indicated by Underwood et al. (1991) Deep reef habitats on the far south coast of NSW are dominated by massive and finger sponges. Sponge gardens tend to dominate gently sloping reefs located in water greater than 10m from Tathra to Disaster Bay, south of Eden (Byron 1956).

2.2.9 Fauna associated with NSW temperate nearshore reefs

Benthic marine animals on temperate reefs tend to follow predictable patterns as one moves from one habitat to another. There is a general trend for specific species to dominate different habitat to the exclusion of other species. For example, the grazing behaviour of the dominant herbivore of Barren habitats; the black sea urchin, excludes some gastropods whilst enabling other species (particularly limpets) to flourish in this apparently denuded environment (Andrews 1998). Sea urchins are also apparent in other habitats (i.e. *Ecklonia* forests and Fringe habitats); however, there abundance is considerably less. Furthermore, other sea urchin species occupy available sheltered sites in these less complex environments, including the Eastern slate-pencil urchin (*Phyllacanthus parvispinus*) and the purple sea urchin (*Heliocidaris erythrogramma*), with the arboreal sea urchin (*Holopneustes pycnotilus*) found living in the kelp canopy of *Ecklonia* forests (Kennelly 1995).

Invertebrate assemblages underlying the canopy of macroalgae forests tend to be dominated by singular and modular sessile species including ascidians, sponges and bryozoans with mobile fauna dominated by gastropod molluscs such as *Turbo torquatus* (cats eye snail) and the limpet *Patellioda altcostata.* Other macrofauna to occur in this area include abalone (*Haliotis rubra*), octopus spp. and lobsters (*Jasus* spp.) (Kennelly 1995).

Fish assemblages of temperate reefs display recognisable association with different habitats, depth regimes and substratum complexity (refer Lincoln Smith 1995). Fishes are dependant on habitats for food, shelter and protection for egg development. Compared to tropical Australia species richness of temperate waters is considerably less with approximately 680 known fish species in southern Australia compared to over 1500 on the Great Barrier Reef (Lincoln Smith 1995). However, many of the species present in temperate locations are endemic to Australian waters, whereas tropical fishes have a large geographical distribution throughout the Indo-Pacific region.

In temperate NSW waters the fish assemblage of rocky nearshore reefs are a mix of tropical families (wrasses and damselfishes) and other families that are southern temperate in origin (rock cales, morwongs and weed whiting). Many juvenile fishes

from tropical locations (butterfly fish and damselfish) are regularly observed during the summer months along the NSW coast; however, they don't survive the cooler waters and do not form active populations in temperate waters (Booth 2003). Demersal fishes have a distinct association with nearshore reefs, with territorial damselfish, leatherjackets, morwongs, wrasses, and cales abundant in temperate waters of NSW.

An important determination of herbivorous species present within nearshore reefs is the habitat type. Many herbivorous feeders such as fish species and sea urchins display a preference for different habitat types. For example, *C. rodgersii* is found in high abundance in areas that provide crevices for shelter from predation. Other plant foragers such as territorial scalyfins (*Parma macrosystic* and *P. unifasciata*) found in southern NSW dominate turfing habitats where they are more of a specialised feeder of red algae. Other fishes common to southern NSW have a preference for *E. radiata* and other brown algae, including species from the genus *Odax*. The haring cale (*Odax cyanomelas*) is present on the east coast of Australia and often observed feeding on adult *E. radiata* within shallow exposed waters. During the spawning season, female haring cales are seen intensely feeding on *Ecklonia* forests from August to October, which coincides with recruitment of juvenile brown algae to available substrate (S. Dalton pers obs).

Patterns of habitat types and foraging fish species have been determined in temperate coastal regions throughout NSW and provide an indication of distinct biogeographical provinces. Kingsford & Battershill (1998), using distribution and abundance of dominant species in combination with habitat type distribution (refer Underwood et al. 1991 and Andrews & O'Neill 2000) describe three distinct regions within NSW. Work on the distribution of fish species suggest that the dominance of specific species corroborate with other delineation patterns of geographical boundaries.

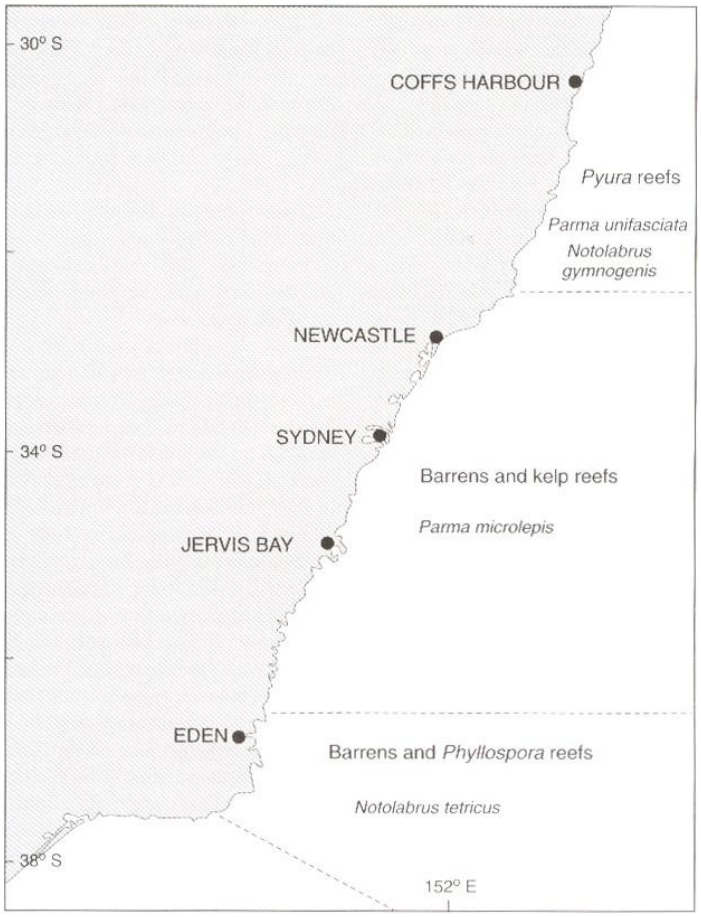

Figure 2.2 General pattern of subtidal habitat types and abundance of fishes along the coast of New South Wales (Kingsford & Battershill 1998).

State of Knowledge in the Sapphire Coast

Little information is available on the distribution and abundance of temperate marine animal within the Sapphire Coast. Previous research has looked at the distribution of the sea urchin *Centrostephanus rodgersii* (Andrews & Underwood 1992; Andrews et al. 1998; Andrews & O'Neill 2000), the affects of predation in barren habitats (Jones & Andrews 1990 and refs. within; Andrews 1993) and the interaction between sea urchins and the commercially important abalone (*Haliotis rubra*) (Andrews & Underwood 1992). The main finding from the above publications was that there were a negative association between abalone and sea urchins, with sea urchins dominating Barren habitats and abalone found within fringing reefs on southern NSW.

A baseline survey of benthic macrofauna in Twofold Bay was completed during 1984 to 1985 (Hutchings et al. 1989), which described macrofauna associated with intertidal and subtidal habitats including; seagrass, soft bottom, intertidal rocky headlands, saltmarsh areas and sheltered and exposed subtidal reefs. Sampling was conducted seasonally, with qualitative data describing the fauna associated with these habitat types.

A detailed inventory of marine fauna collected from Twofold Bay was produced, describing the macrofauna present at all sites examined; however, it is difficult to associate different species observed at nearshore reefs within the paper because all habitat types associated with the two headlands were pooled together in the frequency and abundance data (i.e. samples were collected from intertidal and subtidal rock platforms, Wharf piles and soft sediment habitats at Munganno Point). For a full species list from this study refer to the appendix in Hutchings et al. 1989.

Two subtidal areas were examined during this study; Munganno Point, a north westerly exposed headland, and Murrumbulga Point, a more sheltered site within the bay. Descriptions of the habitats associated with each sampling area was provided, indicating that both reefs supported a good covering of kelp and other algae; however, the topography was different. A tiered rock platform outcrop extended down to 6m at Munganno Point, in contrast to Murrunbulga Point, which is composed of an uneven expanse of boulders to a depth of 9m, supporting an abundance of sea urchins located in sheltered crevices. The information provided a clear indication of the marine fauna associated with marine habitats from Twofold Bay, including introduced species, and provides baseline information for future studies.

Fish assemblages associated with nearshore reefs of southern NSW have previously been described in reviewed literature. Jones & Andrews (1990) describe the herbivorous marine fishes present at Bermagui, NSW, indicating that scalyfin (Family Pomacentridae), herring cale (*Odax cyanomelas*), leatherjacket (Family Monacanthidae), blackfish (Family Girellidae), drummer (Family Kyphosidae) and sea carp (Family aplodactylidae) are present at nearshore reefs. Other fishes present on temperate southern reefs include large omnivorous/carnivorous species including wrasses (genus *Notolaburus*) and morwongs (genus *Cheilodactylus*) (Jones unpublished data cited in Kingsford & Battershill 1998).

2.2.10 Macroalgal assemblages associated with NSW temperate nearshore reefs

Temperate reefs of southern NSW can be described as a mosaic of habitats, with benthic community structure along the Sapphire Coast determined by both physical (temperature, light, water movement and depth, etc.) and biological (competition, predation and recruitment, etc.) interactions. Macroalgae distribution throughout warm/cool temperate Australia is influenced by many abiotic and biotic factors, which determine the dominance of individual species within this region. Abiotic factors include; temperature, nutrient, water motion, available insulation, salinity, substratum type, sediment and pollution. Herbivores are the principle biotic factor that effects the distribution of macroalgae in nearshore environments; however, competition, recruitment and others factors help shape the community composition of sublittoral reefs.

The study of marcoalgae and other plants in temperate regions is still in its infancy with most available data limited too qualitative, presence-absence information. A generalisation of species distribution can be formulated by reviewing previous work (i.e. Womersley 1981, 1984, 1987); however, most historical research has focused on taxonomic information rather than distribution and abundance of marine plants (A. Millar pers. comm.).

Previous published records on marine benthic algae for the state of NSW indicate that there are 131 Chlorophyta (green algae), 140 Phaeophyta (brown algae) and 449 Rhodophyta (red algae) species present along the eastern NSW coast (Millar 2004). Recently, 24 additional species were discovered between Cape Howe and Montague Island, east of Narooma (Millar 2004). All of these algae species are at their most northern distribution indicating the significance of the Sapphire Coast for is biogeographical importance (A. Millar pers. comm.). Additionally, the most northern distribution of a dominant cool temperature brown algae (*Durvillaea potatorum*) within the region further highlights the biological significance of this region for its mix of cool and warm temperate algal species.

Studies by Alan Millar from the Royal Botanic Gardens located in Sydney described a marine epiphyte *Ceramium juliae* sp. Nov. from subtidal habitats adjacent to Eden,

NSW. Millar observed this species occurring attached to other algae, specifically growing on the brown algae *Cladostephus spongiosus* in 15 metres of water. The significance of this discovery is that the location this species was found, the eastern side of Honeysuckle Point (37°5'57"S, 149°56'21"E), Twofold Bay, NSW is the type locality for this species, which is used as a reference of additional discoveries of this species from other locations (Millar 2002).

Priorities for marine research and monitoring within the Sapphire Coast

As previously stated, temperate reefs of Australia including southern NSW are not well studied. General patterns of species distribution have been described for algal assemblages; however, quantitative data is not available for both flora and fauna present on the south coast. An emphasis on developing research and monitoring programs that will fill in the gaps in knowledge need to include a comprehensive database of temperate reefs and associated assemblages. Much of the subtidal research undertaken has been conducted in areas close to populated cities with only a few publications reporting at a regional level. Appropriate research is required at representative locations throughout the Sapphire Coast, which will determine the appropriateness of habitat classifications and include detailed quantitative descriptions of fauna associated with these categories. This will provide baseline data for subsequent monitoring, which may indicate changes to subtidal assemblages due to natural or anthropogenic events (climate change, sewage discharge etc.).

Presently the management of rocky reefs is limited to several small aquatic reserves and four newly declared Marine Parks (refer www.fisheries.nsw.gov.au), which provide for the protection of these areas. Prior to the establishment of these Marine Parks, comprehensive research was undertaken in order to evaluate and determine representative areas of different habitat types for varying protection from anthropogenic impacts (i.e. recreational and commercial fisheries). The development of four different levels of protection (refer MPA 2002) within these recently established Marine Parks enables the conservation of different habitat types whilst enabling sustainable recreational and commercial activities. These Marine Parks and Reserves are limited to Jervis Bay and north of the state, with no protection provided for temperate reefs within southern NSW. In order to establish adequate protection of representative habitat types present along the south coast, a comprehensive base-line survey is required which will

determine the composition of nearshore and deep reefs along the south coast and the marine assemblages (i.e. fishes and invertebrates) associated with these habitats. This information will enable comparison for future surveys, which may indicate changes in community structure following stress events (either natural or anthropogenic) and the effectiveness of Marine Parks within the region once established.

2.3 Estuaries

By definition an estuary is a 'semi-enclosed coast body of water, which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage' (Prichard, 1967, cited in Morrisey, 1995). Generally, habitats associated with estuaries are sheltered from water movement created by tidal exchange, ocean and wind currents and wave energy that generally occur in more exposed sites along the coast. The accumulation of sediment along the estuarine fringe provides the major habitats for flora and fauna that are associated with this brackish environment. Plants such as seagrass, mangroves and saltmarshes provide habitat and food for animals that can tolerate the daily variations in salinity and water saturation.

Estuaries are important both socially, economically and ecologically, as they have historically been focal points of human settlement because of their importance as natural ports for ocean and riverine shipping, proximity to fertile coastal plains and productive fishing grounds. Urbanisation has occurred adjacent to main estuaries throughout Australia, including along the far south coast of NSW. Four main ports established on the Sapphire coast (Eden, Merimbula, Tathra and Bermagui) are important areas because of their access to sheltered ports and the resources available within the estuaries that they were developed near.

Urban development along estuaries has had a significant impact on these areas, resulting in the modification and reclamation of foreshores and wetlands, clearing of catchment for agriculture, forestry and mining, and a change in chemical composition of estuaries due to the disposal of effluent and domestic and industrial wastes. There has also been

a loss in species richness and abundance as a result of commercial and recreational fishing.

Compared to subtidal and intertidal habitats, estuaries have been comprehensively studied, particularly where they are located near major cities. The characteristics and status of Australian estuaries are moderately known, with a database established in 1989 highlighting the information of 783 estuaries throughout Australia (Zann, 1996). However, Zann (1996) suggested that further information was required on individual catchment characteristics, water quality, and assessment of fisheries and conservation values, and baseline studies of biota associated with estuaries.

State of Knowledge in Sapphire Coast

A total of 24 estuaries of varying characteristics are present along the Sapphire Coast, ranging from embayments to small intermittently closed open lagoons (ICOLS). Twofold Bay a semi-enclosed embayment, is characterised by marine waters with little fresh water inflow, which creates a transitional region between true estuarine environments and the open ocean. Ten estuaries along the south coast are typically wave-dominated barrier estuaries (Table 2.1), with a further thirteen estuaries classified as intermittent estuaries that are saline coastal lagoons (refer Roy et al. 2001 for classification).

The first published studies of southern NSW estuaries flora was by Saengar et al. (1977) who detailed the distribution of mangrove along the NSW coast. However, detailed distribution at this time was not available at southern locations. The first published account of flora and fauna associated with estuaries within the Sapphire Coast region was in 1984, when J. Day and P. Hutchings described the fauna and flora of Merimbula, Pambula and Back Lakes during sampling conducted between 1975 and 1976 (Day & Hutchings, 1984). Quantitative sampling occurred at all lakes, and a full list of true plants, algae and fauna associated with sediment, hard substrate and seagrass assemblages is presented (refer Table 1-3 Day & Hutchings, 1984). A description of the distribution and abundance of assemblages present in these lakes was also outlined.

In the early 1980s, West et al. (1985) completed a comprehensive inventory of the distribution of estuaries wetland plant communities, including saltmarsh, mangroves

and seagrass habitats. Detailed maps of many NSW estuaries were produced, which included many located within the southern section of the state. Table 2.1 summarises the results of this study identifying the plant species present and their total cover in each estuary examined.

Table 2.1 Inventory of estuarine characteristics and vegetation within the southern coastal region. Modified from West et al. 1985 and Roy et al. 2001.

Estuary	**Estuary type**	**Mangrove spp. present**		**Mangrove area (km^2)**	**Seagrass spp. present**				**Seagrass area (km^2)**	**Saltmarsh area (km^2)**
		Av	Ac		Z	P	H	R		
Wallaga Lake	II			0.000	x		x	x	1.343	0.295
Bermagui River	II	x		0.434	x	x	x		0.338	1.066
Barragoot Lake	III			0.000	x			x	0.049	0.053
Cuttagee Lake	III			0.000	x		x	x	0.430	0.076
Murrah Lagoon	II			0.000	x				0.016	0.109
Bunga Lagoon	III			0.000					0.000	0.018
Wapengo Lagoon	II	x		0.409	x		x		0.360	0.319
Middle Lagoon	III			0.000	x			x	0.081	0.011
Nelson Lagoon	II	x	x	0.271	x		x		0.114	0.063
Bega River	II			0.000	x				0.304	0.411
Wallagoot Lake	III			0.000	x		x	x	0.647	0.014
Bournda Lake	III			0.000				x	0.043	0.000
Back Lagoon	III			0.000	x			x	0.204	0.018
Merimbula Lake	II	x	x	0.377	x	x	x		2.297	0.629
Pambula Lake	II	x		0.449	x	x			0.868	0.188
Curalo Lagoon	III			0.000	x			x	0.058	0.166
Nullica River	III	x		0.000	x				0.020	0.000
Twofold Bay	I			0.000	x	x			0.026	0.008
Towamba River	II			0.090	x			x	0.027	0.009
Fisheries Creek	III			0.000	x			x	0.046	0.042
Wonboyn River	II	x		0.000	x		x		0.237	0.483
Merrica River	III			0.000	x				0.000	0.000
Nadgee River	III			0.000					0.000	0.000
Nadgee Lake	III			0.000				x	0.075	0.000

Estuary Type: I-Embayment; II-Wave-dominated barrier estuary; III-Intermittent estuary
Mangrove spp.: Av-*Avicennia marina*; Ac-*Aegiceras corniculatum*;
Seagrass spp.: Z-Zosteraceae; P-*Posidonia australis*; H-*Halophila* spp.; R-*Ruppia* spp.

Hutchings et al. (1989) sampled estuarine sites adjacent to Twofold Bay during 1984-85 and described the benthic macrofauna associated with sandy sediment, intertidal rock, and saltmarsh habitats at Fisheries Creek, Nullica River, Shadracks Creek and Curalo Lagoon. Seagrass species from the genus *Zostera* and *Ruppia* were present near the entrance of Curalo Lagoon with extensive saltmarsh habitat occurring on the eastern margin. *Zostera* sp. was also described as inhabiting the channel and tidal pools of Nullica River, with this species also occurring at the smaller Shadracks Creek. Seagrass beds were also observed within the embayment, with stands of *Posidonia australis*

occupying soft sediment at depths greater than 2m adjacent to Quarantine Bay. An inventory of benthic macrofauna of Twofold Bay and associated estuaries are presented in the appendix of Hutchings et al. (1989), and provides a comprehensive list of marine fauna associated with estuarine habitats.

Recent studies by ngh Environmental (2003) described the distribution of seagrass meadows in Merimbula. Results from photographic images and field assessments indicated the total cover of seagrass was approximately 1.9km^2, which was a decline of 0.4km^2 from the assessment by West et al. (1985). Three seagrass species occurred in the lake, *Posidonia australis* (0.88km^2), *Zostera* sp. (0.91km^2) and *Halophila* sp. (0.11km^2). Species replacement generally followed along a gradient of depth, with *Halophila* sp. occurring in shallower shoreline areas, *Zostera* sp. dominating the upper intertidal zone and *P. australis* found in the lower intertidal region.

There has been a trend for seagrass meadows to decline in many lakes and lagoons along the NSW Coast. Meehan (1997 cited in ngh Environmental 2003) found that seagrass meadows have declined 23.5% over the last 50 years in Merimbula Lake, suggesting the loss in cover were related to foreshore development. This development, has caused an increase in storm water runoff, a decline in water quality and increased sedimentation within the lake, smothering the meadows causing dieback. This highlights the vulnerability of this important habitat (nursery for many fish and invertebrate species, some that are commercially) and the need for adequate monitoring programs to determine the exact cause of seagrass loss in areas adjacent to development.

Currently, NSW Fisheries are assessing the distribution and biodiversity of fish habitats within NSW major coastal regions, which includes the boundaries of seagrass, mangrove and saltmarsh within many of southern NSW estuarine systems. Following this investigation a comparison between the current and historical assessments may identify if a decline is occurring in estuarine habitats within the region.

Estuaries are significant for their recreational and commercial fisheries, providing economic advantages to many communities along the east coast of NSW. The Sapphire Coast generates much of its income and employment through tourism and commercial fishing, with the annual catch for estuarine commercial fisheries estimated at $380,000.

Additionally, revenue generated by recreational fishing is estimated at between $6.8 million to $10.2 million per year within the southern region (NSW Fisheries 2001).

Recently many commercial fishing activities have been excluded from the majority of southern estuarine locations. In 2001 NSW Fisheries developed a management framework for the sustainable management of marine resources and has since implemented the closure of important estuaries along the coast of NSW. Further information can be obtained directly from NSW Fisheries (www.fisheries.nsw.gov.au).

Priorities for marine research and monitoring within the Sapphire Coast

There have been many concerns raised about the environmental impacts on estuarine ecosystems on the Sapphire Coast. Increased pressure from tourist development and urbanisation, increased seasonal influx of tourists, reduced water quality, and commercial and recreational fishing affecting aquatic resources has lead to a decline in essential habitat such as seagrass meadows and marine benthic communities. A priority into understanding the affects modification of the natural habitats and recourses is essential throughout the region in order to understand the impacts these and other factors are having on the marine community and ecosystem. Sound rigorous marine studies should be implemented at all locations along the south coast, which will provide managers with information regarding the current state of the estuarine ecosystems in the region and provide a baseline for future studies.

CHAPTER 3 MARINE RESOURCES USE

Recreational and commercial fisheries within the region have and still play an important role in the socio-economics of the far south coast. Fisheries established within the region include; aquaculture, recreational and commercial estuarine fisheries, recreational sport and game fishery and underwater fishery (spear fishing), commercial inshore and deep ocean fisheries, with many fisheries currently at sustainable catch limited or overexploited (NSW Fisheries 2003). Revenue generated from recreational and commercial fishing activities has played a major role in establishing the south coast over the last one hundred years. Early establishment of the whale industry enabled the development of the port of Eden and the subsequent infrastructure of a growing community. However, the whale industry was quickly overfished and following the protection of whales in Australian Waters, commercial whaling operations ceased in the area.

3.1 Commercial Coastal Fisheries

Commercial fisheries in Australia and in particular NSW use a variety of methods (i.e. long line, trawl, traps and poling) to exploit over 200 species of fish, 60 species of crustacean, 30 species of molluscs and a few echinoderms species (Zann 1996). However, whilst Australia has one of the largest Fishing Zones (8.94 million km^2), total commercial catch is considerably lower than other fishing nations. The low productivity of Australian waters is attributed to the lack of nutrients entering the marine environment from terrestrial run off and an absence of large nutrient rich upwellings mixing with coastal waters along the continental shelf.

The economic value of commercial ocean catch (excluding abalone, rock lobster, ocean-hauling and hand-gathering fisheries) landed at the ports of Eden and Bermagui during 1999/2000 was estimated to be approximately $788,000 and $364,000, respectively (Table 3.1). Abalone fisheries along the far south coast were recorded to have landed 305 tonne of live abalone with an estimated value of $9.25 million during the 2001 fishing season (NSW Fisheries 2003a).

Table 3.1 Ocean catch of the main fishery groups landed at the port of Eden and Bermagui during 1999/2000, excluding data from abalone, ocean-hauling and hand-gathering fisheries. (Modified from NSW fisheries 20003)

	Eden		**Bermagui**	
	Weight (kg)	**Value ($)**	**Weight (kg)**	**Value ($)**
Finfish	165,615		55,623	
Molluscs	14,699		2,190	
Crustaceans	3,605		409	
Total	**183,919**	**788,000**	**58,222**	**364,000**

The ocean hauling fishery targets a relatively small number of species compared to other fisheries using similar gear (NSW Fisheries 2003b). Approximately 99% of the catch by total landed weight is comprised of less than 20 finfish species, taken from ocean waters and sea beaches along the NSW coast using five types of commercial hauling and purse seine nets (NSW Fisheries 2003b). Average production during 1997/98 to 1998/99 for all regions of NSW was approximately 4200t with an estimated economic value of $9.2 million. Total catch for the southern region Zone 9-10 (refer NSW Fisheries 2001 p. 37 for ocean zones) for the same period was 412t; approximately ten percent of the total state catch. Other commercial fisheries interest along the far south coast include estuarine and aquaculture. However, with recent closure of many of the previously fished estuaries commercial production in this region has significantly declined.

As many as 33 estuaries along the NSW coast are utilized for the culture of Sydney rock and Pacific oysters, and aquaculture within the far south coast region is dominated by the same culture. Total NSW production of Sydney rock and Pacific oysters during 2000/01 was 7.8 million and 330,000 dozen, respectively; with an estimated to gate value of $31.6 million (NSW Fisheries 2003a). Seven estuaries within the far south coast are utilized for the culture of oysters, accounting for approximately five percent of the state catch, with Merimbula Lake contributing over 37% of overall sales on the far south coast (Table.3.2).

Table 3.2 Total harvest of cultured Sydney Rock oysters in the Sapphire Coast. (Modified from NSW Fisheries 1999).

	Estuaries						
	Bermagui River	Wapengo Lake	Nelson Lagoon	Bega River	Merimbula Lake	Pambula River	Wonboyn Lake
1996/97	26,000	41,874	10,455	0	161,740	89,981	97,208

A recent addition to aquaculture in the region is the development of mussel farming within Twofold Bay. Commercial farming of blue mussel (*Mytilis planulatus*) began in NSW during 1976 and was prompted by experimental farming at sites throughout Southern Australia. Suitable sites in NSW are confined to Twofold and Jervis Bays. Single commercial farms operate on annual renewable research permits; however, only Twofold Bay has consistently produced significant quantities of marketable mussels over recent years. Production over the past six years has fluctuated between 30 to 40 tonnes, which is likely to increase with the commissioning of a 10x30m long-line system with a production potential of an additional 50 tonnes (NSW Fisheries 2003a). With a stable price of $5.00 kg over the past six years, returns are expected to exceed $400,000 in the coming years.

Development of the mussel industry has been slow and many government agencies (NSW Fisheries, EPA, DL&WC, Forestry and NP&WS), environmental groups and other waterways users are concerned with the potential impacts this fishery may have on the Twofold Bay ecosystem and abalone industry. Following application for the expansion of the mussel industry the Pacific Seafood Management Consulting Group were commissioned to evaluate mussel aquaculture in Twofold Bay. Recommendations from this Environmental Impact Statement (EIS), (prepared to identify the advantages and disadvantages of the proposed mussel development in Twofold Bay with respect to the ecology and socio-economic interaction within the local community) completed in 1996, suggested that 105Ha within Twofold Bay be allocated for mussel farm lease, with 50 percent commissioned during Stage 1 (Pacific Seafood Management Consulting Group 1996).

Following the public consultation process, the Minister for Fisheries determination was prepared and published in September 1998. The commercial fisheries development was

approved; however, not to the size recommended in the EIS. Fifteen Ha was approved for development during Stage 1, with a further 32 Ha allocated for Stage 2 adjacent to Torarago Point, Twofold Bay. The approval of Stage 1 would provide the mechanism for ground truthing the benefits and impacts of mussel farming with longlines in Twofold Bay, which would include: the assessment of the environmental and socio-economic outcomes of the activities; the durability of the farming structures under storm events; and, the overall commercial viability and sustainability of the project (Minister for Fisheries 1998). Stage 2 development would only be approved following the satisfactory review of the Stage 1 assessment.

As a part of the Stage 1 permit for expansion of the existing farm from 7.5Ha to 15.5Ha, the Centre of Research on Ecological Impacts of Coastal Cities (EICC) were contracted to assess the potential ecological impacts due to the expanded mussel farm, in order to better inform the design of future monitoring. Results from *in situ* sampling of the macro organisms living within the soft sediment below the farms (impact) and at adjacent sites (controls) indicated that there was significant differences in abundances between sites under mussel rafts and nearby control sites; however, this was only significant at the spatial smallest level (within the farmed bay). Underwood and Hoskin (1999) concluded that there was a small amount of evidence indicating an ecological impact of mussel culture in Twofold Bay; however, they suggested that more detailed assessment of impact on small-scale spatial ecological variability are needed in order to conform to the precautionary principle (when an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically).

3.1.1 Current state of research in the Commercial Fisheries

Many fisheries within NSW waters have lacked adequate conservation strategies for the resources upon which they depend. Current trends in catch numbers suggest that many of these fisheries are overexploited, suggesting that the past belief that the ocean resources were limitless is not the case. Many economically important fisheries such as southern bluefin tuna (*Thunnus maccoyii*), Australian salmon (*Arripis trutta*), eastern rock lobsters (*Jasus* spp.) and snapper (*Chrysophrys auratus*) are in decline. This highlights the lack of conservation in fisheries management (Zann 1996). Better

management practices are required in order to develop an industry that fosters principles that enable sustainable development of marine resources and provide adequate socio-economic benefits to communities reliant on the fishing industry, such as towns along the far south coast. Information including: data on catch and effort is required for all fisheries; target species life history; and, the effects of fishing on marine populations and communities and predator/prey interactions are required in order to adequately manage state fisheries sustainably. Additionally, monitoring impact caused from other stressors such as habitat destruction, pollution, climate change and recreational fishing are also required to determine sustainable catch limits of different target species.

3.2 Recreational Fisheries

Recreational fishing in one of the main outdoor leisure activities in Australia and a major use in the marine and estuarine environments. It has been estimated that the number of Australian recreational fishers is over five million and that between 34,500 and 76,500 people are directly employed servicing this fisheries (Zann 1996).

A recent survey of recreational fishing in NSW estimated the over 1 million people actively fish NSW waters, approximating a 17% participation rate. The level of participation was twice as high in the country than in major metropolitan areas, with the highest participation rate (30.1%) recorded on the NSW south coast. Approximately 48,000 people actively engage in fishing activity along the south coast of NSW (NSW Fisheries 2002a). Comparison between recreational and commercial catches in NSW indicated that both groups harvested approximately 200 species of fish and invertebrates, and the total recreational catch was one third of the total commercial harvest (NSW Fisheries 2002a). Interestingly, there was a geographical difference in where the majority of recreational fish catch occurred compared to commercial catch. Commercial catch generally extended from coastal areas to offshore whilst recreational catch was from estuarine and inshore areas. Species collection results indicate that recreational fishers harvested approximately 14.1 million finfish, from 200 species (30 species making up the bulk of the catch), 16 million prawns and yabbies and 2 million other invertebrate species (crabs, lobsters, shellfish, squid and cuttlefish) (NSW Fisheries 2002a).

The level of harvesting by recreational fishers might have an impact on aquatic resources, particularly within estuarine habitats where fishing pressure from recreational fishers is high (47% participation rate, NSW Fisheries 2002a). There is a need for long-term monitoring to ensure sustainability of the recreational fishing industry. With recreational licensing required in NSW, funding for research into the impact recreational fishing may have on the marine and freshwater environment should be a priority for all the states of Australia. With recreational expenditure in NSW estimated be to more than $550 million per year, many communities throughout NSW particularly coastal regions including the far south coast, rely on the economic activity generated by this leisure sector (NSW Fisheries 2002a).

Four main centres; Eden, Merimbula, Tathra and Bermagui, provide excellent infrastructure for fishing and boating activities, including many fishing charter operators. Currently there is no information on the actual levels of participation and catch numbers verses catch effort along the far south coast. For general information on NSW recreational fishing statistics refer to the NSW Fisheries Status of fisheries resources 2001-2002, which gives general information on specific fishing techniques and indications of impacts associated with each method (NSW Fisheries 2003a).

Environmental impacts influencing recreational fishers, particularly within estuarine systems, include; habitat decline, urban and catchment development, water quality decline, introduced pest species, acid sulphate soils, river flow regulation, dredging, and sea level rise caused by global warming. Fishing also impacts on the environment, including changes in food-web and fish community dynamics, by-catch of non target species, impact on aquatic habitats (i.e. seagrass beds and benthic communities), impacts from boating, littering (e.g. plastic bags and discarded fishing line) and bank erosion caused by boating wake.

Recreational fishery is of great economic and social importance, and has a significant impact on many targeted coastal and estuarine species. With poorly documented data on catch and effort and limited management strategies currently established, monitoring and research is required to understand the impact recreational fishing has on stock size, habitat destruction (i.e. from netting and anchor damage) and the flow on ecosystem effects.

CHAPTER 4 ECOLOGICAL IMPORTANCE OF THE SAPPHIRE COAST MARINE ENVIRONMENT.

4.1 Endemism and biodiversity

Southern Australia marine biota are characterised by high species diversity and endemism (Poore 1995). In temperate southern Australian waters, which have been geographically and climatically isolated for around 65 million years, most species (90-95%) are endemic or confined to the area (Zann 1996). According to groups of major species, approximately 85% of known fish, 95% of molluscs, and 90% of echinoderms are endemic (Zann 1996). The richness of the temperate macroalgal flora (i.e. 1,155 species) is 50-80% greater than other comparable regions, with approximately 800 species and over 75% of the red algae alone regarded as endemic (Womersley 1990). The diversity of temperate species of macroalgae is approximately three times that recorded in the tropical regions of Australia.

As previously mentioned the Sapphire Coast is geographically important as it has been described as the biogeographical boundary of cool temperate to the south and warm temperate zones to the north of the region. The significance of this has not been fully appreciated and additional qualitative and quantitative research is required to understand the unique habitats that are present, including the distribution and abundance of these areas and associated flora and fauna.

4.2 Protected and threatened marine species

Several areas along the far south coast of NSW provide habitat for a number of threatened species that have been previously identified as being endangered (species likely to become extinct in nature if threats continue) or vulnerable (species likely to become endangered if threats continue) (refer NSW Fisheries web site). For example, recent studies have suggested that the population size of the Grey Nurse shark (*Carcharias taurus*) have reached a critical level and without the implementation of the proposed recovery plan, this species will become extinct in the near future (Otway & Parker 2000; NSW Fisheries 2002b). Grey Nurse sharks are known to frequent the

Sapphire Coast and have previously been reported to congregate at specific locations, with many females sighted at three locations adjacent to Montague Island (Otway & Parker 2000). Additionally, sightings of Grey Nurse sharks have been reported at two locations (Mewstone Rock and South Head) near Eden (Otway & Parker 2000); however, specific *in situ* studies at these sites were not conducted during the 1998-99 surveys. This may suggest that migratory Grey Nurse sharks may frequent Eden and other areas along the far south coast seasonally.

Other threatened marine species that have been observed to occur throughout the far south coast include whales (particularly Humpback and Southern Right whales), which frequent the coast during their migration to warmer northern waters in winter and on their return to the southern ocean following breeding. Whales and the south coast have a significant history, which included the establishment of the whale industry, and more recently the development of whale tourism in the region. Many charter operators along the coast regularly provide visitors to the south coast the opportunity of viewing whales during the migration season.

Research into the biology and ecology of whales that frequent Twofold Bay particularly Humpback whales (*Megaptera novaeangliae*), has provided important information on the recovery of the species following near extinction due to hunting, population dynamics, behaviour and social affiliations, individual identification and species susceptibility to human impacts (Kaufman, 1996,1997; Pacific Whale Foundation 2004). Other Mysticetes (baleen whales) and Odontocetes (toothed whales) are observed along the south coast, particularly bottlenose and common dolphins, with large pods regularly encountered off the mainland. Other mammals found along the coast include the Australian fur seal (listed as vulnerable under the Threatened Species Conservation Act), which has a healthy population at Montague Island and at Green Cape south of Eden. Recently, many sightings of fur seals have been reported in areas along the south coast that are frequented by locals and tourists. Australian fur seal population numbers have been increasing following the near extinction of this species due to hunting and more sighting are expected at populated beaches and estuarine areas in the future (C. Dickman pers. comm.) This highlights the effective management of this species, which includes total protection under the protection act.

Other protected species present along the far south coast are identified in Table 4.1, further highlighting the significance of this region and that protection from human impacts are required in order to maintain this unique system. Long-term monitoring programs are required to ensure the survival of protected species and to gauge the effectiveness of management strategies implemented by the respective authorities.

Table 4.1 List of threatened marine species that have a distribution range extending into the far south coast of NSW. (Modified from NSW Fisheries, NSW threatened, protected and pest species sighting program information and reporting booklet)

Protected species or habitat	**Protection status**	**Threatening processes**	**Distribution**	**Habitat preference**
Weedy seadragon (*Phyllopteryx taeniolatus*)	Protected (NSW Fisheries)	Habitat loss, overfishing	Sydney and south to Victoria to Tasmania. Found in Twofold bay & Tathra (Baker 2000).	Generally found in shallow protected reefs and in seagrass meadows.
Syngnathiformes	Protected (NSW Fisheries)	Habitat loss, overfishing	Temperate, subtropical and tropical protected reefs. 30 spp. occur in temperate reefs.	Generally found in shallow protected reefs and in seagrass meadows.
Great White shark (*Carchardon carcharias*)	Vulnerable (NSW Fisheries)	Commercial fisheries bycatch & shark finning, rec fishing, beach nets and other shark control programs	Found throughout the world in temperate and subtropical oceans.	Pelagic species can be observed close to beaches and on shallow reefs.
Black Cod (*Epinephelus daemelii*)	Vulnerable (NSW Fisheries)	Hunted by spearfishers and fished by recreational and commercial fishers	Found in reefs and outer parts of estuaries, from tropical to temperate regions along east coast.	Found inhabiting caves crevices and under ledges.
Eastern Blue Devilfish	Protected (NSW Fisheries)	Collection for aquarium trade	Southern QLD to Montague Island.	Rocky shores found in cave and under ledges.
Elegant wrasse	Protected (NSW Fisheries)	None Identified	Southern QLD, NSW, Lord Howe Island.	Juveniles found in algal beds on rocky shallow reefs, adults 2-28m depth.

CHAPTER 5 MARINE PESTS

5.1 Introduction

The introduction of marine pest flora and fauna species has become a particular concern, especially where international vessels may translocate exotic species through ballast water discharge and hull fouling. Previous outbreaks of toxic marine algae, introduced Pacific oysters and Japanese starfish in temperate Australian waters have highlighted the need to monitor and regulate maritime travel of international commercial vessels in Australian waters. A high proportion of marine pest species have been introduced into Australian waters through the discharge of ballast waters or as fouling organisms off vessels hulls, which have originated from other international ports. Zann (1996) reported that two species of algae, the majority of the 52 invertebrate species and four Pisces (fish) species were introduced into the Australian marine environment through discharged ballast waters.

5.2 Marine pest of the Sapphire Coast

Along the south coast of NSW, in particular Twofold Bay, marine pest species have been reported to occur within the bay or adjacent estuaries. During a baseline survey of Twofold Bay, Hutchings et al. (1989) collected seven introduced species from intertidal and shallow subtidal habitats, including artificial substrata such as wharf pylons and breakwater. Three crustaceans (*Notomegabalanus algicola*, *Carcinus maenas* and *Eurylana arcuata*), three molluscs (*Polycera capensis*, *Theba pisana* and *Crassostrea gigas*) and one ascidian (*Styela plicata*) may have been introduced by ballast water discharge or as fouling organisms, with the exception of *Theba pisana*, which may have been brought into Australia as a food item from Italy. Reference to the impact these introduced species have on the native fauna was not quantified, with only an indication that the Pacific oyster (*Crassostrea gigas*) might out-compete native species, which may have an impact on commercial fisheries within the bay and other affected areas.

In a more recent study of Twofold Bay and adjacent areas (refer CSIRO 1997), other introduced organisms were reported. During surveys conducted in 1996, in addition to the abovementioned introduced species, five species of bryozoans were found to inhabit many artificial substrata within Snug Cove. The New Zealand piecrust crab, *Cancer novaezelandiae*, was also recorded invading silty sand areas of Snug Cove. One gastropod, *Maoricolpus roseus* and one bivalve, *Theora fragilis* were found within the embayment during this study. Additionally, Pollard and Rankin (2003) reported that all these species were present during a three years study of the bay between 1999 and 2002, which was undertaken to complement the 1996 study and determine the distribution and abundance of three species (the European Shore Crab, *Carcinus maenas*, the Mediterranean Sea Fan, *Sabella spallanzanii*, and the toxic dinoflagellates, *Alexandrium* spp.) that were identified as potential concern from the earlier study.

Results from these previous studies suggested that these introduced species are having varying impacts on the local native community, and that there is a need for further studies into the management and control of these invading species. Research is required in order to understand the impact of introduced organisms within the Twofold Bay region, and the development of eradication programs which will control outbreaks of translocated or domestically reintroduced organisms.

Pollard & Rankin (2003) recent management recommendation for the control of the high priority introduced species (i.e. European Crab, Mediterranean Sea Fan and toxic dinoflagellate species) outlined that monitoring and removal of these species is a high priority in order to: maintain current low population numbers; evaluate effectiveness of implemented removal programs; and monitor the impacts of large populations of European Crab at Fisheries Beach and the gastropod *Maoricolpus roseus* present throughout Twofold Bay. In addition, they recommended biannual monitoring and removal of introduced *Sabella spallanzanii*, which would decrease the probability of recruitment from local spawning individuals and potential dispersal to other locations within Twofold Bay and neighbouring areas. Results and conclusions from the 2003 study indicated that further research is needed in order to control the infestation of pests present in Twofold Bay, including the development of effective trapping methods and biological controls, such as natural predators of invasive pest species.

Priorities for marine research and monitoring within Sapphire Coast

No information in regards to the distribution and abundance of introduced marine organisms is presently available for any other location along the south east coast of NSW, which may be particularly important in areas that are frequented by passing marine vessels, such as Bermagui and Merimbula. Additional baseline information is required along the entire Bega Valley coast, which will identify pest species outbreaks within this region. Additionally, threats from other organisms such as the recently introduced aquarium plant *Caulerpa taxifolia*, which has invaded central NSW shelter bays, has the potential to spread further south and out-compete native flora in enclosed water bodies. Other potential introduction mechanisms of this species into the south coast region may be through the incorrect disposal of unwanted aquarium samples, which may establish populations in sheltered or moderately exposed areas adjacent to developed areas. A monitoring program which will act as a early warning system to potential *C.taxifolia* outbreaks needs to be established, which could be ran in conjunction with other pest programs.

A recent initiative from the NSW Department of Primary Industry (DPI) is the Threatened, Protected and Pest Species Sighting Program, which provides information on pest species of the NSW coast, including identification cards and a mechanism for reporting sightings through a 24 hour hotline and electronic contact report forms. The identification cards provide morphological and ecological information of eight pest species present along the NSW coast and information regarding the reporting of sightings. This available information in combination with enthusiastic voluntary organisations and active monitoring programs along the NSW coast would act as an early warning system for any introduced marine species outbreak. Further information is available from the DPI Website: www.dpi.nsw.gov.au.

CHAPTER 6 RESEARCH PRIORITIES AND CAPACITY BUILDING

Whilst this report highlights much of the research that has been conducted within the Sapphire Coast through access to peer reviewed literature, many resources (grey literature) from government agencies (NSW Fisheries, National Parks & Wildlife and local council) and universities has not been reviewed due to time constraints and inability to gain access to library resources. Further reviewing and access to resources would provide a greater understanding of what additional research has been completed along the far south coast of NSW. However, what has been reviewed has highlighted the little understanding of the coastal and marine environment along the far south coast of NSW. Additionally, with previous research material located at many government agencies, local council and universities, there is a need for collaboration between these organisations. This would provide a vehicle for representatives from each group to collate all relevant information and present material through a workshop forum. Outcomes from these meetings would form the framework for future research priorities and provide a mechanism for capacity building, where community groups can become actively involved.

Partnership for capacity building between community groups such as the Eden Whale and Marine Discovery Centre volunteers, government agencies and universities would ensure: capacity building at the local level; enable consultation across all sectors; strengthen research facilities; develop institutions and local communities' capacity to conserve and manage marine resources; and develop knowledge of the local marine environment (Wescott 2002).

Previously a number of partnership programs in the marine and coastal environments have been developed in Australia, which has fostered an emphasis on community participation. These have included Government/Community based programs (i.e. Coastcare), community network (i.e. Marine & Coastal Community Network) and university and government partnerships (Australian Research Council (ARC) Linkage Grants). Partnership development has provided opportunities for community groups to gain knowledge and practical experience of the marine and coastal environments and develop a sense of stewardship within the community. The implementation of programs

mentioned above throughout the Bega Valley Shire would enable a collaborate approach to ecological sustainable development of the marine and coastal resources.

Monitoring programs that determine the status of the marine and coastal environments and act as baseline data for subsequent research need to be a high priority along the far south coast. With the limited information available of the flora and fauna associated with the marine and coastal habitats there is a need for appropriate monitoring programs to be established within this region. Community involvement and support from scientific researchers and government agencies would significantly increase the understanding of marine ecosystems along the south coast of NSW. As indicated throughout this review, there is a need for comprehensive documentation of habitats and associated flora and fauna present along the coast. However, any baseline or monitoring program established by community groups needs to be adequately planned to ensure that the program is achievable with the resources available and appropriate training and quality control procedures implemented. Rigorous and accurate data collected by collaborative programs will provide managers with useful data that will answer specific questions and provide information on management strategies.

Much of the Sapphire Coast is currently underdeveloped with many established National Parks adjacent to the coast, providing a unique opportunity for researchers to understand the ecological processes that occur within areas not subjected to anthropogenic stressors. Additionally, monitoring pristine areas and comparing them to regions that are close to urban development and influenced by agriculture and industry may provide information in regards to the effects human stress has on the fauna and flora associated with these areas. There is a need for extensive baseline information along within this region, as only isolated areas have been previously studied. However, establishing a comprehensive research program (which may include aerial photographic inventory with appropriate ground trothing) along the far south coast would require the collaborative efforts including government funding, university and research institution expertise and contribution by voluntary organisations such as the Eden Whale and Marine Discovery Centre.

Data collected from future research programs would provide managing authorities such as the NSW Marine Park Authority with vital information on the importance of

this area and help to determine the significance of this region in regards to its biogeographical importance and unique habitats present along the coast.

REFERENCES:

Andrews, N.L. (1993) Spatial heterogeneity, sea urchin grazing and habitat structure on reefs in temperate Australia, *Ecology* **74,** 292-302.

Andrews, N.L. (1999) *Under Southern Seas: the ecology of Australia's rocky reefs,* University of New South Wales, Sydney.

Andrews, N.L. and O'Neill, A.L. (2000) Large-scale patterns on habitat structure on subtidal rocky reefs in New South Wales, *Marine and Freshwater Research,* **51,** 255-63.

Andrews, N.L. and Underwood, A.J. (1989) Patterns of abundance in the sea urchin Centrostephanus rodgersii on the central coast of New South Wales, Australia. *Journal of Experimental Marine Biology*, **131,** 61-80.

Andrews, N.L. and Underwood, A.J. (1992) Association and abundance of sea urchins and abalone on shallow subtidal reefs in southern New South Wales. *Australian Journal of Marine and Freshwater Research,* **43,** 1547-59.

Baker, J. (2000 accessed 27/07/2004) New South Wales dragon search project: Preliminary bioregional summary of sighting data January 1998 – June 2000, MCCN, St Leonards. www.dragonsearch.asn.au

Bega Valley Shire Council (BVSC) (2002) Bega Valley Shire: Coastal Planning and Management Strategy, Bega Valley Shire Council, Bega.

BVSC (2003a, accessed 09/09/04) History of the Shire, Bega. http://www.begavalley.nsw.gov.au

BVSC (2003b) Bega Valley Shire Community Snapshot.

Bennet, I and Pope, E.C. (1953) Intertidal zonation of the exposed rocky shores of Victoria, together with a rearrangement of the biogeographical provinces of temperate Australian shores. *Australian Journal of Marine and Freshwater Research,* **4,** 105-59.

Chapman, M.G. and Underwood, A. J. (1998) Inconsistency and variation in the development of rocky intertidal algal assemblages, *Journal of Experimental Marine Biology and Ecology,* **224,** 265-289.

Connell, J., T. P. Hughes, and C. C. Wallace. (1997) A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. *Ecological Monographs* **67,** 461-488.

CSIRO (1997) Introduced species survey: Port of Eden and Twofold Bay, New South Wales, CSIRO, marine Research, Canberra.

Dakin, W.J., Bennet, I. and Pope, E. (1956) *Australian seashores: a guide for the beach-lover, the naturalist, the shore fisherman and the student.* Angus and Robertson, Sydney.

Day, J.H. and Hutchings, P.A. (1984) Descriptive notes on the fauna and flora of Merimbula, Pambula and Back Lakes, New South Wales. *Australian Zoology,* **21,** 169-89.

Edgar, G.J. (2000) *Australian marine life, the plants and animals of temperate waters.* Reed New Holland, Sydney.

EPA (2003, accessed 19/11/2004) Project example 1: Project AWARE on the rocks – Pittwater, Warringah and Manly, Sydney
http://www.environment.nsw.gov.au/community/edproject/section+3.02.html

Hutchings, P., van der Velde, J. and Keable, S. (1989) Baseline survey of the benthic macrofauna of Twofold Bay, NSW, with a discussion of the marine species introduced into the bay. *Proc. Linn. Soc. N.S.W.,* **110,** 339-367.

Jones, G.P. and Andrews, N.L. (1990) Herbivory and patch dynamics on rocky reefs in temperate Australasia: The role of fish and sea urchins. *Australian Journal of Ecology,* **15,** 505-520.

Kaufman, D.G. and Naessig, P.J. (1997) 1996 Humpback whale research off Eden, NSW. Annual report to the NSW NPWS, Hurstville.

Kaufman, D.G. and Naessig, P.J. (1998) 1997 Humpback whale research off Eden, NSW. Annual report to the NSW NPWS, Hurstville.

Kennelly, S.J. (1995) Kelp Beds. In: *Coastal marine ecology of temperate Australia.* (Eds, Underwood, A.J. and Chapman, M.G.) UNSW Press, Sydney.

Kingsford, M. & Battershill, C. 1998, Studying temperate marine environments a handbook for ecologists. Canterbury University Press, Christchurch.

Lincoln-Smith, M.P. and Jones, G.P. (1995) Fishes of shallow coastal habitats. In *Coastal marine ecology of temperate Australia.* (Eds, Underwood, A.J. and Chapman, M.G.) UNSW Press, Sydney.

Millar, A.J. (2002) Ceramium juliae (Ceramiaceae, Ceramiales), a new red algal species with distinctive spines from eastern Australia. *Australian Systematic Botany,* **15,** 493-500.

Millar, A.J. (2004) New records of marine algae from New South Wales, eastern Australia, *Phycological Research,* **52,** 117-128.

Minister of Fisheries (1998) Mussel aquaculture in Twofold Bay, nominated determining authority report, NSW Government, Sydney.

Morrisey, D. 1995, Estuaries, In. *Coastal marine ecology of temperate Australia*. (Eds Underwood, A.J. & Chapman, M.G.) UNSW Press, Sydney.

ngh Environmental (2003) Draft: Merimbula estuary management, natural resources inventory, Ngh Environmental Pty. Ltd., Bega.

NSW Fisheries (1999) Status of fisheries resources 1997/98. NSW Fisheries Research Institute, Pyrmont.

NSW Fisheries (2001 accessed 27/07/2004), Region 8-South of Narooma to the Victorian Border; Issues paper.
http://www.fisheries.nsw.gov.au/rec/rfa/region8_summary.htm

NSW Fisheries (2002a accessed 16/11/04) Survey of recreational fishing in New South Wales, Interim Report, NSW Fisheries, Sydney.
www.fisheries.nsw.gov.au/rec/survey.htm

NSW Fisheries (2002b) NSW Fisheries threatened species recovery planning program, Grey Nurse Shark, Draft recovery plan, NSW Fisheries, Cronulla.

NSW Fisheries (2003a) Status of fisheries resources 2000/01. NSW Fisheries, Cronulla Fisheries Centre, Cronulla.

NSW Fisheries (2003b) Fisheries management strategy for the Ocean Hauling Fishery. NSW fisheries, Cronulla Fisheries Centre, Cronulla.

NSW Marine Parks Authority (NSWMPA) (2002) Solitary Islands Marine Park issues and options. Marine Park Authority, Coffs Harbour.

Otway, N.M. & Parker, P.C. (2000) The biology, ecology, distribution, abundance and identification of marine protected areas for the conservation of threatened Grey Nurse Sharks in south east Australian water. NSW Fisheries report, Nelson Bay.

Pacific Whale Foundation (2004 accessed 16/11/04) Biological assessment of the area V humpback whale population in the southern ocean region. http://www.pacificwhale.org/learn/sapphire.htm

Pollard, D. A. & Rankin, B. K. (2003) Port of Eden, introduced marine pest species study. NSW Fisheries Office of Conservation, Cronulla.

Poore, G.C.B. (1995) Biogeography and diversity of Australia's marine biota. In: L. Zann and P. Kailola (eds). *State of the marine environment report for Australia. Technical annex 1: The marine environment.* GBRMPA for the Department of the Environment, Sport and Territories, Ocean Rescue 2000 Program: Canberra.

Roy, P.S., Williams, R.J., Jones, A.R., Yassini, I., Gibbs, P., Coates, B., West, R.J., Scanes, P.R., Hudson, J.P. and Nichols, S. (2001) Structure and function of south-east Australian Estuaries. *Estuarine, Coastal and Shelf Science,* **53,** 351-384.

Saengar, P., Specht, M.M., Specht, R.L. and Chapman, V.J. (1977) Mangroves and coastal saltmarsh communities in Australasia. In: *Ecosystems of the World. Vol. 1 Wet coastal formations.* Elsevier Publ. Co. Amsterdam.

Shepard, S.A. and Womersley, H.B.S. (1970) The sublittoral ecology of West Island, South Australia: 1. Environment features and algal ecology. *Trans. R. Soc. S. Aust.,* **94,** 105-138.

Shepard, S.A. and Womersley, H.B.S. (1971) Pearson Island expedition 1969. 7. The sub-tidal ecology of benthic algae. *Trans. R. Soc. S. Aust.,* **95,** 155-167.

Shepard, S.A. and Womersley, H.B.S. (1976) The subtidal algal and seagrass ecology of St Francis Island, South Australia. *Trans. R. Soc. S. Aust.,* **100,** 177-191.

Shepard, S.A. and Womersley, H.B.S. (1970) Algal and seagrass ecology of Waterloo Bay, South Australia. *Aquatic Botany* **11,** 305-371.

Smith, S. D. A. (1995). Descriptions of marine benthic communities in the Solitary Islands Marine Reserve, northern NSW: progress report, August 1995. Report prepared for NSW Fisheries. August 1995.

Smith, S. D. A. and James, K. A. (1999). Surveys of rocky shore habitats at Sandon Bluffs and Station Creek Headland. Report to the NSW Marine Park Authority. September 1999.

Smith, S. D. A. and James, K. J. (2003). Rapid assessment of rocky shore biodiversity in the Byron Bay region. Report prepared for the NSW Marine Parks Authority. August 2003.

The Herman Slade Foundation (2004 accessed 27/07/04) Marine algae of southeastern Australia. www.hermanslade.projects/HSF_98_1/hsf_98_1.htm

Underwood, A. J. (1981) Structure of a rocky intertidal community in New South Wales: patterns of vertical distribution and seasonal changes. *Journal of Experimental Marine Biology and Ecology*, **51,** 57-85.

Underwood, A. J., Kingsford, M. J. and Andrew, N. L. (1991) Patterns in shallow subtidal marine assemblages along the coast of New South Wales, *Australian Journal of Ecology*, **6,** 231-249.

Underwood, A. J. & Chapman, M.G. (1995) *Coastal marine ecology of temperate Australia.* UNSW Press, Sydney.

Underwood, A. J. & Chapman, M.G. (1998a) Spatial analyses of intertidal assemblages on sheltered rocky shores. *Australian Journal of Ecology,* **23,** 138-157.

Underwood, A. J. & Chapman, M.G. (1998b) Variation in algal assemblages on wave-exposed rocky shores in New South Wales. *Marine and Freshwater Research,* **49,** 241-254.

Underwood, A.J. and Hoskin, M.G. (1999) Examination of potential ecological effects of mussel culture in Twofold Bay NSW. Final report, Centre of Research on Ecological Impacts of Coastal Cities, Marine Ecology Laboratories, University of Sydney, Sydney.

Underwood, A. J. and Jernakoff, P. (1984) The effects of tidal height, wave-exposure, seasonality and rock-pools on grazing and the distribution of intertidal macroalgae in New South Wales. *Journal of Experimental Marine Biology and Ecology,* **75,** 71-96.

Underwood, A. J. and Kennelly, S.J. (1990) Ecology of marine algae on rocky shores and subtidal reefs in temperate Australia. *Hydrobiologia,* **192,** 3-20.

Underwood, A. J., Denley, E.J. and Moran, M.J. (1983) Experimental analyses of the structure and dynamics of mid-shore rocky intertidal communities in NSW. *Oecologia,* **56,** 202-219.

West, RJ., Thorogood, C.A., Walford, T.R. and Williams, R.J. (1985) An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2. Department of Agriculture, New South Wales, 140pp.

Womersley, H.B.S. (1981) Biogeography of Australasian marine macroalgae. In: Clayton and King (eds) *Marine botany an Australian perspective part 1.* Government Printers, Adelaide, pp.292-307.

Womersley, H.B.S. (1984) *The Marine Benthic Flora of Southern Australia. Part I.* Government Printers, Adelaide, 329 pp.

Womersley, H.B.S. (1987) *The Marine Benthic Flora of Southern Australia. Part II.* Government Printers, Adelaide, 484 pp.

Womersley, H.B.S. (1990) Biogeography of Australian Marine Macroalgae. In: Clayton and King (eds) *Biology of Marine Plants.* Longman Cheshire, Melbourne, pp.368-381.

Zann. L.P. 1996, State of the Marine Environment, Report for Australia. Great Barrier Reef Marine Park Authority, Australia.