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Developing long-term indicators for the sub-tidal embayment communities of Cockburn Sound

Swan Catchment Council Project – 01-0506 T
2006 – 2008 program

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Forward

Progress towards developing explicit metrics for Resource Condition Targets.

This project is one of three that has been undertaken by the Department of Fisheries (DOF), and funded by the Swan Catchment Council (SCC), that aim to gain a better understanding of the biodiversity and community structure within the Swan region. Ultimately, the goal of the SCC projects is to provide information that will allow development of effective and efficient resource condition targets (RCTs).

While fishing is one of the significant factors that needs to be considered when managing coastal marine ecosystems it is not the only driver of change in these communities. Therefore, the various SCC-funded projects undertaken by DOF not only included a focus on targeted species (*e.g.* Category 1 angling species, blue swimmer crabs, western rock lobster) but they all (including some other non-SCC projects) have focussed on the most appropriate sampling method (in terms of time, accuracy and cost) to generate information on biodiversity so as to provide a measure for general ecosystem health. They have all provided information on the abundance (or relative abundance) and diversity of species from particular categories (*e.g.* fish, macro-invertebrates), from particular habitats or regions and at particular time intervals (*e.g.* seasonal comparisons). They have also addressed one of the key issues pertaining to the development of RCTs for biodiversity and community structure, which is to provide baseline information on natural levels of variability.

It has been widely acknowledged that there is a dearth of broad scale ecological studies within the marine ecosystems of WA. This means that these current, or recently completed, studies are essentially establishing baseline descriptions of these communities or assemblages. Consequently, it is not yet possible to set explicit reference points for the management of marine biodiversity because no adequate metrics have been established. This is in contrast to the generally agreed metrics that are now used for the management of individual stocks of exploited fish. For this, the biomass level of a species is often the metric against which the resource condition target (often termed biological reference points, BRPs) is set (*e.g.* maintain biomass above 40% of the unfished level). The lack of a common metric for measuring biodiversity (or ecosystem health) limits our ability to set meaningful and defensible RCTs. While aspirational RCTs can be developed, to achieve pragmatic management outcomes it is critical that even these are based on a credible scientific understanding or hypothesis if they are to have any real impact on managing marine systems.

In the near future it is likely that the achievable goals for management might include objectives such as to ensure: - no loss of biodiversity; - no change in the community assemblage for a particular group such as fish or algae; - an improvement in habitats or ecosystems deemed to be degraded. Therefore this current suite of studies should be considered as the starting point for the management of biodiversity, not as the end point.

Further work will be required to develop metrics that can “describe” biodiversity and ecosystem structure in a pragmatic and measurable manner. The scope of the current projects did not include the types of comparative tests required to ascertain with confidence which data sets and analyses are most appropriate for developing the required metrics for biodiversity or community structure. Therefore, each of the projects undertaken by DOF for the SCC could undertake further analytical work on the data already available.

Data collected by these three complimentary studies within the Swan region indicates that the habitats within this ecosystem can differ significantly. For example, different categories of benthic cover and demersal scalefish occur at each of the locations examined, which included some areas closed to fishing. Similarly, different beaches along the coast have different assemblages of fish despite the habitats often superficially appearing similar. The ongoing challenge for managing marine ecosystems, therefore, is not only what to measure/monitor, but also at what spatial and temporal scales.

DOF in association with DEC and broader membership of the State Marine Policy Stakeholders Group has been addressing this significant challenge through the development of a risk assessment approach, which is being undertaken within the WAMSI project on ecosystem-based fisheries management (EBFM). This project is identifying all the natural assets within the entire West Coast Bioregion, including the region of specific interest to the SCC. The EBFM project builds on the considerable work undertaken over the past decade to develop a practical system to implement ESD across Australian fisheries. This system, which has full support from all Australian state and federal agencies involved in managing natural marine assets, critically recognises that not all issues (or species, habitats, problems etc) can be dealt with at a highly detailed level, so the only practical solution is to prioritise issues based on their risks (see www.eafm.com.au for more details).

The risk assessment approach, which forms the basis of the EBFM project, follows nationally agreed standards and methods to help identify priorities. The outcomes from this and the other SCC projects (and other activities focussed on assessing baseline of biodiversity) are now being utilised within the context of the EBFM project, the state's regional marine planning process and any other relevant planning processes. This is being done to ensure the newly acquired information is used to help assess risk status for different habitats within ecosystems as well as to help develop pragmatic metrics for RCTs to underpin the effective management of our marine resources.

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Executive Summary

The geomorphology of Cockburn Sound is unique to the lower west coast of Australia due to the relative paucity of sheltered nearshore marine embayments along this coastline. Numerous studies on many of the commercially and/or recreationally important species that inhabit Cockburn Sound have demonstrated that for many of them this marine embayment constitutes an integral part of their life history. Since the commencement of industrial and urban development in the mid 1950s, in the waters and along the shores of Cockburn Sound, the marine fauna utilising this area have been exposed to ongoing changes in environmental quality. These detrimental, anthropogenic influences have impacted on many attributes that affect the faunal composition, including, for example, habitat alteration and/or loss.

Recent data has also revealed that blue swimmer crab stocks in Cockburn Sound are more vulnerable than previously thought with this fishery collapsing in 2005/06. The broader impacts of the declining numbers of crabs on the ecology, *i.e.* predator-prey relationships, are unknown. Likewise, adult populations of snapper in the lower west coast region have been identified as being low/depleted. Recent studies on the biology of snapper have identified the nearshore marine embayments of Owen Anchorage, Cockburn and Warnbro Sounds as important sources of recruitment for the adult population. Until recently, very little research had been done on the structure of the faunal community in these embayments to which blue swimmer crab, snapper and other commercially and/or recreationally important species belong. A broader understanding of the diversity of fauna that resides in this marine embayment will provide insights into their ecological interactions and thus aid in their sustainable management. The objectives of this study were:

1. Describe the trawled community structure associated with the key indicator species, *i.e.* blue swimmer crabs and snapper, in Cockburn Sound.
2. Assess changes in the distribution and abundance of blue swimmer crab and snapper by comparison with the Department of Fisheries long-term dataset.
3. Establish a system to monitor the abundance and distribution of sub-tidal embayment faunal communities in Cockburn Sound.

The marine fauna was sampled from three trawl surveys at approximately six monthly intervals in April/May and October/December 2007 and February 2008 from six sites in Cockburn Sound and one site in Owen Anchorage. An additional survey was conducted in April 2008 to collect data for blue swimmer crabs and snapper. Trends in the abundances of blue swimmer crab and snapper were compared from historic trawl surveys undertaken since February 2000.

A total of 216 taxa from six phyla were identified in the sub-tidal faunal communities sampled. These communities were dominated by small benthic predators and detritivores. The majority of these species were well within their known geographic distributions and have previously been collected in Cockburn Sound or Owen Anchorage. Faunal communities differed significantly among sites and surveys, but the differences were more apparent among sites. With the exception of Jervois Bay, all sites sampled in Cockburn Sound during the current study were located in an area previously identified to have a distinct assemblage, *i.e.* the central basin area. The area sampled in Jervois Bay had a different community from the other sites due in part to the presence of sponges and their associated fauna. Differences in the faunal community structure at Jervois Bay largely caused an east to west gradient in sites evident on the MDS ordinations. This was a result of a different community composition at this site compared with other sites, *i.e.* generally lower total abundance and species richness, but higher abundance of some component species,

e.g. southern calamari squid *Sepioteuthis australis* and western smooth boxfish *Anoplocapros amygdaloides*. A north to south gradient was also evident on the ordinations and this was driven by higher species richness, diversity, and evenness of the faunal community sampled at Owen Anchorage. All these diversity measures decreased moving southwards into the Sound with the lowest values being recorded at Mangles Bay. These patterns may be related to an environmental impact gradient but this was not investigated in the current study. Mean abundance and biomass differed between survey times with some sites having a higher mean abundance in February 2008 and others in May 2007, and there were similar variations in biomass through time. As sampling in this study occurred during different seasons in 2007 and 2008, interannular variation in the seasonal composition of the community structure could not be determined.

Recreational fishers in Cockburn Sound and Owen Anchorage retain approximately 14 % of the taxa collected. Commercial fishers in this area retain fewer species (*ca* 7 %) due to permanent spatial closures to the South West Trawl Managed Fishery and West Coast Estuarine Fishery. Numbers of blue swimmer crab recruits were significantly higher in 2008 than 2007. This was most likely due to greater recruitment success on account of a slow recovery of spawning stock following the collapse of this fishery in 2006, evident from abundances in historic trawls, and subsequent closure to commercial and recreational fishing in December 2006 to presently in Cockburn Sound. The abundances of blue swimmer crab recruits (0+) were highest at James Point, Jervois Bay and Mangles Bay. A lack of significant interaction between year and site further confirmed these sites are important crab recruitment areas, irrespective of year. There did not appear to be any site preference by residual (≥ 1+) blue swimmer crabs with abundances highest in 2007 at the Research Area, Garden Island South and Mangles Bay, compared to higher abundances at Jervois Bay, James Point and Mangles Bay in 2008.

Only juvenile snapper less than six months of age (0+) were collected in this study. There have been two strong years of recruitment of juvenile snapper in Cockburn Sound in recent years, *i.e.* the 1999 and 2007 year-classes. There was no site selectivity displayed by the 0+ snapper between surveys. However, the numbers of snapper caught were consistently higher for Garden Island North and James Point, and consistently lower for Garden Island South and Jervois Bay between February and April 2008. The remaining three sites showed large fluctuations in abundance between these two periods. The only site where 0+ snapper were collected in each survey was James Point.

The frequency required to monitor the structure of the trawled faunal community in this area would benefit from a periodical approach of at maximum every five years, as ecological processes associated with changes in the community structure could occur within this period, *e.g.* the large-scale loss of seagrass from the eastern shelf of Cockburn Sound between 1967 and 1972. In addition, the structure of the trawled faunal community would need to be described prior to any potential disturbance from a major development in the area, *e.g.* the proposed Outer Harbour facility for the Port of Fremantle and then monitored afterward to document any changes and recovery rates. Monitoring of commercially and/or recreationally important species would need to be more frequent for the following reasons. 1) To obtain useful estimates of the annual abundance of recruits of blue swimmer crab and snapper, annual sampling between March and June is needed. 2) To monitor the annual abundance and associated reproductive biology of residual blue swimmer crab, sampling would need to be undertaken between September and December each year. 3) To estimate the annual rates of mortality (specifically natural mortality where possible) for key indicator species and commercially and/or recreationally important species, *e.g.* blue swimmer crab and snapper, sampling would need to be undertaken at least three times in a single year.

Future sampling regimes would benefit from using the seven sites from this study, as changes in the structure of the trawled faunal community could be detected at a smaller/localised spatial scale than was possible prior to this study. Future trawl surveys should incorporate Jervois Bay, James Point and Mangles Bay to accurately represent crab recruits, whereas a wide range of sites is needed to accurately represent residual crabs, juvenile snapper and the fauna community. Future sampling should consider additional sites in depths less than ten metres in north-western and south-eastern areas of Cockburn Sound to determine the influence of depth and habitat on the trawled faunal community structure at Jervois Bay from other sites. Future surveys should consider sampling in Warnbro Sound to 1) allow an improved interpretation of the trawled faunal community structure described in Cockburn Sound in this study, from a similar nearby marine embayment that has not had the large-scale environmental disturbance; 2) improve our understanding of recruitment abundances of blue swimmer crab and snapper for the lower west coast, where the relative paucity of protected nearshore marine embayments results in few suitable recruitment areas; and 3) allow comparisons of the natural mortality rates of key indicator species and juvenile blue swimmer crab and snapper between Cockburn Sound and Warnbro Sound, to provide insight into the probability of survival between an environmentally impacted and non-impacted embayment/recruitment area.

This study has improved our understanding of the faunal community in Cockburn Sound and Owen Anchorage. It is unknown whether the detection of changes in the structure of the faunal community in these areas in future surveys will provide sufficient capacity to evaluate levels of environmental disturbance. However, the current status of the structure of the trawled faunal community described in this study provides sound quantitative data for which future comparisons can be made. The acquisition of information on the current demographics of the faunal community in this area is timely, considering the potential environmental changes that may occur from the high level of industrial and urban development proposed in its immediate vicinity in the very near future.

KEYWORDS: Biodiversity, Cockburn Sound, trawling, indicator species, blue swimmer crabs, snapper, marine embayment

1.0 Introduction

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1.1 Background

1.1.1 Cockburn Sound

The geomorphology that comprises the embayment of Cockburn Sound is typically a depressed land contour between the Spearwood and Garden Island ridges that lie along the eastern and western margins, respectively. To the north, two shallow submerged sand ridges, *i.e.* Success and Parmelia Banks, represent the respective northern and southern boundaries of Cockburn Sound and Owen Anchorage (Fig. 1). The southern entrance of Cockburn Sound has been almost closed through the construction of a rock-filled causeway, built in 1971-73 to provide vehicle access to Garden Island. This construction effectively reduced water flow into Cockburn Sound by 40 % and wave energy by 75 % (D.A. Lord & Associates Pty Ltd 2001). These boundaries provide a sheltered marine embayment *ca* 16 by 9 km in size, with a sea surface area of *ca* 100.5 km^2 and a maximum depth of 23 m. Large and relatively deep marine embayments, such as this, are rare on the south-western coast of Australia, with the closest areas with similar geomorphic attributes being Shark Bay to the north (*ca* 700 nm) and King George Sound on the south coast (Seddon 1972).

The main habitat types found in Cockburn Sound include small patches of limestone reef, extensive soft sediment areas (typically silt) and seagrass meadows. These diverse habitats support a wide variety of marine fauna including numerous species of fishes, crustaceans, molluscs, marine mammals and seabirds (see Section 1.1.2). For a majority of these species Cockburn Sound has been found to constitute an important area during certain stages of their life history, *i.e.* spawning and/or nursery. These species include invertebrates, *e.g.* blue swimmer crabs (Potter *et al.* 2001) and western king prawns (Penn 1975; Penn 1976); fish, *e.g.* snapper (Lenanton 1974; Wakefield 2006), white bait (Gaughan *et al.* 1996) and king george whiting (Hyndes *et al.* 1998); marine mammals, *e.g.* bottlenose dolphins (Finn 2005) and Australian sea lions (Simpson *et al.* 1993) and seabirds, *e.g.* fairy penguins (Simpson *et al.* 1993). Thus, any changes to environmental conditions or habitat within the Sound will potentially impact on fauna from all trophic levels.

Cockburn Sound's sheltered waters and close proximity to the capital city of Western Australia, Perth (*ca* 20 km to the north), made it an ideal location for numerous industrial, shipping and naval ventures. Industrial development commenced in this area in 1955 and over an extended period of time has resulted in the accumulation of pollutants and nutrient enrichment in Cockburn Sound. Physical alteration of the benthos in this area also occurred with the mining of shell sand and dredging of shipping channels. The combination of these anthropogenic inputs has been detrimental to the ecosystem and this is evident through the extensive depletion of seagrass meadows, with estimates of less than 20 % of their original coverage remaining (Anon. 1996).

1.1.2 Studies of biodiversity

Biodiversity encompasses all life forms (bacteria, fungi, plants and animals), and includes variability in genes, species, habitats, ecological communities, ecosystems and ecological processes (Anon. 1993; Anon. 1999). Australia is a signatory to the Convention on Biological Diversity (Anon. 1993), and has an international responsibility to ensure the conservation and sustainable use of biological resources. This includes an obligation to describe and monitor biodiversity and to implement measures to manage activities (*e.g.* fishing, mining, and farming) and processes (*e.g.* nutrient runoff, species introductions, pollution, and climate change) that threaten biodiversity. The Western Australian Government has developed biodiversity conservation policies (DEC 2006; DEC 2008), State of Environment reports (D.A. Lord & Associates Pty Ltd 2001; Anon. 2005), and management plans for specific areas (Anon. 2005) in part to address these issues and undertake actions to address biodiversity loss.

Published studies of the biodiversity in Cockburn Sound and Owen Anchorage are limited and have principally focussed on seagrasses and their decline (*e.g.* Cambridge & McComb 1984; Cambridge *et al.* 1986; Walker *et al.* 2001; Kendrick *et al.* 2002). Results of taxonomic surveys of the fauna of the area are largely in unpublished reports, and the numbers of taxa reported have been influenced by sampling methods used and habitats sampled. Using a variety of sampling methods including scuba diving, shore collections and dredges, a series of surveys documenting the benthic invertebrate fauna of Cockburn Sound were undertaken by the Western Australian Naturalists' Club (1950s) and the Western Australian Museum (1970s). These studies identified a range of fauna including 28 species of cnidarians (Marsh 1978a), 75 species of echinoderms (Devaney 1978; Marsh 1978b), and 276 species of molluscs (Wells & Threlfall 1980). A quantitative survey of soft bottom fauna conducted in 1978 using a Van Veen grab, found 138 species of invertebrates from eight phyla with molluscs (34 species) dominating these collections by biomass and abundance (Wells 1978; Wells & Threlfall 1980). Between 1977 and 1978 surveys sampled fish and large invertebrate species (crustaceans, calamari squid and cuttlefishes), using a variety of trawling and beach seining methods, and found 144 species, including 81 species (73 fishes and eight invertebrates) of commercial and recreational interest (Dybdahl 1979). Some sampling using seine nets in 1995 off six beaches around Cockburn Sound (three adjacent to seagrass meadows and three without extensive seagrass beds) yielded 55 fish species and three species of large invertebrates (Vanderklift & Jacoby 2003). Two other studies have considered fish assemblages in the Sound (Hutchins 1994; Ayvazian & Hyndes 1995), however, the results were pooled with other sites from the Perth Metropolitan area so it was not possible to determine the number of species recorded from Cockburn Sound.

When a new species is first described a specimen is designated as the holotype specimen and the locality where it was collected is the type locality. Cockburn Sound is the type locality for one species of cnidaria (an anemone *Bunodactis maculosa* Carlgren, 1954; (Griffith & Fromont 1998) and three mollusc species (two gastropods *Pseudovertagus peroni* Wilson, 1975 and *Nassarius cockburnensis* Kool & Dekker, 2006 and one bivalve *Tellina cockburnensis* Brearley & Kendrick, 1984; (Wells 1977 and WAM Mollusc Database).

Introduced species can have a substantial impact on native species as they can compete with them for resources. This can potentially reduce native biodiversity and impact on ecosystem function (Haas & Jones 2000; Huisman *et al.* 2008). The three main ways that species are introduced into areas are through ballast water discharge, hull fouling and deliberate introductions such as aquaculture (Huisman *et al.* 2008). Cockburn Sound has major industrial development along its shores and cargo ships regularly enter the Sound. Additionally, the largest proportion of the native Blue Mussel *Mytilus planulatus* that are harvested in the Sound come from aquaculture. Twenty introduced marine species (one species of algae, two bryozoans, four crustaceans, one cnidarian, four molluscs, two polychaetes, four ascidians and two fishes) have been recorded from Cockburn Sound (Huisman *et al.* 2008; Maddern & Morrison in press). The potential for more introductions to occur in the Sound is high and an improved understanding of its biodiversity would aid in detecting these species.

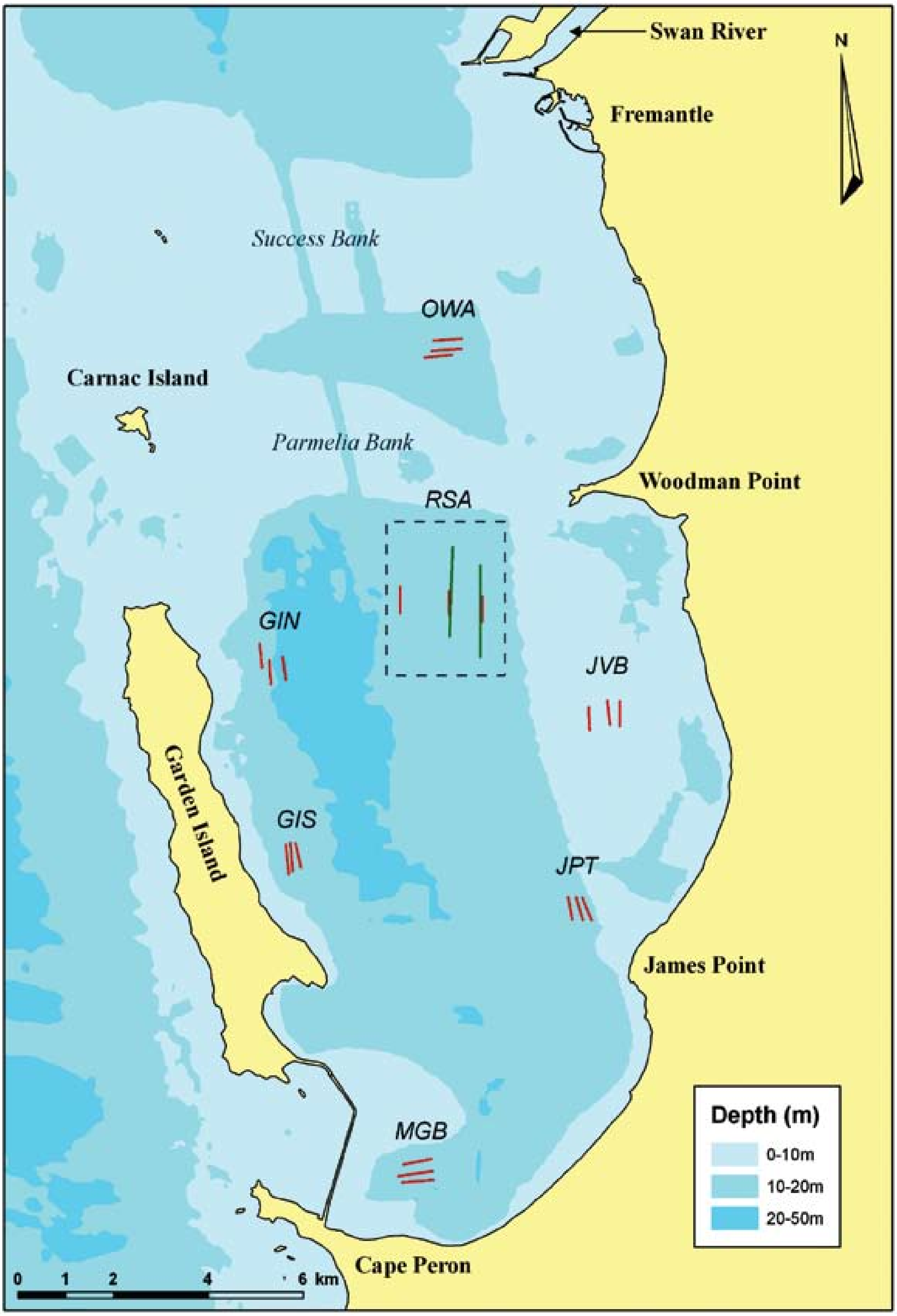

Figure 1.1. Map of Cockburn Sound and Owen Anchorage showing the location of the 23 trawls, consisting of three replicate trawls of five minutes duration at each of the seven locations sampled (red lines), and two trawls of twenty minutes duration (green lines, RSA). OWA, Owen Anchorage; RSA, Research Area (dashed lines); GIN, Garden Island north; GIS, Garden Island south; MGB, Mangles Bay; JPT, James Point; JVB, Jervois Bay.

1.1.3 Blue swimmer crab

Distribution and biology

The blue swimmer or blue manna crab, *Portunus pelagicus,* occurs in nearshore, marine embayment and estuarine systems throughout the Indo-West Pacific region (Stephenson 1962). They live in a wide range of inshore and continental shelf habitats, including sandy, muddy or algal and seagrass habitats, from the intertidal zone to at least 50 m depth (Williams 1982; Edgar 1990). Blue swimmer crabs have been recorded in all States of Australia, except Tasmania (Stephenson 1962). In Western Australia their distribution extends from Cape Naturaliste in the southwest, north along the coast to the Northern Territory. They are a highly valued species to commercial and recreational fishers, with the Shark Bay fishery the largest commercial blue swimmer crab fishery in Australia. Blue swimmer crabs are also the most important recreationally fished species in Western Australia in terms of community participation rate.

The reproductive cycle of blue swimmer crabs is influenced strongly by water temperature. In Cockburn Sound mating occurs in late summer – autumn (January to April), when females have finished spawning and recently matured recruits are soft-shelled (Kangas 2000). These females store the sperm for a number of months over winter, after which eggs are extruded and fertilised, with females becoming ovigerous and spawning between October and January (Penn 1977; Smith 1982). Incubation takes 10 to 18 days, depending upon water temperature, with each female releasing up to one million eggs during this period (Kangas 2000). The larval phase, *i.e.* egg, zoea, megalopa, extends for up to six weeks in coastal waters, with larvae drifting as far as 60 km out to sea in some locations, before settling in inshore waters (Kangas 2000). Rapid growth occurs over summer during the juvenile phase with recruits entering the fishery between March and June after which they move into deeper water. The size at which maturity occurs can vary with latitude or location and between individuals at any location. In Cockburn Sound, most (50 %) are mature in less than 12 months at a carapace width (CW) of between 86 and 96 mm. Blue swimmer crabs in estuaries and embayments in southwestern Australia typically start to attain minimum legal size (130 mm CW commercial and 127 mm CW recreational) in late summer, when they are approximately 12-16 months of age. Most animals in exploited crab stocks have died either through natural or fishing mortality by the time they are 20 months old (Potter *et al.* 2001), but without fishing pressure, blue swimmer crabs can live for three to four years.

Genetic studies have indicated that the population of blue swimmer crabs in Cockburn Sound is generally independent of other stocks in the State, such as the Peel-Harvey Estuary (Chaplin *et al.* 2001). This implies that it is unlikely there would be pronounced recruitment of blue swimmer crabs from outside Cockburn Sound into this embayment. Hence, adverse changes in environmental conditions or high levels of fishing pressure in the embayment could have highly detrimental and long-term effects on crab stocks in Cockburn Sound (Chaplin *et al.* 2001). Further research is currently assessing the genetic relationship between crab populations in Cockburn Sound, Swan River and Warnbro Sound (Chaplin & Sezmis 2008). Preliminary data has suggested that these populations are genetically similar so it appears migration between the stocks has occurred in the past and may also be occurring currently. As a result, the implications for the management of these stocks are currently being assessed.

Status

Historically, commercial blue swimmer crab catches in Cockburn Sound have shown large fluctuations, *e.g.* 92 t in 2001/02 *vs.* 362 t in 1996/97. These fluctuations have previously been attributed to changes both in commercial fishing practices and normal variations in recruitment strength. In recent years, commercial catches have declined significantly from 231 tonnes in 2002/03 to 42 tonnes in 2005/06. Recruitment surveys in 2006 revealed the abundance of 0+ crabs was the lowest on record, with numbers in 2007 only marginally higher. It was concluded that high levels of fishing pressure, coupled with three years of reduced recruitment due to unfavourable environmental conditions, namely lower than average water temperatures, resulted in significantly reduced levels of relative egg production in 2004/05. Recruitment data has been used to generate an index from which catch prediction for the following year can be made. Based on these indices the predicted catch for the 2006/07 and 2007/08 seasons were 59 and 80 tonnes, respectively. On this basis the fishery has been closed to commercial and recreational fishing for the 2006/07 and 2007/08 seasons to allow levels of spawning stock and subsequent recruitment to recover. Current assessments during 2008 have indicated that recovery is slower than expected, despite warmer water temperatures, and that blue swimmer crabs have perhaps been more vulnerable than previously thought. Past reliance on minimum size limits (130 mm CW commercial and 127 mm CW recreational), set well above the size at sexual maturity (98 mm CW), clearly do not provide adequate protection to breeding stock if there are a number of years of adverse environmental conditions. Future management arrangements will focus on protecting the spawning stock under all environmental conditions to ensure recruitment is at an acceptable level.

Although blue swimmer crabs are found in reasonable numbers throughout southwestern Australian waters, they are at the southernmost extreme of their temperature tolerance. This inherent vulnerability to subtle changes in water temperature has revealed that blue swimmer crabs are an excellent potential indicator species for monitoring the environmental health of Cockburn Sound. The importance of this system throughout all aspects of their life cycle (with recruitment in the Sound responsible for rebuilding the spawning stock due to their relative independence from other stocks), highlights that monitoring these stocks as part of a wider study to assess faunal abundance and distribution, will be an integral part of assessing environmental health.

1.1.4 Snapper

Snapper, *Pagrus auratus*, is a widely distributed sparid found predominantly in the temperate waters of the Indo-Pacific region, from New Zealand and Australia to China and Japan (Paulin 1990). This species is highly valued by commercial and recreational anglers throughout its distribution, which in Western Australia includes marine waters from Exmouth Gulf (*ca* 18°S) southwards along the entire west and south coasts. Within this extensive distribution the species occurs in habitats ranging from shallow coastal lagoons and nearshore embayments to depths exceeding 200 m on the continental slope.

This species is highly vulnerable to overexploitation given its predictable reproductive strategy of forming large spawning aggregations in protected nearshore areas at the same time and location each year. It is believed that high levels of fishing pressure targeting spawning aggregations of this species contributed to the serious depletion of stocks in the eastern gulf of Shark Bay (Stephenson & Jackson 2005) and in the oceanic waters off the coast of Carnarvon in Western Australia (Moran *et al.* 2004). The hydrodynamics of a large majority of these nearshore areas, which are utilised by spawning aggregations of snapper, result in the retention of progeny as eggs and pre-settled larvae (Nahas *et al.* 2003; Doak 2004). As a consequence, these areas are important nursery or recruitment locations for this species. Some examples of these nearshore embayments include Gulf St Vincent and Spencer Gulf in South Australia

(Fowler *et al.* 2005), Port Phillip Bay in Victoria (Hamer *et al.* 2005) and Hauraki Gulf in New Zealand (Crossland 1980; Francis 1995).

Although this species occurs along a large area of the Western Australian coast, recent studies on the biology of this species have identified very few spawning and nursery/recruitment areas (Wakefield 2006; Jackson 2007; St John *et al.* in press). The locations identified for recruitment of snapper from these three studies include three self-replenishing areas within the inner gulfs of Shark Bay; Koks, Bernier and Dorre Islands and Turtle Bay for the oceanic stocks off Carnarvon; Cockburn and Warnbro Sounds in the Perth metropolitan area; the area surrounding and including the Blackwood River on the lower west coast; and Wilsons Inlet and King George Sound along the south coast.

Cockburn Sound was first identified as a nursery area for snapper in 1971 from monthly trawl surveys conducted by the Department of Fisheries, from which juvenile snapper were found to remain in the area for at least the first 14 months of their life (Lenanton 1974). In addition, Cockburn Sound was recognised as an important location for annually occurring spawning aggregations of snapper as a result of catches of large mature fish taken during the spawning period by commercial fishers since 1979 (from compulsory catch statistics provided by commercial fishers to the Department of Fisheries Western Australia). To reduce fishing mortality on the spawning aggregations of this species, a seasonal closure (currently 1 October to 31 January) prohibiting the fishing of snapper by commercial and recreational anglers in Cockburn Sound during their vulnerable spawning period, was first introduced in 2000. Recent studies have suggested that this marine embayment may represent an important area for spawning and recruitment for a significant portion of the west coast managed bioregion, which extends from *ca* 27°00'S (slightly north of Kalbarri) to *ca* 115°30'E (slightly south of Augusta) (Wakefield 2006; St John *et al.* in press).

Given this demonstrated importance of Cockburn Sound for snapper, an improved understanding of the faunal composition of this marine embayment would provide key indicators of the areas environmental health and ultimately benefit the future conservation and sustainable management of this important area for snapper.

1.2 Objectives

1. Describe the trawled community structure associated with the key indicator species, i.e. blue swimmer crabs and snapper, in Cockburn Sound.
2. Assess changes in the distribution and abundance of blue swimmer crab and snapper by comparison with the Department of Fisheries long-term data set.
3. Establish a system to monitor the abundance and distribution of sub-tidal embayment faunal communities in Cockburn Sound.

2.0 General methods

C. Wakefield and A. Sampey

2.1 Sampling gear

Sampling was undertaken by trawling using the *RV Naturaliste* (21.6 m in length) with surveys commencing at approximately 30 minutes after sunset. The vessel was equipped with port and starboard deployed otter-board nets configured with a headrope length of 6 fathoms (*ca* 11 m) and 50 mm mesh (stretched) in the wings and 45 mm mesh (stretched) in the cod-ends. The nets were demersal with a 10 mm ground chain that was positioned two links in front of the ground rope. The effective opening of each net was *ca* 7.3 m wide by *ca* 1 m high.

2.2 Sites and periodicity of sampling

A series of three trawl surveys aimed at identifying all the faunal species retained in the nets were conducted at approximately six monthly intervals between April 2007 and February 2008. An additional survey was conducted in April 2008 to collect data for blue swimmer crabs and snapper. Each survey consisted of sampling at seven locations over two nights. However, due to the limited availability of the research vessel for the first two of the four surveys, each night was sampled in different months. The survey periods were April/May 2007, October/December 2007 and February 2008. In April 2008 blue swimmer crabs and snapper only were sampled.

Of the seven locations sampled in each survey, six were located in Cockburn Sound and one in Owen Anchorage (Fig. 1.1, Table 2.1). The six locations within Cockburn Sound were in the vicinity of Mangles Bay (MGB), James Point (JPT), Jervois Bay (JVB), toward the southern (GIS) and northern (GIN) ends of Garden Island and the northern part of the deeper basin area (RSA). The latter location is situated within an area historically designated as the 'Research Area', which has been the location of numerous trawl surveys conducted by the Department of Fisheries since 1971 (Lenanton 1974; Penn 1977). The location sampled in Owen Anchorage (OWA) was in the deeper basin area (*ca* 15 m, Fig. 1.1).

At each of the seven locations three trawls (shots) were undertaken within close proximity and parallel to each other (Fig. 1.1, Table 2.2). This replication of sampling at each location was to allow for any inherent patchiness that may be associated with some fauna. In addition this method provided sufficient power for statistical analyses to adequately describe the composition of the fauna and compare differences among locations.

All 21 trawls were five minutes in duration and *ca* 500 m in length, except for two trawls of 20 minutes duration (*ca* 1900 m in length), which were undertaken in the 'Research Area' (RSA) during the survey in April 2007 (Fig. 1.1, Table 2.1). Only blue swimmer crabs and snapper were sampled from the 20-minute trawls to ensure size distributions and abundances were representative in the 5-minute trawls and to facilitate comparisons with historic data (from the Department of Fisheries) from similar trawl surveys, which had used 20-minute trawls. The use of 5-minute trawls in this study were to reduce the time of sorting and processing of the entire catch but still provide a representative sample and to facilitate direct comparisons of data with a concurrent research project that used trawling to assess the biodiversity of marine fauna beyond diving depths on the west and south coasts of Western Australia (Marine Futures Biodiversity Team 2007).

Table 2.1. Latitude and longitude, average distance (m) and average depth (m) of each of the 5-minute and 20-minute trawls.

Site Code	ShotNo.	Latitude In	Longitude In	Latitude Out	Longitude Out	Av. Distance Trawled (m)	Average Depth (m)
Trawl duration 5 minutes							
OWA	1	32°06.62`S	115°43.25`E	32°06.64`S	115°42.95`E	491	15.0
	2	32°06.53`S	115°43.35`E	32°06.55`S	115°43.04`E	495	14.7
	3	32°06.42`S	115°43.36`E	32°06.45`S	115°43.06`E	487	14.4
RSA	4	32°09.63`S	115°43.59`E	32°09.36`S	115°43.58`E	505	18.4
	5	32°09.55`S	115°43.21`E	32°09.27`S	115°43.21`E	509	19.4
	6	32°09.52`S	115°42.66`E	32°09.26`S	115°42.66`E	500	20.2
GIN	7	32°10.06`S	115°41.18`E	32°10.33`S	115°41.20`E	505	20.8
	8	32°09.87`S	115°41.07`E	32°10.14`S	115°41.10`E	509	20.3
	9	32°10.28`S	115°41.37`E	32°10.02`S	115°41.33`E	500	20.6
GIS	10	32°12.47`S	115°41.40`E	32°15.21'S	115°41.26`E	505	17.9
	11	32°12.13`S	115°41.37`E	32°12.39`S	115°41.48`E	505	18.2
	12	32°12.14`S	115°41.47`E	32°12.40`S	115°41.56`E	505	18.7
JVB	13	32°10.53`S	115°42.02`E	32°10.79`S	115°45.04`E	495	9.4
	14	32°10.84`S	115°44.82`E	32°10.58`S	115°44.82`E	495	9.4
	15	32°10.73`S	115°45.15`E	32°10.53`S	115°45.14`E	495	9.4
JPT	16	32°12.99`S	115°44.73`E	32°12.74`S	115°44.66`E	505	14.4
	17	32°13.00`S	115°44.83`E	32°12.74`S	115°44.74`E	505	14.2
	18	32°12.99`S	115°44.61`E	32°12.73`S	115°44.53`E	500	14.1
MGB	19	32°15.97`S	115°42.70`E	32°15.97`S	115°43.04`E	505	18.0
	20	32°15.84`S	115°42.02`E	32°15.89`S	115°42.64`E	528	18.4
	21	32°15.76`S	115°42.70`E	32°15.70`S	115°43.02`E	505	18.2
Trawl duration 20 minutes							
RSA	22*	32°08.98`S	115°43.57`E	32°10.02`S	115°43.58`E	1926	18.5
	23*	32°08.78`S	115°43.26`E	32°09.79`S	115°43.22`E	1870	18.9

OWA, Owen Anchorage; RSA, Research Area; GIN, Garden Island North; GIS, Garden Island south; JVB, Jervois Bay; JPT, James Point; MGB, Mangles Bay. *only blue swimmer crab & snapper were sampled.

Table 2.2. Number of replicate trawls of five minutes duration at each of the seven locations for each night during the four surveys.

	Survey							
	1		2		3		4	
Site Code	3 Apr 07	2 May 07	29 Oct 07	12 Dec 07	12 Feb 08	13 Feb 08	15 Apr 08	16 Apr 08
OWA		**3**		**2**		**3**	**3***	
RSA	**3**			**3**	**3**		**3***	
GIN		**3**	**3**	**3***		**3**		**3***
GIS	**3**		**3**			**3**		**3***
JVB		**3**		**3**	**3**		**3***	
JPT		**3**	**3**		**3**		**3***	
MGB	**3**		**3**		**3**			**3***

OWA, Owen Anchorage; RSA, Research Area; GIN, Garden Island North; GIS, Garden Island south; JVB, Jervois Bay; JPT, James Point; OWA, Owen Anchorage. *only blue swimmer crab & snapper were sampled.

2.3 Processing, identification and storage of specimens

Onboard the *RV Naturaliste* there were three teams of research staff responsible for collecting the data for i) fish, ii) blue swimmer crab *Portunus pelagicus* (Linnaeus 1758) and western king prawn *Melicertus latisulcatus*[1] (Kishinouye 1896) and iii) all remaining invertebrates.

Processing of fish specimens involved weighing (to the nearest 10 g) and measuring the total lengths (mm TL) of the larger specimens and returning them to the water at the same location they were caught. All smaller specimens were separated into plastic bags by the net they were caught in, *i.e.* Port and Starboard, for each trawl shot and stored frozen. These samples of smaller specimens were later processed at the Western Australian Fisheries and Marine Research Laboratories (WAFMRL), where they were identified to species and a total weight for each species was obtained (to the nearest 0.01 g). The largest and smallest individuals for each species in each of those samples were measured (mm TL), with the exception of snapper, where a fork length (mm FL) was obtained for every individual. Sue Morrison at the Western Australian Museum verified the names of some species that were difficult to identify. Scientific and common names were validated with the Codes for Australian Aquatic Biota (CAAB) fish species list (CSIRO 2008). Voucher specimens of the majority of fish species collected are in permanent storage at the Western Australian Museum.

Counts and weights (to the nearest 10 g) of blue swimmer crabs and western king prawns were obtained onboard the research vessel for each net, *i.e.* port and starboard, for each trawl shot. In addition, the carapace width (CW) was measured to the nearest 1 mm and sex of each blue swimmer crab was determined.

All remaining invertebrates were sorted and identified to species where possible for all taxa except for ascidians, which were only identified to form (colonial or solitary). The number of individuals of each species was counted and a total species weight (wet weight) was obtained in the field. Counts for colonial species were more difficult to determine as colonies were frequently broken up during trawling. An effort was made to count colonies but this will be an underestimate and sometimes only reflect presence or absence. Larger specimens were weighed to the nearest 50 g, and smaller specimens to the nearest 1 g. Length measurements were taken for some species. When species identification was not possible in the field, specimens were kept and frozen, or preserved in ethanol to enable later identification.

Invertebrates were identified at the Western Australian Museum (WAM) in consultation with WAM staff (see Acknowledgements) and using the available literature including field guides (Wells & Bryce 1985; Wells & Bryce 1993; Edgar 1997; Norman & Reid 2000), taxonomic texts (Hale 1929; Shepherd & Thomas 1982; Shepherd & Thomas 1989; Lamprell & Whitehead 1992; Wilson *et al.* 1994; Shepherd & Davies 1997; Lamprell & Healy 1998; Hooper & Van Soest 2002; Poore 2004), original species descriptions and expertly identified specimens in the WAM collections. Except for ascidians, an attempt was made to identify all specimens to species, with a particular focus on sponges, molluscs, echinoderms and crustaceans due to the available expertise. Species names were standardised according to the current accepted scientific and common names using the appropriate Australian Faunal Catalogue (*e.g.* Rowe & Gates 1995; Davie 2002) or web resource (ABRS 2008; CSIRO 2008). At least one of each invertebrate species was retained and these are permanently kept in the Western Australian Museum Collections (see Appendix 1).

[1] In the scientific literature the western king prawn is also known as *Penaeus latisulcatus* and *Penaeus* (*Melicertus*) *latisulcatus*. Pérez Farfarnte & Kensley (1997) revised the genus *Penaeus* and upgraded *Melicertus* to full generic status and although this has caused considerable controversy the name has not been rescinded. Hence, we use the current valid scientific name.

3.0 Objective 1

A. Sampey, J. Fromont, C. Wakefield, and D. Johnston

Objective 1. Describe the trawled community structure associated with the key indicator species, i.e. blue swimmer crabs and snapper, in Cockburn Sound.

3.1 Introduction

The structure of a community is determined largely by the relative abundances of its constituent species. Biological surveys that aim to describe the diversity of a community are expensive to undertake and identifying the species present is time consuming, labour intensive and requires specialised expertise. The resulting dataset is large and difficult to analyse using standard methodology as the assumptions of the statistical models such as normality and homogeneity of variances are rarely met. Finding patterns in such a large dataset and generating a useful summary of complex relationships is challenging, however, over the last decade there has been development and refinement of statistical tools and methodological approaches (Quinn & Keough 2002) that now make this task much simpler.

A community that has equal abundances of all species is considered to be more diverse than one which has higher abundances of a few species and lower abundances for the majority of species, *i.e.* few common and many rare species (Clarke & Warwick 2001). The most widely used univariate measure for estimating diversity is species richness, which is simply the number of species found. However, this measure is strongly influenced by sampling effort and gives equal weighting to rare and abundant species. Diversity indices, *e.g.* Shannon diversity index, provide information on both the number of species and their proportional abundance, but are also sensitive to sampling effort and should only be compared across equivalent sampling designs (Clarke & Warwick 2001). Species evenness measures, *e.g.* Pielou's evenness index, provide information on whether species of a community have similar abundances or if the community is dominated by one or a few species with the rest comparatively rare. In combination these measures provide some useful information on the numbers and proportional representation of the species in a community. However, they do not allow us to determine which species are abundant or rare or how component species abundance and distribution varies in space and time.

A variety of multivariate statistical tools exist to enable exploration of how species in a community relate to each other. All these methods have various strengths and weaknesses in highlighting aspects of the community structure. Multidimensional scaling (MDS) is an unconstrained ordination that is useful for the visual interpretation of a multidimensional dataset (Clarke & Warwick 2001). Cluster analysis aims to find groupings in samples, but as it is hierarchical it forces grouping of samples and does not detect gradients. If the data forms a gradient then an ordination also needs to be examined (Clarke & Warwick 2001). During an unconstrained ordination such as MDS the patterns of overall dispersion in the data may mask real patterns in the factors being tested. Thus, using a constrained ordination, such as canonical analysis of principal coordinates (CAP, Anderson & Willis 2003), enables detection of patterns in the community due to predetermined factors such as a disturbance, spatial and/or temporal gradients. This method also allows the species that are correlated to these patterns to be detected. When used in combination, these univariate and multivariate statistical tools enable the detection of relationships among species, how they vary in space and time, and an overall interpretation of the community structure.

As species of commercial and/or recreational importance are subjected to additional levels of mortality associated with fishing practices, their biomass typically fluctuates from naturally occurring levels more so than other species. Currently, the stock levels of some commercially and recreationally important species are low/depleted, *e.g.* blue swimmer crab (Johnston *et al.* 2007) and snapper (Wise *et al.* 2007), and for many others their stock levels are unknown, *e.g.* octopus and squid. Thus, although commercially and/or recreationally important species may not be statistically significant indicator species, their fluctuations in biomass may have broader ecological impacts and thus should be considered in community analysis.

3.2 Methods

3.2.1 Analysis of community structure

The counts and weights for each taxa from each trawl shot were standardised to abundance (individuals.m^{-2}) and biomass (grams.m^{-2}) using the swept area of the net. The swept area was calculated as the product of the size of the openings of the two nets (m), the effective spread of each net (*ca* two thirds the headrope length) and the distance trawled (m). Some univariate and all multivariate analyses were carried out in PRIMER v6.1.11. Three univariate measures of diversity were calculated using the standardised abundance data of all taxa, *i.e.* species richness (S), Shannon diversity index (H′) and Pielou's evenness index (J′). S is the number of species or taxa, $H' = \sum_i p_i \log_e(p_i)$, where p_i is the proportional abundance of the i^{th} species, and $J' = H' / \log S$. Univariate analyses of variance (ANOVA) were used to test for differences in these diversity measures, total abundance and biomass among sites, surveys and their interaction using the software 'R' (R Development Core Team 2008). Data were transformed prior to analyses to meet the assumptions of normality and homogeneity of variances based on the gradient of the lineal relationship between the logarithms of standard deviation and mean for each diversity measure according to Clarke and Warwick (1994). Consequently, the following transformations were performed, abundance – square root, biomass – log, H′ – not transformed, S and J′ – 4^{th} root. The sampling design was a crossed design with site and survey being random factors.

Multivariate analyses were conducted using two main approaches: 1) pattern exploration in order to reveal how the samples grouped and 2) testing for differences between the predetermined factors of site and sample period. Both sets of analyses were conducted on the species only dataset by first removing taxa that included mixed species, *e.g.* ascidians. For both approaches the data was square root transformed so that rare species would contribute to the patterns observed and the Bray–Curtis distance measure was used as this preserved the abundance structure of the dataset (Clarke & Warwick 2001). Non-metric multidimensional scaling (nMDS) and cluster analyses were used to explore how the faunal community grouped with the significance of the groupings assessed using the similarity profile test (SIMPROF) (Clarke & Gorley 2006). The species that contributed to these groupings were then identified using similarity percentages (SIMPER, Clarke & Warwick 2001). Species that could discriminate between sites or sampling periods were determined by the dissimilarity to standard deviation ratio (Diss/SD) and the average abundance in each group. Species that typified a group were determined from Diss/SD, with species with a Diss/SD > 2 being selected. This cut off value was determined as the intercept of the lineal regression of Diss/SD values. Two groups of species were then identified as 1) those that typify the groups being compared (high Diss/SD but equal average abundance) and 2) those that are able to discriminate between the groups (high Diss/SD but different average abundances between groups).

The second approach tested the significance of differences between the predetermined factors of site and survey using analysis of similarities (ANOSIM) and permutation multivariate analysis of variance (PERMANOVA) and canonical analysis of principal coordinates (CAP). The species that contributed to these differences were assessed using SIMPER and also by plotting species on the CAP biplot if they had a Pearson's correlation coefficient ≥ 0.5. ANOSIM and SIMPER can only test for differences among sites across all surveys and among surveys across all sites, but does not allow for a testing of the interaction between these factors. ANOSIM was used to test for differences between sites and surveys based on their rank similarity, with the significance assessed using the R statistic. R statistic values range between negative one and one, with values of one indicating all replicate tows within a site are more similar to each other in community composition than any replicates from different sites. The Global R was first examined to see if there was a difference in the entire dataset. If there was a significant difference, pairwise comparisons were done for each site and survey combination to identify where the differences occurred. PERMANOVA tested for differences in the entire community among sites and surveys and the interaction of these factors against an ANOVA model using the distance between samples in a similarity matrix. PERMANOVA was undertaken as a permutation of the residuals under a reduced model using type III sum of squares.

3.2.2 Commercially and/or recreationally important species

The species of marine fauna collected during this study were compared to those that are commercially and recreationally retained by fishers over two spatial scales that included the larger West Coast Bioregion (WCB, between Kalbarri at 27^{o}00' S and Augusta at 115^{o}30' E) and the nearshore embayment area sampled in this study of Owen Anchorage and Cockburn Sound (see Fig. 1.1). Information on species retained by commercial fishers for these two spatial scales were obtained from compulsory catch statistics provided by commercial fishers to the Department of Fisheries, Western Australia. Information on species that were retained by recreational fishers in the WCB was obtained from a recent 12-month study of recreational boat-based fishing in this area in 2005-06 (Sumner *et al.* 2008). Consultation with the investigators of this study on recreational boat-based fishing provided information on the species that were retained in Owen Anchorage and Cockburn Sound (Sumner *et al.* unpub.).

In some cases species that were retained by either commercial or recreational fishers were only identified to family. Thus, to compare the lists of species that were collected from this study with those that are retained by commercial and recreational fishers, we assumed that at least one species had been collected from each of the families. For example, skates and rays were only identified to family in the commercial and recreation catch statistics, so we assumed that at least one of the species we had collected from these families were the same species collected by commercial and recreational fishers, *i.e.* pooled our results at family. In the case of families that were identified as being commercially and/or recreationally retained by fishers and that also had species within that family identified, only the counts of identified species were used.

3.2.3 Blue swimmer crab

Length frequency analysis of blue swimmer crab

Modality in the length frequency distributions from all historic trawls were used to distinguish age cohorts of blue swimmer crabs, *i.e.* recruit or residual. These age cohorts were estimated by fitting a probability model that allocates an individual to an age cohort, assuming this frequency follows a normal probability density function. A chi-squared statistic was then used to decide which competing solution to the model best fits the data (Schnute & Fournier 1980). Numbers of recruit and residual crabs were then determined for each trawl during a survey to develop mean abundances for each modal class for that survey date.

Analysis of site selectivity of blue swimmer crab

Analysis of variance (ANOVA) was applied to determine whether there were any significant differences in the number of recruit and residual blue swimmer crabs between sites in Cockburn Sound. The factors in the model included site, year and month, with the interaction between site and year also considered. The number of recruits (0+) was transformed using *Log*(recruits + 0.0025) to better meet the assumption of normality required for ANOVA. The number of residuals (≥ 1+) did not need to be transformed. Type III sum of squares were used due to the unbalanced nature of the data.

When site was significant, the least-squared means were presented (and back-transformed if required) to identify the influence of each site on the numbers of blue swimmer crab recruits. Least-squared means are to an unbalanced design as the mean is to the balanced design. Statistically significant results were presented with F values, degrees of freedom and p values.

3.2.4 Snapper

Selectivity of trawl gear and site preference

To achieve a better representation of the size distribution of snapper in each trawl, snapper were categorised into sequential 1 cm FL size classes and their numbers were adjusted to allow for the selectivity of the fishing gear according to Wakefield *et al.* (Table 3.10, 2007). The adjusted numbers of snapper for each trawl were used to identify the size composition for each survey and to compare their abundance at each site for each survey.

Differences in the number of snapper caught at each site, sampling period and the interaction between site and sampling period were tested using analysis of variance (ANOVA) using the software 'R' (R Development Core Team 2008). The data was first tested for normality and homogeneity of variance and transformed accordingly (Clarke & Warwick 2001).

Table 3.10. Percentage of snapper retained in the trawl gear for each sequential 1 cm size class (from Wakefield *et al.* 2007).

Fork Length (cm)	Retention by trawl gear (%)
3	8.33
4	21.50
5	37.67
6	69.29
7	87.83
8	95.09
9	98.04
10	99.62
11	100.00
12	100.00
13	100.00
14	100.00
15	100.00

3.3 Results

3.3.1 Species composition, biomass and abundance

A total of 216 taxa from 6 phyla were identified during the study (see Appendix 2). This included 141 invertebrate taxa and 75 fish taxa (Porifera: 32 species and 1 taxa; Cnidaria: 2 species and 5 taxa; Crustacea: 30 species and 1 taxa; Mollusca: 37 species and 1 taxa; Echinodermata: 28 species; Chordata: Ascideacea: 3 taxa; Chordata: Pisces: 73 species and 2 taxa). All identified species have either previously been collected in Cockburn Sound and Owen Anchorage or are well within their expected range. The only exceptions to this were a snapping shrimp *Alpheus* cf. *rapax* and asymmetric goatfish *Upeneus* cf. *asymmetricus*, which are both considered to be predominantly tropical species, but these identifications need to be confirmed with in depth taxonomic study, which is beyond the scope of this project. The only introduced species collected was the streaked goby *Acentrogobius pflaumii*, at GIN and RSA during the October/December 2007 survey.

Many of the species were rare and only collected at one site on one sampling occasion (52 species, *ca* 24 % of the total). Only 35 species (*ca* 16 %) could be considered common and widespread, occurring at all sites and in most surveys (Table 3.1). Taxa of mixed species that occurred at all sites were orange sea pens *Cavernularia* spp., all ascidians, both colonial and solitary forms, and the lefteye flounder *Arnoglossus* spp. The seastar *Stellaster inspinosus* was common at the three northern most sites (OWA, RSA & GIN) but absent from the other sites. Some species were generally common across sites and surveys, but missing from one site only. For example, the sea cucumbers *Cercodema anceps* and *Colochirus quadrangulatus*, an urchin *Temnopleurus michaelseni*, and southern fiddler ray *Trygonorrhina fasciata* were all absent from MGB.

Table 3.1. List of common and widespread species collected from trawling in Cockburn Sound and Owen Anchorage. See Appendix 2 for full list of taxa collected during the project. * *Metapenaeopsis* spp. includes *M. fusca* and *M. lindae*.

Taxa	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Cnidaria																						
Anthozoa																						
Cavernularia spp.	sea pen	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●
Arthropoda: Crustacea																						
Decapoda																						
Belosquilla laevis	mantis shrimp		●	●	●	●	●		●	●	●	●	●		●	●	●	●	●	●	●	●
Melicertus latisulcatus	western king prawn	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
Metapenaeopsis fusca	velvet prawn			●		●	●		●	●	●	●	●		●	●		●	●	●	●	●
Metapenaeopsis lindae	velvet prawn		●	●		●	●		●	●		●	●		●	●	●	●	●		●	●
Metapenaeopsis spp.*	velvet prawn	●			●			●						●			●					
Portunus pelagicus	blue swimmer crab	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Portunus rugosus	swimmer crab	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Thalamita sima	four-lobed swimmer crab		●	●		●	●			●		●	●		●	●	●	●	●		●	●
Mollusca																						
Gastropoda																						
Euprymna tasmanica	southern bobtail squid	●		●	●	●	●	●	●	●		●	●	●	●		●	●	●	●	●	●
Sepia braggi	Bragg's cuttlefish	●		●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●		●
Sepia novaehollandiae	cuttlefish	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●		●
Sepioteuthis australis	southern calamari squid	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●		●
Echinodermata																						
Crinoidea																						
Comatula purpurea	featherstar		●	●	●	●	●	●	●	●			●		●		●		●	●		
Asteroidea																						
Astropecten preissi	seastar	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
Luidia australiae	seastar	●	●	●	●	●	●	●	●	●	●	●	●	●				●	●	●		
Stellaster inspinosus	seastar	●	●	●	●	●	●	●	●	●												
Ophiuroidea																						
Macrophiothrix spongicola	brittlestar		●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	
Echinoidea																						
Temnopleurus michaelseni	urchin		●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●			
Holothuroidea																						
Cercodema anceps	sea cucumber	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●					
Colochirus quadrangularis	sea cucumber	●	●	●	●	●	●	●	●	●	●	●			●		●		●			
Chordata																						
Ascidiacea																						
Herdmania sp.	sea squirt		●	●		●			●	●	●	●			●		●		●	●		
ascidian spp. - colonial	sea squirt		●	●	●		●	●	●	●	●	●	●		●		●	●			●	
ascidian spp. - solitary	sea squirt	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	
Pisces																						
Anoplocapros amygdaloides	western smooth boxfish	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
Apogon rueppellii	western gobbleguts	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Arnoglossus spp.	lefteye flounder	●		●	●	●	●	●	●	●	●	●		●	●		●	●	●			●
Diodon nicthemerus	globefish	●	●	●					●		●	●	●	●	●	●	●	●	●	●	●	●
Heterodontus portusjacksoni	Port Jackson shark	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●			●	●
Inegocia japonica	rusty flathead	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●
Lepidotrigla papilio	spiny gurnard	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Maxillicosta scabriceps	little gurnard perch	●		●		●	●	●	●	●			●	●	●	●	●	●	●		●	
Monacanthus chinensis	fanbelly leatherjacket	●	●	●		●	●	●	●	●	●	●		●	●			●			●	●
Myliobatis australis	southern eagle ray			●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●
Onigocia spinosa	midget flathead	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pagrus auratus	snapper	●		●			●			●		●	●		●	●	●	●	●			●
Parapercis haackei	wavy grubfish	●	●	●	●	●	●	●	●	●		●		●	●		●	●		●	●	●
Parequula melbournensis	silverbelly	●	●	●	●			●	●	●				●		●	●		●	●	●	●
Pegasus volitans	slender seamoth	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●
Pentapodus vitta	western butterfish	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●		●	●	
Pseudocalliurichthys goodladi	longspine dragonet	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pseudocaranx georgianus	sand trevally	●		●	●		●	●	●	●	●		●	●		●	●		●	●		●
Pseudocaranx wrighti	skipjack trevally	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●		●
Pseudorhombus jenynsii	smalltooth flounder	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Sillago burrus	western trumpeter whiting	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●
Trygonorrhina fasciata	southern fiddler ray	●		●	●		●	●	●	●	●	●	●		●				●			
Upeneichthys vlamingii	bluespotted goatfish	●	●	●	●			●	●	●			●	●		●		●				●

There were no general trends in total abundance and biomass across sites and surveys but these factors were significantly different due to a site and survey interaction (Table 3.2). The highest mean abundance occurred at some sites in February 2008 (MGB, GIS & GIN) and at others in April/May 2007 (JPT, JVB, RSA & OWA) (Fig. 3.1). The mean biomass was highest at some sites (JPT, RSA & OWA) in April/May 2007 and other sites (MGB, GIS & GIN) in October/December 2007. The high mean biomass and standard error at GIN in October/December 2007 was due to the capture of a large (estimated to weigh *ca* 150 kg) smooth stingray *Dasyatis brevicaudata* in one tow.

Table 3.2. Univariate ANOVA results for (a) total abundance and (b) biomass, (c) species richness (S), (d) diversity (H') and (e) evenness (J'). Significance codes, $p < 0.001$*** and $p < 0.01$**.

	Sum Sq.	df	F	Pr(>F)	Sig.
a) total abundance					
site	0.1	6	18.4	3×10^{-10}	***
survey	0.01	2	7.8	0.001	**
site x survey	0.08	12	7.4	5×10^{-10}	***
residuals	0.03	41			
b) total biomass					
site	2.02	6	1.3	0.27	
survey	0.28	2	0.5	0.58	
site x survey	8.24	12	2.7	0.008	**
residuals	10.41	41			
c) species richness (S)					
site	0.93	6	16.2	2×10^{-9}	***
survey	0.03	2	1.7	0.2	
site x survey	0.18	12	1.6	0.13	
residuals	0.39	41			
d) species diversity (H')					
site	1.72	6	10.8	3×10^{-7}	***
survey	0.28	2	5.2	0.009	**
site x survey	1.04	12	3.3	0.002	**
residuals	1.1	41			
e) species evenness (J')					
site	0.14	6	22.5	2×10^{-10}	***
survey	0.02	2	8.7	2×10^{-4}	***
site x survey	0.08	12	6.4	3×10^{-6}	***
residuals	0.04	41			

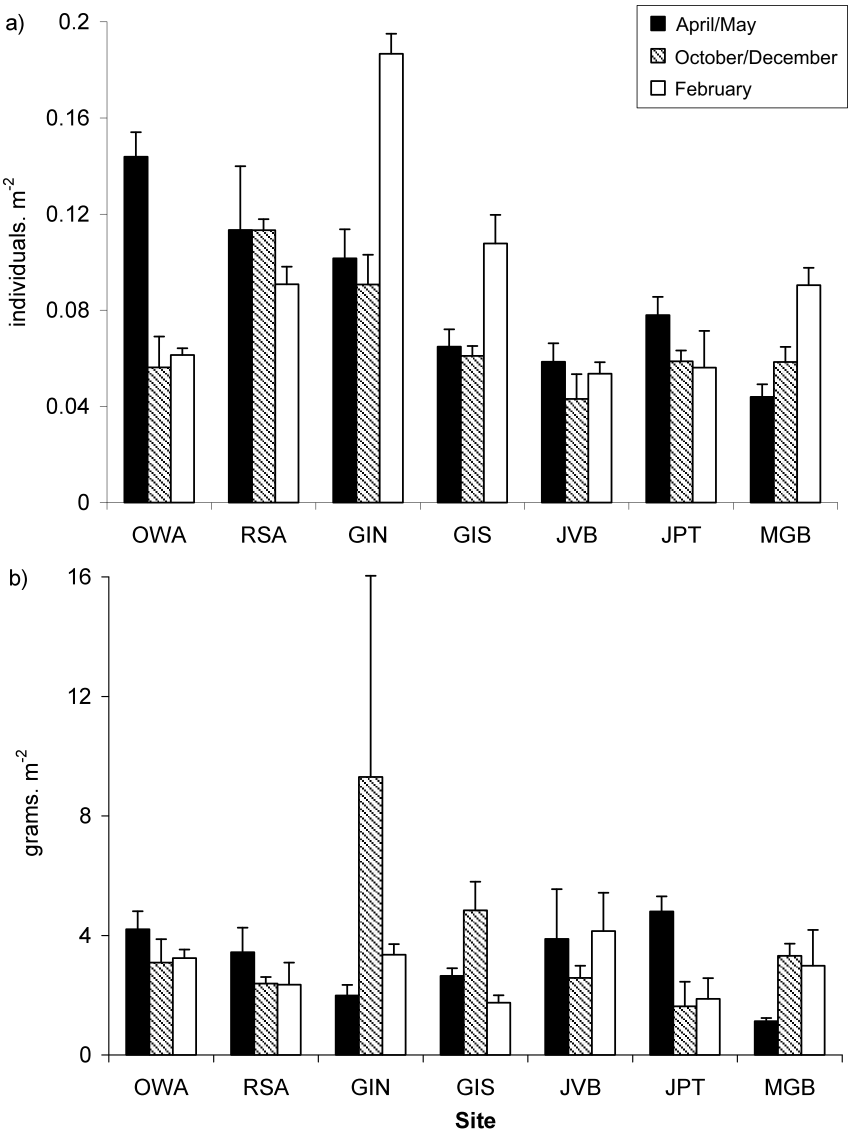

Figure 3.1. Mean (± 1 SE) (a) abundance and (b) biomass of the entire community sampled for each site and survey.

3.3.2 Diversity measures

Species richness (S) varied among sites and surveys but was only significantly different among sites (Table 3.2). Mean S ranged from 24 (MGB in April/May 2007) to 56 species (GIN in February 2008) and was generally highest at GIN and OWA (mean across all months 50 and 47 species, respectively) and lowest at MGB (27 species, Fig. 3.2). Species diversity (H′) and evenness (J′) also varied significantly among sites and months (Table 3.2). H′ ranged from 2.2 (GIN & GIS in February 2008 and RSA in April/May 2007) to 3.1 (OWA in February 2008) and J′ ranged from 0.5 (GIN in February 2008) to 0.8 (JVB in October/December 2007 and OWA in February 2008, Fig.3.2). OWA and GIN had similar species richness values to each other but OWA had higher diversity and evenness than GIN indicating that more species had similar abundances across the community at OWA than at GIN, where the community was dominated by a few species. RSA and GIN generally had the lowest evenness values indicating that the communities at these sites are dominated by fewer species compared to the other sites where more species have similar abundances.

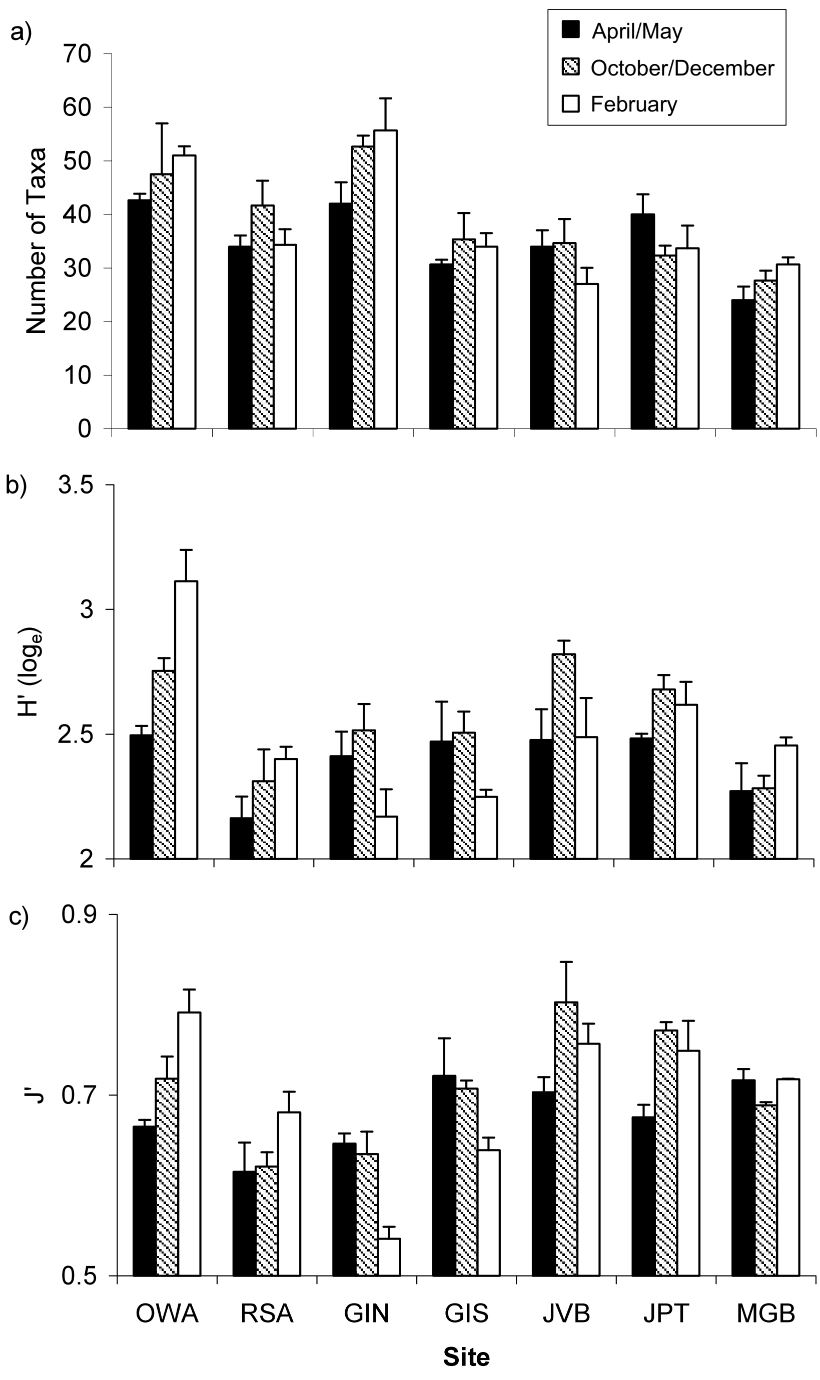

Figure 3.2. Mean (± 1 SE) (a) species richness, (b) diversity, and (c) evenness indexes for each site and survey.

3.3.3 Community groupings and discriminating species

Clustering and unconstrained ordination of the abundance data resulted in six groups (a-f) that were significant using SIMPROF ($p < 0.1$ %) at 50 % similarity (Fig. 3.3). JVB (group's d-f) was significantly different from the rest of the sites. Group d consisted of one shot that was sampled in December 2007 and the faunal community included a mixture of sponge species and associated fauna (Fig. 3.3 & Table 3.3). Group e consisted of the May 2007 samples and group f of the remaining December 2007 samples and all February 2008 samples. Group e had a higher abundance of five species, *Penaeus latisulcatus*, *Portunus rugosus*, *Temnopleurus* *michaelseni*, *Pseudocalliurichthys goodladi* and *Sillago bassensis*, compared to group d (Table 3.3). OWA in December 2007 (group b) had a very different community from the remaining sites and this was due to a high abundance of the sea cucumber *Colochirus quadrangulatus* and the presence of another sea cucumber *Cladolabes schmeltzii* (Fig. 3.3a-c and Table 3.3). The seastar *Stellaster inspinosus* and bighead gurnard perch *Neosebastes pandus* also contributed to this separation. The remaining OWA samples formed group c, the sea cucumber *Cladolabes schmeltzii* and a murex gastropod *Bedeva paivae* separated group c from group d (Table 3.3). The remaining samples formed group a, but there was significant structure at > 50 % similarity forming groups due to sites and surveys and this is evident on the nMDS ordination where the samples form a gradient from north to south and east to west (Fig. 3.3a & b).

Clustering and ordination of the biomass data resulted in nine groups (a-i) that were significant using SIMPROF (p < 0.1 %) at 50 % similarity (Fig. 3.4). The patterns were broadly similar to the abundance data with groupings according to the site collected and displaying a north/south and east/west gradient visible on the nMDS ordination (Fig. 3.4b). Within these trends were groupings according to survey that indicated seasonal variation in the biomass of the community. Groups d and g formed due to the high biomass of a single individual of a black stingray *Dasyatis thetidis* (25.2 kg) at GIS in October 2007 (group d) and a smooth stingray *Dasyatis brevicaudata* (estimated to weigh *ca* 150 kg) at GIN in October 2007 (group g). *Dasyatis brevicaudata* also contributed to group a as one of the top ten species by weight, and is the main species that separates group g from all other groups, except a (Table 3.4). The presence of four species of sponge and their associated fauna also separates group g from all other groups (Table 3.4). The higher biomass of silverbelly *Parequula melbournensis* at OWA in May 2007 separated this group from all other groups (Fig. 3.4, Table 3.4). *Dasyatis thetidis* was the main species that drove the separation of one sample at GIS in October 2007 from the rest of the groups, but the triton *Cymatium* cf. *exaratum*, the sea slug *Pleurobranchus peroni* and little weed whiting *Neoodax balteatus* also contributed to this separation (Fig. 3.4, Table 3.4).

Community composition was significantly different among sites and months for estimates of both abundance and biomass (Tables 3.5 & 3.6). In almost all cases, abundance was a better discriminator of these differences than biomass (sites: global R = 0.913 *vs.* 0.793 for sites and months: global R = 0.931 *vs.* 0.636, abundance and biomass, respectively, at 0.01 % significance, Table 3.5). All site groups were significantly different from each other, with the least difference between GIS and RSA (R = 0.827 for abundance and R = 0.358 for biomass, Table 3.5). The similarity between RSA and GIS is also evident on the nMDS plots where most of the samples from these two sites are very close together (Fig. 3.3b). The community was most different between February 2008 and April/May 2007 (R = 0.725 and R = 0.704, for abundance and biomass, respectively). Estimates of abundance and biomass of the fauna was most similar in February 2008 and October/December 2007 (R = 0.9 and R = 0.561). Based on the biomass of the fauna, JVB was significantly different from GIN, GIS and OWA, and OWA was significantly different from GIS and MGB (all pairs having R = 1).

In general, no species typified a survey, except for *Sepia novaehollandiae*, which was more abundant in February 2008 than in October/December 2007 and *Portunus rugosus*, which had a higher biomass in April/May 2007 than October/December 2007 (Table 3.7). The abundance and biomass of the seastar *Stellaster inspinosus* and bluespotted goatfish *Upeneichthys vlamingii* was higher at OWA than the other sites (Table 3.7). The sponge *Holopsamma* sp. C1 separated GIN from all other sites. The mantis shrimp *Belosquilla laevis* was more abundant at JPT than GIN, OWA and JVB.

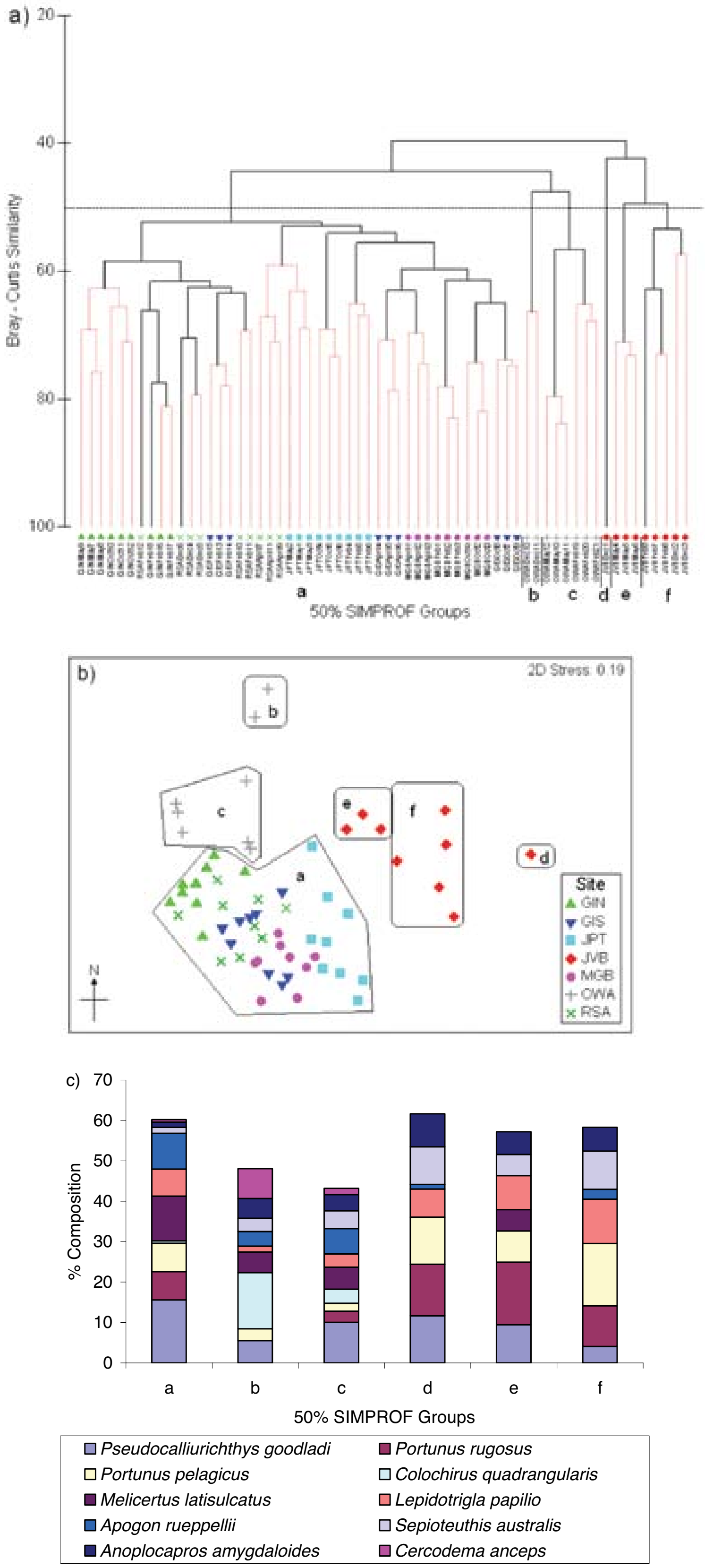

Figure 3.3. Dendrogram (a) and two-dimensional ordination (b) of abundance (individuals.m^{-2}) of species only for each site and survey. Groups (a-f) at 50 % similarity are identified on the dendrogram as significant (black lines) and non-significant (red lines) as determined by SIMPROF, p < 0.1 %. The top ten species that contributed to these groupings are displayed (c).

Table 3.3. Discriminating species for each 50 % similarity SIMPROF grouping based on abundance (•) determined from SIMPER analysis, where Diss/SD > 5.7, r^2 = 0.4. [1]all species are in higher abundance in the indicated group except where indicated, [2]abundance is higher in this group, *Species are in equal abundance in both groups so not able to discriminate between them. Groups not listed had no species fitting the criteria used.

Indicator Species	a vs. b^1	b^1 vs. c	b^1 vs. d^2	b^1 vs. e^2	b^1 vs. f^2	c vs. d^1	d^1 vs. e^2	d^1 vs. f
Phylum Porifera								
Echinodictyum clathrioides						●	●	●
Igernella sp. C1						●	●	●
Semitaspongia sp. C1						●	●	
Tedania sp. C1						●	●	●
Tethya cf. *ingalli*						●	●	
Phylum Arthropoda								
Fultodromia nodipes							●	●
Hyastenus sebae						●	●	
Melicertus latisulcatus							●^{2}	
Pilumnus fissifrons						●	●	
Portunus pelagicus			●*					
Portunus rugosus				●^{2}			●^{2}	
Thalamita sima							●	
Phylum Mollusca								
Bedeva paivae		●		●				
Sepioteuthis australis			●*					
Phylum Echinodermata								
Astropecten preissi			●		●			
Cercodema anceps			●					
Cladolabes schmeltzii	●	●		●	●			
Colochirus quadrangularis	●		●	●	●			
Coscinasterias muricata						●	●	
Luidia australiae			●		●			
Stellaster inspinosus	●		●	●	●			
Temnopleurus michaelseni			●				●^{2}	
Phylum Chordata								
Gymnapistes marmoratus				●	●			
Lepidotrigla papilio			●^{2}		●^{2}			
Neosebastes pandus	●			●	●			
Omegophora armilla							●	
Pagrus auratus							●	
Pegasus volitans			●					
Pentapodus vitta							●	
Pseudocalliurichthys goodladi							●^{2}	
Sillago bassensis							●^{2}	
Sillago burrus			●		●			

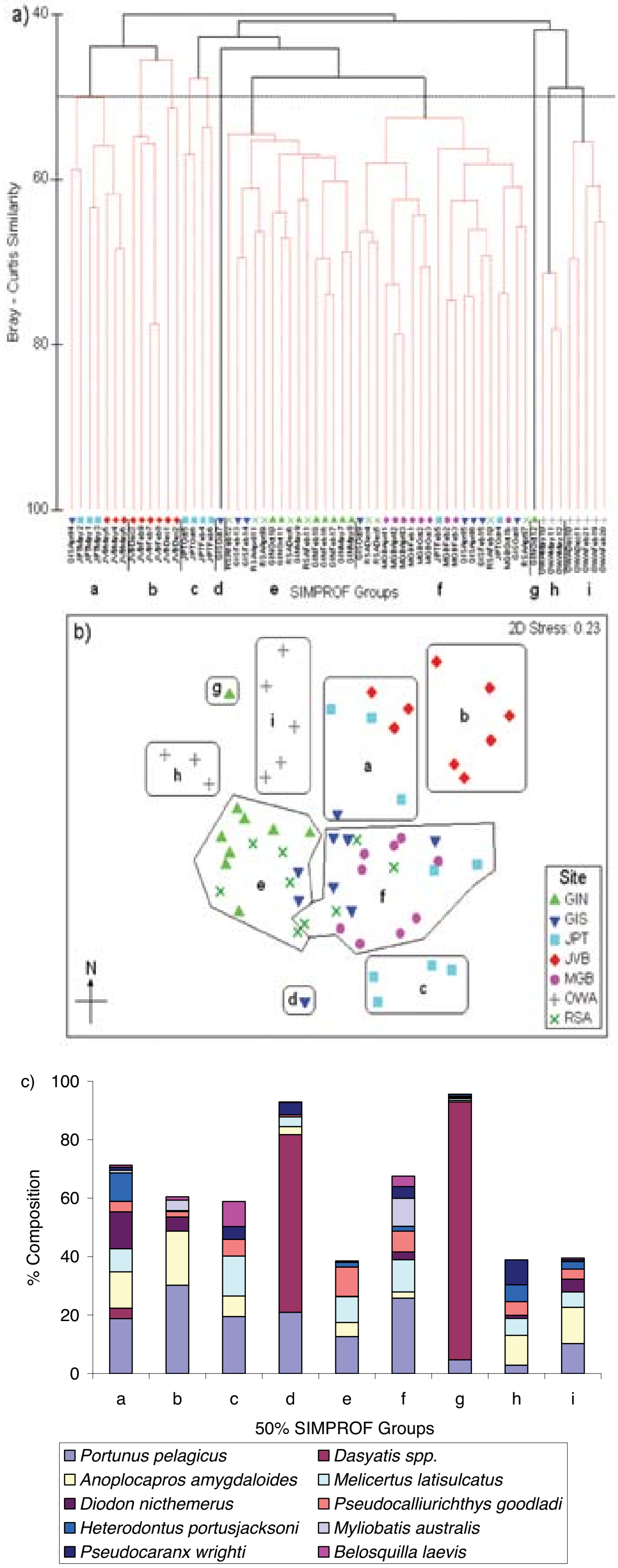

Figure 3.4. Dendrogram (a) and two-dimensional ordination (b) of mean biomass (g.m^{-2}) of species only, for each site and sampling period. Groups (a-h) are identified on the dendrogram as being significant (black lines) and non-significant (red lines) as determined by SIMPROF, p < 0.1 %. The top ten species that contributed to these groupings are displayed (c).

Table 3.4. Discriminating species for each 50 % similarity SIMPROF grouping based on biomass (○) determined from SIMPER analysis, where Diss/SD > 3.7, r^2 = 0.2. [1]all species are in higher abundance in the indicated group except where indicated, [2]abundance is higher in this group, *Species are in equal abundance in both groups so not able to discriminate between them. Groups not listed had no species fitting the criteria used.

Indicator Species	a vs. d^1	a vs. g^1	a vs. h^1	b vs. d^1	b vs. g^1	b vs. h^1	b vs. i^1	c vs. d^1	c vs. g^1	c vs. h^1	d^1 vs. e	d^1 vs. f	d^1 vs. h^2	d^1 vs. i	e vs. g^1	f vs. g^1	f vs. h^1	g^1 vs. h^2	g^1 vs. i
Phylum Porifera																			
Ciocalypta sp. C1		○			○				○							○		○	○
Holopsamma sp. C1									○							○		○	○
Leucosolenida sp. C1		○			○				○						○			○	○
Tethya cf. ingalli									○									○	
Phylum Arthropoda																			
Belosquilla laevis													○						
Hyastenus sebae		○							○						○	○		○	
Metapenaeopsis fusca	○	○											○					○	○
Metapenaeopsis lindae	○	○											○					○	
Melicertus latisulcatus				○	○		○							○					○
Pilumnus fissifrons		○							○									○	
Portunus pelagicus								○	○				○					○	
Thalamita sima													○						
Phylum Mollusca																			
Aplysia dactylomela		○			○				○							○			
Cymatium cf. *exaratum*	○			○				○			○	○	○						
Euprymna tasmanica													○^{2}					○	
Pleurobranchus peroni	○	○		○	○			○	○			○	○	○		○		○	○
Sepiadarium austrinum					○				○									○	○
Sepioloidea lineolata					○														○
Phylum Echinodermata																			
Cercodema anceps								○	○									○	
Colochirus quadrangularis					○											○		○	
Comatula purpurea																		○	○*
Echinocardium cordatum	○			○									○						
Luidia australiae					○														
Macrophiothrix spongicola																		○	
Peronella lesueuri									○						○				
Stellaster inspinosus		○			○				○							○			
Temnopleurus michaelseni				○									○					○	
Phylum Chordata																			
Anoplocapros amygdaloides																		○^{2}	
Brachaluteres jacksonianus		○			○				○							○			○
Dasyatis brevicaudata					○				○						○	○		○	○
Dasyatis thetidis	○			○				○			○	○		○					
Engraulis australis													○	○					
Eubalichthys mosaicus		○			○				○									○	○
Gymnapistes marmoratus					○														
Heterodontus portusjacksoni													○^{2}						
Hippocampus subelongatus					○				○									○	
Hyporhamphus melanochir													○	○					
Inegocia japonica				○	○														
Lepidotrigla papilio																		○	
Monacanthus chinensis		○							○										
Neoodax balteatus	○			○				○					○						
Onigocia spinosa																		○	
Parequula melbournensis			○			○				○			○^{2}				○	○^{2}	
Pentapodus vitta						○				○			○^{2}						
Platycephalus longispinis					○				○	○						○			○
Pomatomus saltatrix		○			○				○							○		○	
Pseudocalliurichthys goodladi					○														
Pseudocaranx wrighti				○	○	○		○		○								○^{2}	
Sillago bassensis										○									
Sillago burrus				○	○			○*											
Spratelloides robustus		○			○				○						○	○		○	○
Trygonorrhina fasciata	○	○																	
Upeneichthys vlamingii																○			

The constrained ordination (CAP) separated all of the sites based on abundance, with JVB being most different from the other sites due to the abundance of the western smooth boxfish *Anoplocapros amygdaloides* and southern calamari squid *Sepioteuthis australis* (Fig. 3.5). The globefish *Diodon nicthemerus* was more abundant at JVB and JPT. The mantis shrimp *Belosquilla laevis* was associated with JPT and MGB and this was also indicated by the SIMPER results (Fig. 3.5 & Table 3.7). *Stellaster inspinosus* was associated with the northern sites OWA, RSA and GIN. Species that were positively correlated with different survey periods and thus indicated higher abundance and biomass in those respective periods, included the cuttlefish *Sepia novaehollandiae* in February 2008 and a swimmer crab *Portunus rugosus* in April/May 2007 (Fig. 3.6).

The two key indicator species, snapper and blue swimmer crab were not strong discriminating species in either the SIMPER or CAP analysis. Blue swimmer crab *Portunus pelagicus* was equally abundant at OWA and JVB in October/December 2007, and was able to discriminate groups d and g from groups c and h. However, as groups d and g were formed from a single trawl shot, and are thus outliers, this is not particularly useful (Tables 3.3 & 3.4). This species had higher biomass at GIN compared to OWA, and higher abundance at MGB compared to GIN, and JVB compared to OWA (Table 3.7), but it was not strongly correlated with any site or survey period (Figs 3.5 & 3.6). Snapper *Pagrus auratus* only discriminated between group d and e and this was due to a higher abundance at JVB in October 2007 (Table 3.7, see Section 3.3.7). This species also showed a positive correlation with survey 3, due to a higher abundance and biomass during February 2008 (Fig. 3.6, see Section 3.3.7).

The results from these two statistical approaches concur and were beneficial in describing slightly different features of the community structure. Sites were generally different from each other in contrast to survey periods, which with a few exceptions were very similar. Overall, the trends exhibited by the diversity and evenness of the faunal community were highest at the northern site, *i.e.* Owen Anchorage (OWA), and decreased to their lowest at the southernmost site, *i.e.* Mangles Bay (MGB).

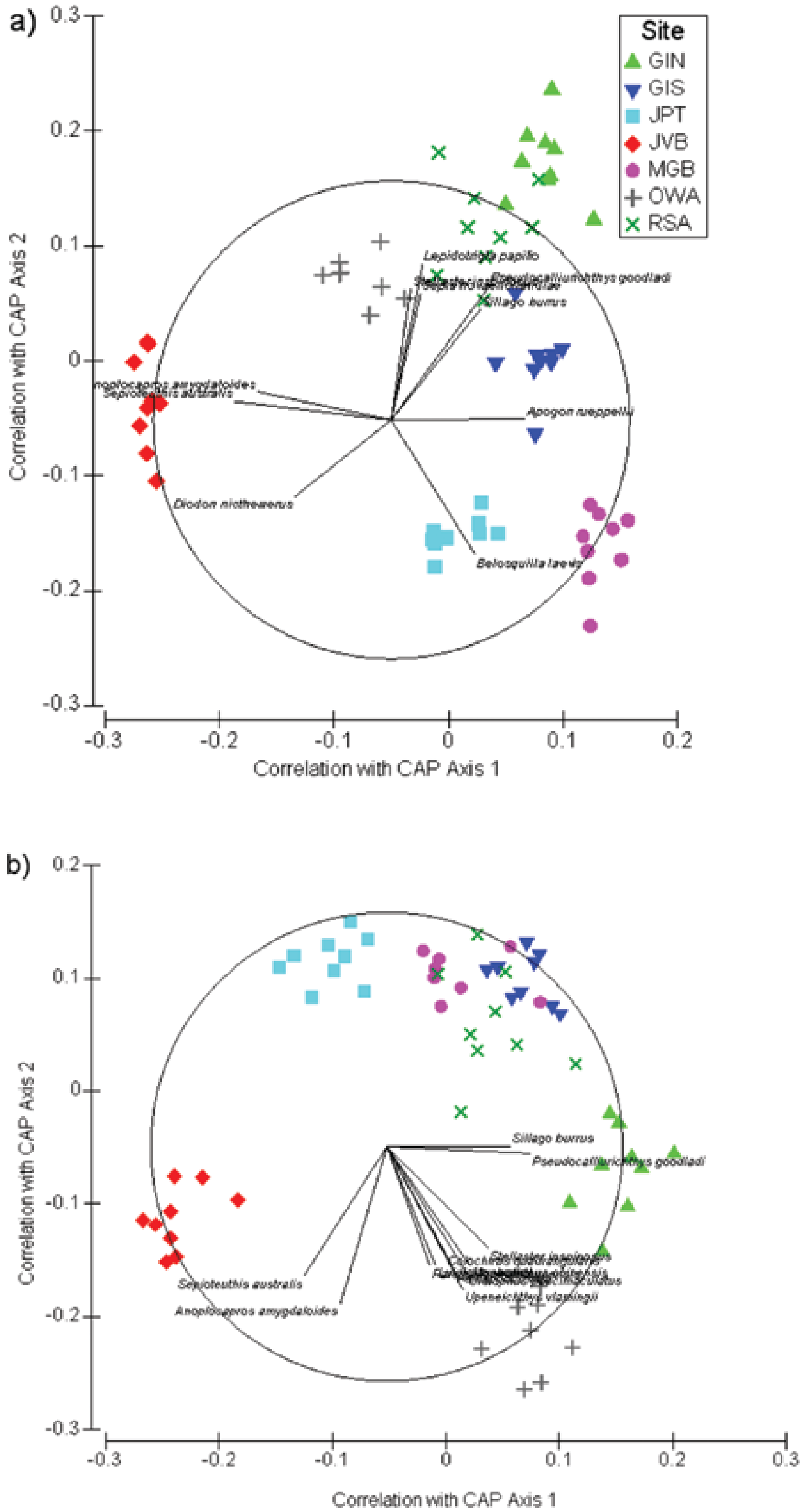

Figure 3.5. CAP results on a) abundance and b) biomass for differences among sites. Species with a Pearson's correlation coefficient > 0.5 are plotted. Length of the lines represents the strength of the correlation and the direction in relation to each axis represents a negative or positive correlation.

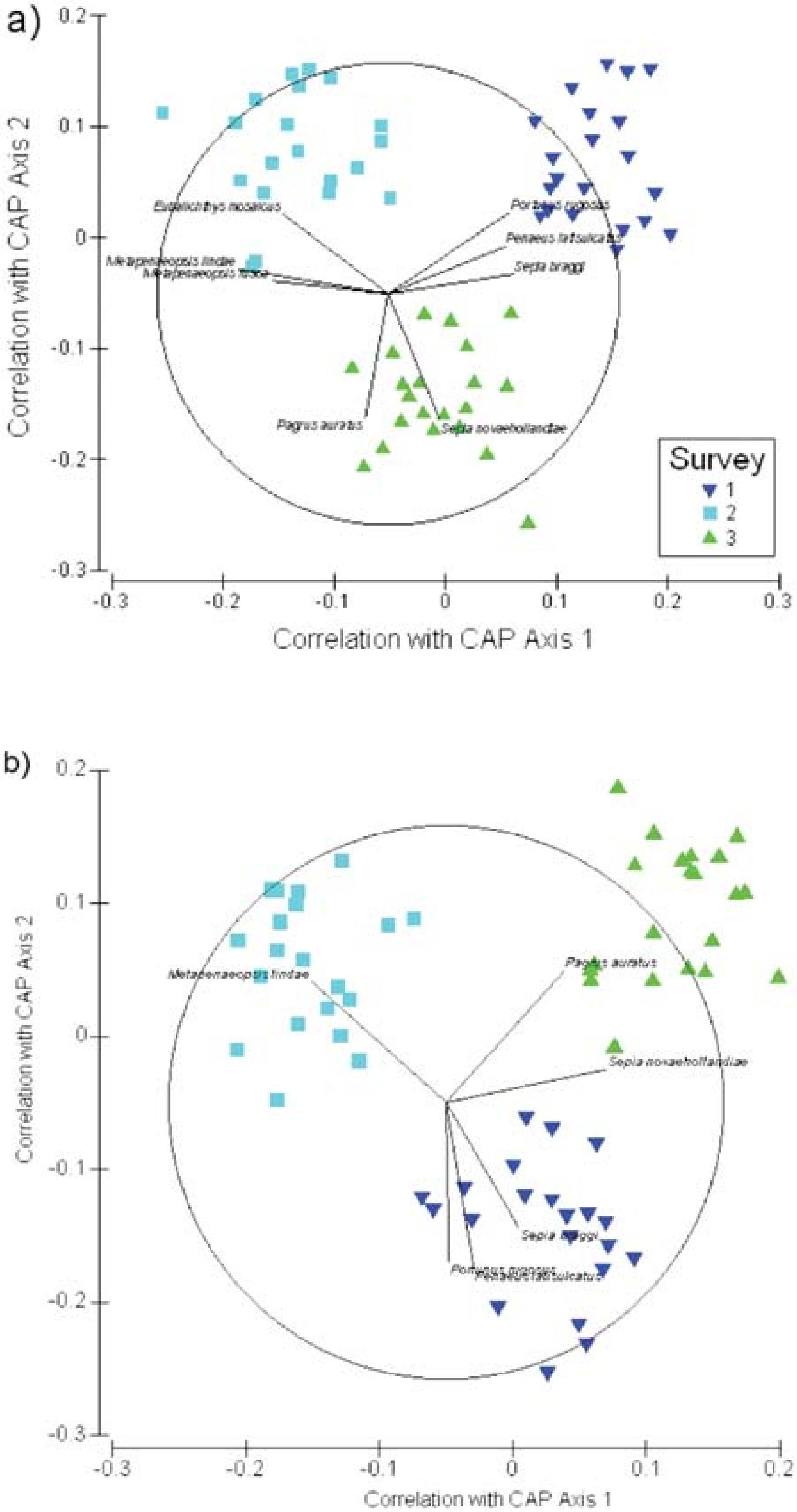

Figure 3.6. CAP results on a) abundance and b) biomass for differences among surveys (1 refers to April/May 2007, 2 to October/December 2007 and 3 to February 2008). Species with a Pearson's correlation coefficient > 0.5 are plotted. Length of the lines represents the strength of the correlation and the direction in relation to each axis represents a negative or positive correlation.

Table 3.5. Pairwise Tests from ANOSIM analysis based on 9999 permutations, for each site and sampling period.

	Abundance		Biomass	
Groups	R Statistic	Significance Level %	R Statistic	Significance Level %
GIN, GIS	1	0.1	0.802	0.1
GIN, JPT	1	0.1	0.975	0.1
GIN, JVB	1	0.1	1	0.1
GIN, MGB	1	0.1	0.889	0.1
GIN, OWA	1	0.1	0.959	0.1
GIN, RSA	0.852	0.1	0.481	0.1
GIS, JPT	1	0.1	0.654	0.1
GIS, JVB	1	0.1	1	0.1
GIS, MGB	1	0.1	0.716	0.2
GIS, OWA	1	0.1	1	0.1
GIS, RSA	0.827	0.1	0.358	0.9
JPT, JVB	0.889	0.1	0.679	0.1
JPT, MGB	0.988	0.1	0.568	0.6
JPT, OWA	1	0.1	0.986	0.1
JPT, RSA	0.926	0.1	0.704	0.2
JVB, MGB	0.975	0.1	0.926	0.1
JVB, OWA	1	0.1	1	0.1
JVB, RSA	1	0.1	0.988	0.1
MGB, OWA	1	0.1	1	0.1
MGB, RSA	0.951	0.1	0.667	0.2
OWA, RSA	1	0.1	0.903	0.1
Feb, Apr/May	0.974	0.01	0.725	0.01
Feb, Oct/Dec	0.9	0.01	0.561	0.01
Apr/May, Oct/Dec	0.95	0.01	0.644	0.01

Table 3.6. Results of PERMANOVA based on 999 permutations on the residuals under a reduced model, a) abundance and b) biomass. P was constructed by permutation and also a Monte Carlo test, both procedures yielded the same results.

Source	df	SS	MS	Pseudo-F	P
a)					
Site	6	35700	5949.9	12.849	0.001
Survey	2	11524	5762	12.443	0.001
Site x Survey	12	16067	1338.9	2.8914	0.001
Residuals	41	18985	463.05		
Total	61	82039			
b)					
Site	6	36269	6044.9	7.8928	0.001
Survey	2	9044.8	4522.4	5.9049	0.001
Site x Survey	12	18525	1543.7	2.0157	0.001
Residuals	41	31401	765.87		
Total	61	95351			

Table 3.7. Discriminating species for each site and sampling period based on abundance (○) and biomass (●), determined from the SIMPER analysis, where Diss/SD > 2, $r^2 > 0.8$. [1]all species are in higher abundance in the indicated group except where indicated, [2]abundance is higher in this group, *Species are in equal abundance in both groups so not able to discriminate between them. Groups not listed had no species fitting the criteria used.

Indicator Species	OWA[1] vs. RSA	GIN[1] vs. OWA	GIN[1] vs. RSA	GIN[1] vs. GIS[2]	GIN[1] vs. JVB	GIN[1] vs. JPT[2]	GIN[1] vs. MGB[2]	GIS[2] vs. OWA[1]	GIS vs. RSA[1]	GIS[1] vs. JVB[2]	GIS[1] vs. JPT	GIS[1] vs. MGB	JVB[2] vs. OWA[1]	JVB[2] vs. RSA[1]	JVB[2] vs. MGB[1]	JPT[2] vs. OWA[1]	JPT[1] vs. JVB[2]	JPT vs. MGB[1]	MGB[2] vs. OWA[1]	MGB vs. RSA[1]	April/May[1] vs. Oct/Dec	Oct/Dec vs. Feb.[1]
<u>Phylum Porifera</u>																						
Holopsamma sp. C1		●○	●○	●○	●	●	●○															
<u>Phylum Arthropoda</u>																						
Belosquilla laevis						●○[2]	●○[2]	●[2]							●	●[2]	●		●○[2]			
Melicertus latisulcatus					●○			●[2]		●○	○*		●○	●○	●○		●○					
Portunus pelagicus		○					●[2]						●[2]									
Portunus rugosus		○				●[2]							●○[2]								○	
<u>Phylum Mollusca</u>																						
Sepia novaehollandiae		○																				●
Sepioteuthis australis															●○[2]		●[2]		●○			
<u>Phylum Echinodermata</u>																						
Cercodema anceps						●																
Colochirus quadrangularis				○[2]	●○		●○															
Luidia australiae					●*○		●															
Stellaster inspinosus				○				●○					●○			●○			●○			
<u>Phylum Chordata</u>																						
Anoplocapros amygdaloides	●○							●		●[2]				●[2]					●○			
Apogon rueppellii								○*		●					●○				○[2]			
Heterodontus portusjacksoni								●											●○			
Inegocia japonica		●			●○									●○	●○			○				
Lepidotrigla papilio		●○		●○	●	●○	●○		●											●○		
Monacanthus chinensis							●															
Onigocia spinosa			●○		○	●○																
Parequula melbournensis																○						
Pegasus volitans																			○			
Pentapodus vitta					○	●○		○					○			○						
Platycephalus longispinis				○	○		○															
Pseudocalliurichthys goodladi				●○	●○		●					●○		●	●○							
Pseudocaranx wrighti		○								●○	●○	●○										
Sillago bassensis	●							●								●○						
Sillago burrus			●		●									●○								
Upeneichthys vlamingii	●○		●○			○							●○			●○			●			

3.3.4 Commercial and/or recreational species collected

Taxa from this study were identified from six phyla of which only taxa belonging to Arthropoda, Mollusca and Chordata were of commercial and/or recreational significance. Of the 216 taxa collected *ca* 13 % (*ca* 28 species from 24 families) were reported to be retained by commercial fishers from the WCB (Table 3.8). The number of species that are retained by commercial fishers in Owen Anchorage and Cockburn Sound was markedly less, with only *ca* 15 species from 13 families (Table 3.8). Those species that were not reported as being retained by commercial fishers in Owen Anchorage and Cockburn Sound were two species of Penaeidae (prawns, including western king prawn *Melicertus latisulcatus*), Ballot's saucer scallop *Amusium balloti*, western butterfish *Pentapodus vitta* and species belonging to the families Rhinobatidae (guitarfishes), Atherinidae (hardyheads), Triglidae (sea robins and gurnards), Platycephalidae (flatheads), Mullidae (goatfishes), Sillaginidae (whitings) and Bothidae (lefteye flounders).

In the WCB, recreational fishers were reported to retain a slightly higher number of species than commercial fishers, which is *ca* 14 % (*ca* 30 species from 24 families, Table 3.8) of the 216 taxa collected from this study. The numbers of species retained by recreational fishers in Owen Anchorage and Cockburn Sound were slightly less than that of the WCB with the differences being Australian pilchard *Sardinops neopilchardus*, bighead gurnard perch *Neosebastes pandus* and the family Bothidae (Table 3.8).

Table 3.11. List of all species caught with their retention by commercial and recreational fishers in the West Coast Bioregion (WCB) and Cockburn Sound (CS) and Owen Anchorage (OA) noted (•). [1] from compulsory catch statistics provided by commercial fishers to the Department of Fisheries. [2] Sumner *et al.* 2008. [3] from a boat-based recreational fishing survey by the Department of Fisheries (Sumner *et al.* unpub.).

Taxa	Commercial		Recreational	
	WCB[1]	CS & OA[1]	WCB[2,3]	CS & OA[3]
Arthropoda, SubPhylum Crustacea				
Malacostraca				
Decapoda				
Penaeidae				
Metapenaeopsis spp.	•			
Melicertus latisulcatus	•			
Portunidae				
Portunus pelagicus	•	•	•	•
Mollusca				
Bivalvia				
Ostreoida				
Pectinidae				
Amusium balloti	•			
Cephalopoda				
Octopoda				
Octopodidae				
?*Grimpella sp.*				
Hapalochlaena sp.				
Octopus sp.	•	•	•	•
Sepiida				
Sepiidae	•	•	•	•
Sepia apama				
Teuthida				
Loliginidae				
Sepioteuthis australis	•	•	•	•
Chordata				
Pisces				
Rhinobatiformes				
Rhinobatidae	•		•	•
Aptychotrema vincentiana				
Trygonorrhina fasciata				
Rajiformes				
Urolophidae			•	•
Trygonoptera mucosa				
Trygonoptera testacea				
Urolophus paucimaculatus				
Myliobatidae				
Myliobatis australis	•	•	•	•
Clupeiformes				
Clupeidae				
Sardinops neopilchardus	•	•	•	
Spratelloides robustus	•	•		
Engraulidae				
Engraulis australis	•	•		
Beloniformes				
Hemiramphidae			•	•
Hyporhamphus melanochir	•	•	•	•
Atheriniformes				
Atherinidae	•			
Atherinomorus vaigiensis				

Table 3.11. Continued.

Taxa	Commercial		Recreational	
	WCB[1]	CS & OA[1]	WCB[2,3]	CS & OA[3]
Scorpaeniformes				
Triglidae	●		●	●
Chelidonichthys kumu				
Lepidotrigla papilio				
Neosebastidae				
Maxillicosta scabriceps				
Neosebastes pandus			●	
Platycephalidae	●		●	●
Inegocia japonica				
Onigocia spinosa				
Platycephalus endrachtensis				●
Platycephalus longispinis				
Platycephalus speculator				●
Perciformes				
Carangidae	●			
Pseudocaranx georgianus	●		●	●
Pseudocaranx wrighti			●	●
Seriola hippos	●	●	●	●
Trachurus novaezelandiae	●	●	●	●
Labridae	●		●	●
Notolabrus parilus			●	●
Mullidae	●		●	●
Upeneichthys vlamingii				●
Upeneus asymmetricus				
Upeneus spp.				
Upeneus tragula				
Nemipteridae				
Pentapodus vitta	●		●	●
Pomatomidae				
Pomatomus saltatrix	●	●	●	●
Sillaginidae	●		●	●
Sillago bassensis			●	●
Sillago burrus			●	●
Sillago vittata			●	●
Sparidae				
Pagrus auratus	●	●	●	●
Terapontidae	●	●	●	●
Pelates octolineatus			●	●
Pelsartia humeralis			●	●
Pleuronectiformes				
Bothidae	●		●	
Arnoglossus spp.				
Paralichthyidae				
Pseudorhombus jenynsii			●	●
Pleuronectidae			●	
Ammotretis elongatus			●	●
Tetraodontiformes				
Monacanthidae	●	●	●	●
Acanthaluteres spilomelanurus				
Acanthaluteres vittiger				●
Brachaluteres jacksonianus				
Eubalichthys mosaicus				
Monacanthus chinensis				
Scobinichthys granulatus				●

3.3.5 Blue swimmer crab

Site selection of blue swimmer crab

A temporal comparison of the abundance of all blue swimmer crabs sampled from seven sites in Cockburn Sound is presented in Figures 3.9 & 3.10. Blue swimmer crabs were found at all sites sampled throughout 2007 and 2008. Their numbers were relatively similar between sampling times, although numbers increased significantly in April 2008. Overall, the sites where the highest numbers of crabs were recorded included Jervois Bay, James Point and Mangles Bay, whereas very few crabs were recorded at Owen Anchorage.

Separation of blue swimmer crabs into recruits (0+) and residuals (≥ 1+, Fig. 3.8) revealed trends in abundance that were not previously apparent. The abundance of recruits were significantly different between sites ($F_{(6,12)} = 3.37$; $p = 0.035$) with recruit numbers highest at James Point, Jervois Bay and Mangles Bay (least squared means 0.022, 0.020 and 0.019, respectively). Recruit numbers differed significantly between 2007 and 2008 ($F_{(1,12)} = 16.69$; $p = 0.002$) with numbers significantly higher in 2008. There was no significant interaction between year and site indicating that numbers of recruits were consistently higher at specific sites, *i.e.* James Point, Jervois Bay and Mangles Bay, irrespective of year. No recruits were sampled in October/ December 2007 but this was most likely due to the trawl gear on the *RV Naturaliste* being unable to sample recent recruits for that season (females spawn in September/October).

There was a significant site*year interaction for the abundance of residuals ($F_{(6,12)} = 4.72$; $p = 0.01$), where in 2007, sites with the highest numbers of residuals included the Research Area, Garden Island South, and Mangles Bay, whereas in 2008, the highest numbers of residuals were found at Jervois Bay, James Point and Mangles Bay which are the areas with high abundance of recruits as well.

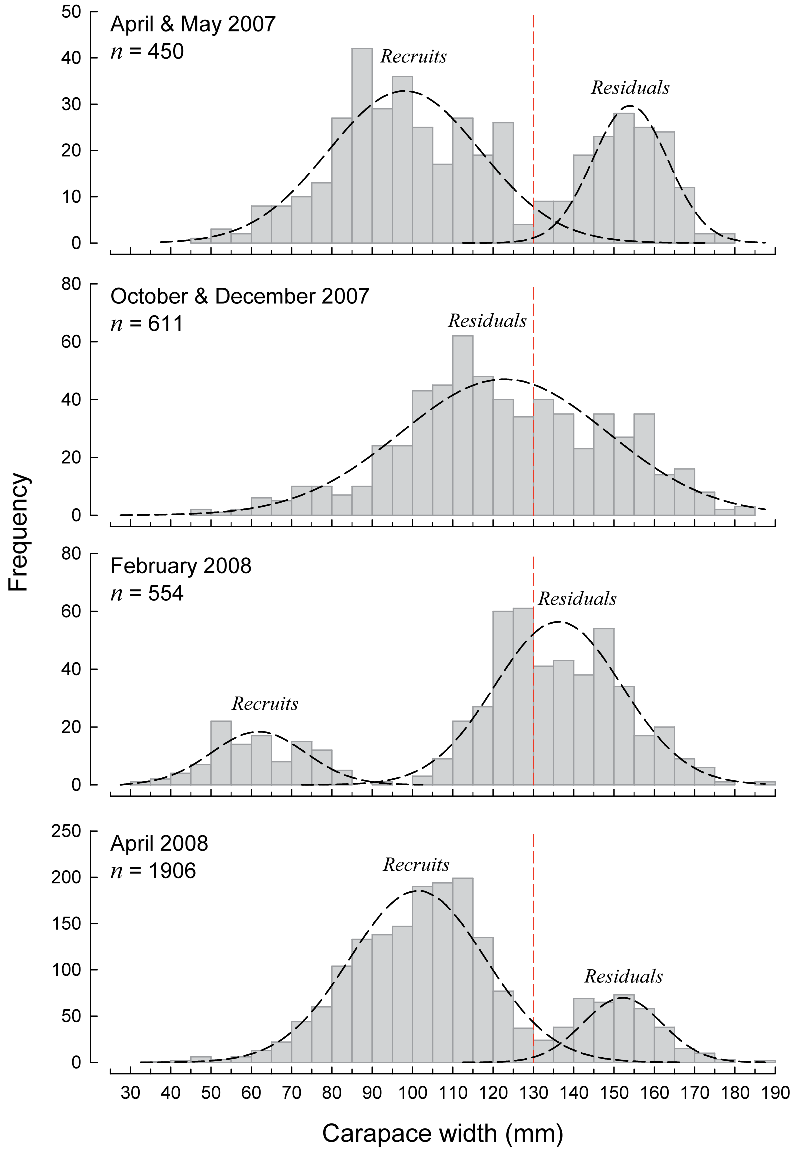

Figure 3.8. Length frequency histograms of blue swimmer crabs (grey bars) fitted with expected frequency distributions plots using Schnute & Fournier (black dashed line, 1980), to determine recruit (0+) and residual (≥ 1+) modal classes. The dashed red lines represent the size limit for commercial fishers of 130 mm carapace width.

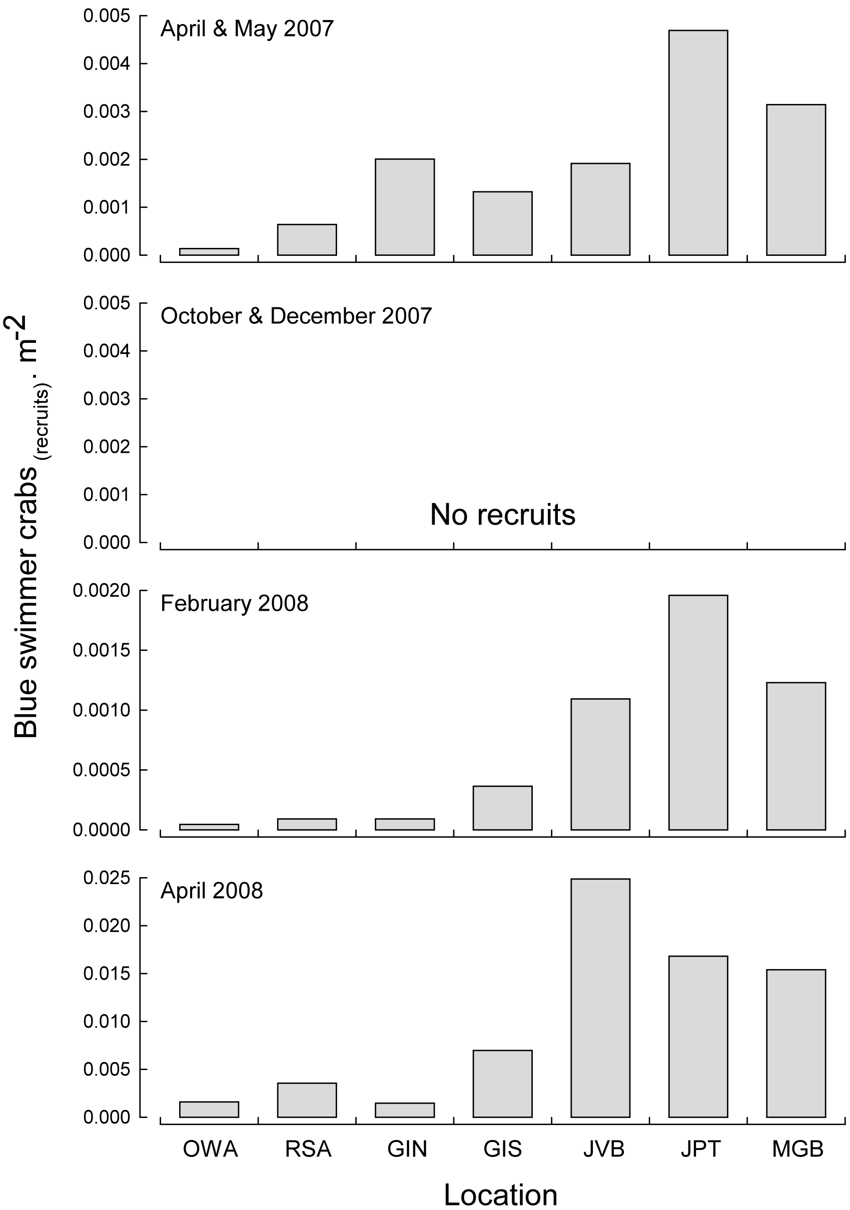

Figure 3.9. Numbers of recruitment (0+) blue swimmer crabs per m^2 for each location during the four survey periods. OWA, Owen Anchorage; RSA, Research Area; GIN, Garden Island North; GIS Garden Island South; JVB, Jervois Bay; JPT, James Point; MGB, Mangles Bay.

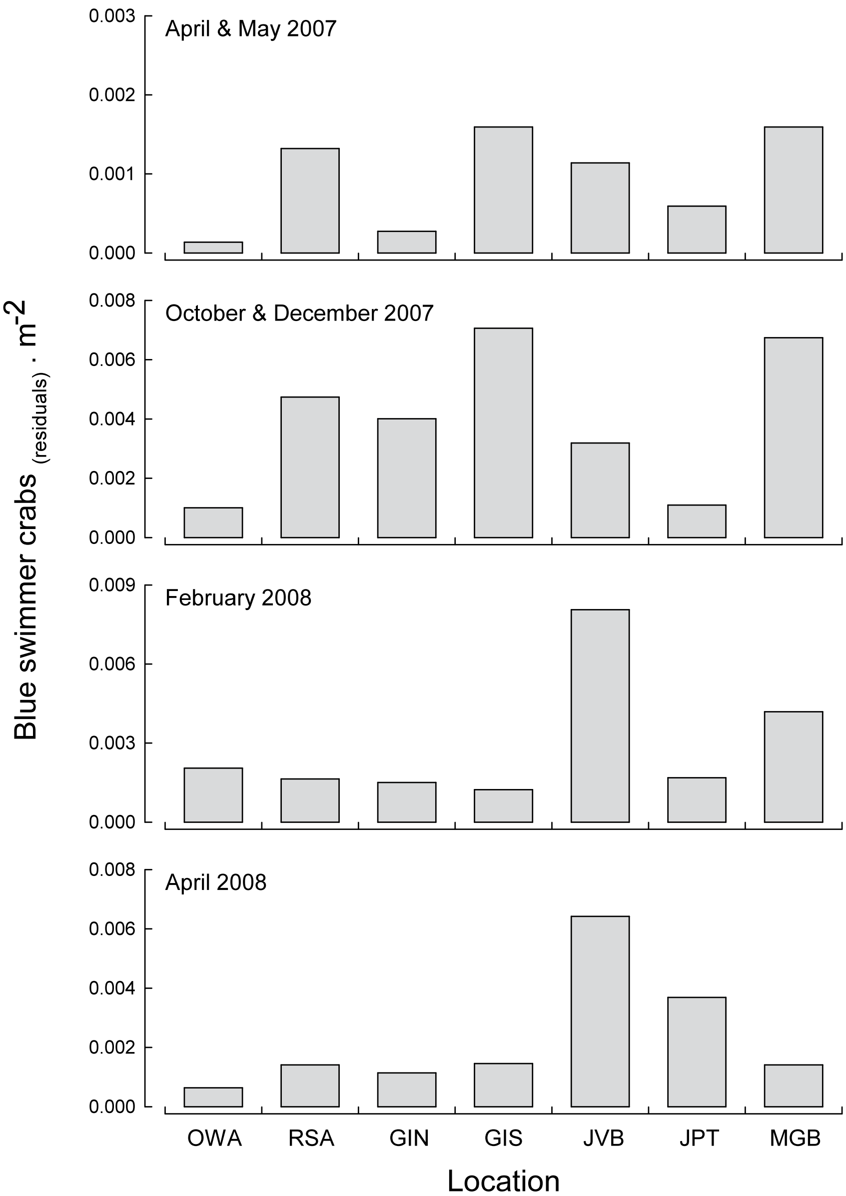

Figure 3.10. Numbers of residual (≥ 1+) blue swimmer crabs per m^2 for each location during the four survey periods. OWA, Owen Anchorage; RSA, Research Area; GIN, Garden Island North; GIS Garden Island South; JVB, Jervois Bay; JPT, James Point; MGB, Mangles Bay.

3.3.6 Snapper

The numbers of snapper caught in the April/May and October/December trawl surveys in 2007 were markedly lower than those in the February and April surveys in 2008 (Fig. 3.11). The sizes of snapper in each sampling period displayed a unimodal distribution. Snapper caught in the April/May survey in 2007 ranged in size between 75 and 116 mm FL with a mean of 98 mm FL (*NB* mean lengths have been adjusted for the selectivity of the trawl gear). The snapper caught during the following survey approximately six months later in October/December 2007, were much smaller ranging from 43 to 75 mm FL with a mean size of 57 mm FL. The sizes of the snapper in the next two surveys increased progressively in size with means of 75 mm FL (ranging from 47 to 130 mm FL) and 100 mm FL (ranging from 70 to 130 mm FL) in February and April 2008, respectively. Thus, the mean size for snapper was the same for both surveys in April 2007 and 2008.

There was a significant difference between the abundances of snapper at each site, sampling period and the interaction between site and sampling period ($p < 0.001$, Fig. 3.12). The only site where snapper were caught in each survey was James Point (Fig. 3.11). In the surveys in 2007, when the numbers of snapper caught were markedly lower, the sites that had the highest catches were James Point and Jervois Bay. In the February and April surveys in 2008, when the numbers of snapper caught were significantly higher, the numbers of snapper at Garden Island North and James Point consistently had the highest catches. In contrast, Garden Island South and Jervois Bay consistently had the lowest catches. The numbers of snapper caught at the remaining three sites during the 2008 surveys, *i.e.* Owen Anchorage, Research Area and Mangles Bay, varied greatly within this two-month period (Fig. 3.12). This suggests that the distribution of snapper may vary temporally within Cockburn Sound and Owen Anchorage and would need further investigation.

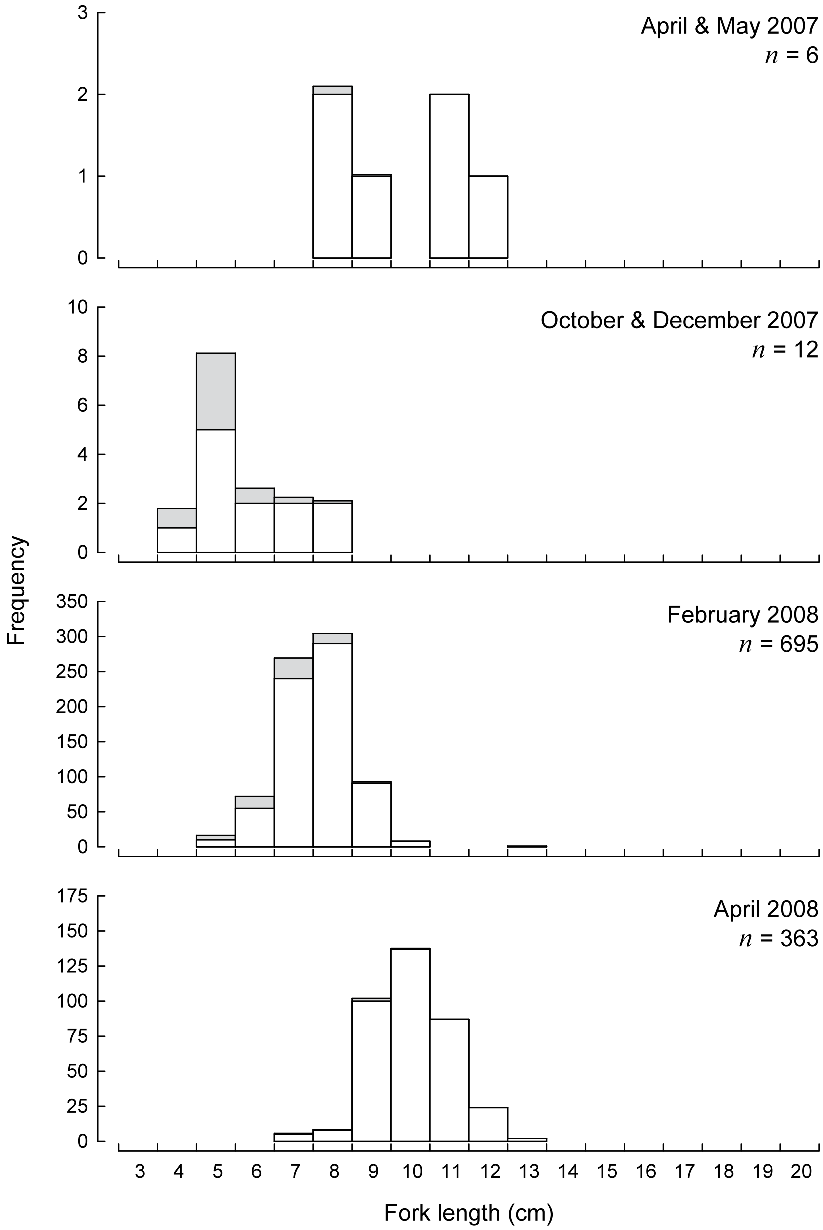

Figure 3.11. Frequency histograms of the number of snapper caught (observed, white bars) for each 1 cm size class from each survey period (sample sizes shown). Grey bars represent frequencies adjusted to allow for the selectivity of the sample gear calculated for each sequential 1 cm size class (Table 3.10, Wakefield *et al.* 2007).

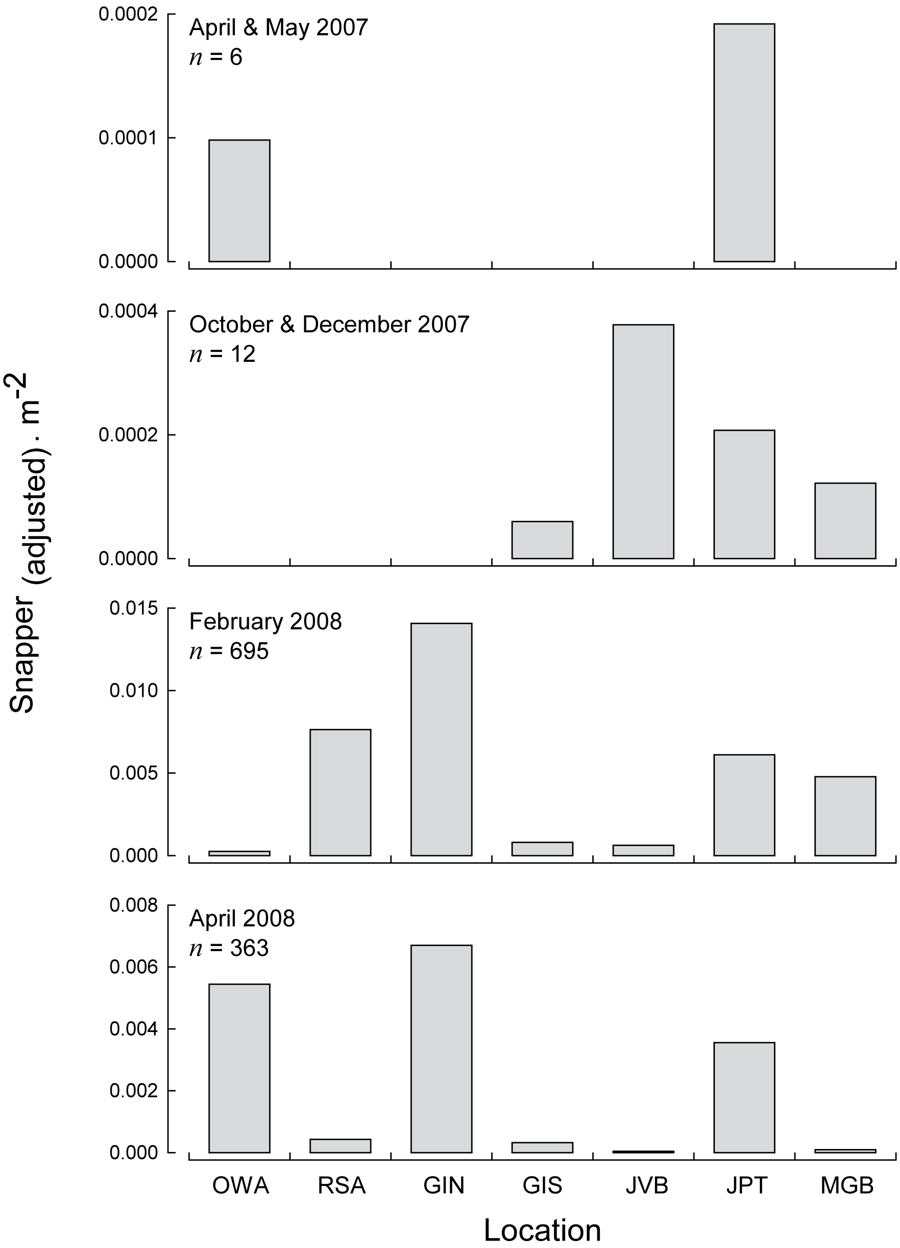

Figure 3.12. Numbers of snapper per m^2 adjusted for each 1 cm size class to allow for selectivity of sampling gear (Table 3.10, Wakefield *et al.* 2007) and pooled for each location during the four survey periods. OWA, Owen Anchorage; RSA, Research Area; GIN, Garden Island North; GIS Garden Island South; JVB, Jervois Bay; JPT, James Point; MGB, Mangles Bay.

3.4 Discussion

3.4.1 Community structure

Most of the 216 taxa found in this study were either previously known from Cockburn Sound and Owen Anchorage or they were within their known geographic range in Western Australia. The three exceptions were two tropical species that require confirmation of their identification and an introduced species. Fifty-two species (24 %) were rare, *i.e.* reported at one site in one survey, and only 35 species (16 %) could be considered common, *i.e.* found at all sites in most surveys. This large component of rare species in biological faunal communities is common and has been reported from a variety of habitats and locations (Krebs 1994).

Mean abundance and biomass differed between survey times with some sites having a higher mean abundance in February 2008 and others in May 2007, and there were similar variations in biomass through time. These variations are most likely due to biological factors such as recruitment variability and/or aggregation behaviour (*e.g.* schooling) of some species resulting in clustered distributions. We found that no species was typical of a particular survey period except for the cuttlefish *Sepia novaehollandiae*, which was more abundant in February 2008 and the swimmer crab *Portunus rugosus*, which had a higher biomass in April/May 2007. As sampling in this study occurred during different seasons in 2007 and 2008, interannular variation in the seasonal composition of the community structure could not be determined. It would be important for future surveys to compare results from previous surveys undertaken at the same time of year to account for possible differences in abundance and biomass as a result of population variation due to seasonality.

Species richness and community diversity varied among sites with the southernmost site at Mangles Bay (MGB) having the lowest diversity (27 species) and two of the northernmost sites GIN and OWA, having the highest diversity (50 and 47 species, respectively). Owen Anchorage (OWA) also had the highest evenness value suggesting that this site was more diverse than the other sites, *i.e.* consisting of more species with similar abundances. The factors responsible for these differences are unknown and were not examined in this study, but could be related to industrial discharges that have influenced water quality in the area (Cambridge *et al.* 1986; Anon. 1996). Alternatively, intrinsic differences in habitat composition among the sites may have contributed to the differences seen in community structure.

Owen Anchorage (OWA) had a different trawled community compared to the other sites, mainly due to a higher number of rare species, *e.g.* sea cucumber *Cladolabes schmeltzii* (in October/December 2007), and the higher abundance of common species, *e.g.* the seastar *Stellaster inspinosus*, sea cucumber *Colochirus quadrangulatus*, bighead gurnard perch *Neosebastes pandanus* and silverbelly *Parequula melbournensis*. Owen Anchorage is subjected to fewer impacts and to a lesser extent than Cockburn Sound. Thus, the water quality of Owen Anchorage is not considered to be as compromised as Cockburn Sound (Oceanica 2007), and there is evidence of seagrass recovery at the Success and Parmelia Banks (Kendrick *et al.* 2000; Kendrick *et al.* 2002), which border Owen Anchorage to the north and south respectively. The seagrass beds at Success Bank are known to have higher species richness than adjacent bare sand areas (Brearley & Wells 1998). The close proximity of these banks to Owen Anchorage may mean species can move between seagrass and sand, and increase species diversity at this site. Larger amounts of seagrass and wrack were collected in trawls in OWA as compared to all other sites in Cockburn Sound thus supporting the suggestion that seagrass proximity could influence the species diversity at this site.

Jervois Bay (JVB) was significantly different from all other sites. This was partly due to a single trawl shot in December 2007 that collected a mixture of sponges and associated fauna, and partly due to the higher abundance of specific species at JVB compared to other sites. For example, higher abundances of the following species were found at JVB, western smooth boxfish *Anoplocapros amygdaloides* compared to GIS and RSA, southern calamari squid *Sepioteuthis australis* compared to MGB and JPT, and swimmer crabs *Portunus pelagicus* and *P. rugosus* compared to OWA. JVB was shallower than all other sites sampled and had some hard substrate associated with it that provided attachments for sponges and ascidians, which were not found as extensively at the other sites. Earlier studies within Cockburn Sound identified five main benthic habitats or biotypes, including 1) peripheral sills, spits and banks, 2) the central Basin, 3) slopes, 4) hard substrates and 5) the NE shelf (Devaney 1978; Marsh 1978a; Marsh 1978b; Wells 1978; Wilson *et al.* 1978; Wells & Threlfall 1980); each of these biotypes had a distinguishing faunal assemblage. Five of the sites sampled in Cockburn Sound in this study were located in the central basin biotype (*i.e.* RSA, GIN, GIS, JPT & MGB), whereas JVB was located within the NE shelf biotype.

The seastar *Stellaster inspinosus* previously had a more widespread distribution and was common throughout the Sound during surveys in the 1950s and 1970s when it was found at JPT (1950s) and GIS (1950s and 1970s) (Marsh 1978b), but was absent from these sites during the current study. This may indicate altered substrate and or water quality at these latter sites as the species is a deposit feeder. However, seastars are known to have variable recruitment and longer term monitoring would be required to ascertain if the current absence of this species at the southernmost sites was due either to poor recruitment in recent years or a decline in the population due to anthropogenic induced changes to the ecosystem.

Biomass patterns were heavily influenced by the occasional presence of single large individuals such as the smooth stingray *Dasyatis brevicaudata* at GIN in one tow (*ca* 150 kg). Multivariate analyses indicated that abundance was a better discriminator of the differences among sites and surveys in community composition than biomass. Analysis comparing biomass and abundance simultaneously, *e.g.* abundance-biomass comparison curves (ABC, Warwick & Clarke 1994), can provide valuable information about a community and provide insights into their corresponding environmental health, and would be a useful analysis to undertake on this data.

In summary, the findings from the univariate and multivariate analyses supported each other and highlighted some characteristic features of the community composition at various sites. In general, the sites differed from each other with a gradient in community composition from higher diversity and evenness in the north at Owen Anchorage (OWA) than the south at Mangles Bay (MGB), where the community was dominated by a few species. A west to east gradient was also present, although this was largely determined by the differences in the community composition at Jervois Bay (JVB), compared to the other sites sampled.

3.4.2 Commercial and/or recreational species collected

The differences in the lists of species that are retained by commercial fishers between the WCB and Owen Anchorage and Cockburn Sound are representative of the commercial fisheries that operate in the two areas. The fisheries (and their main target species) that operate in the waters of Owen Anchorage and Cockburn Sound include the West Coast Purse Seine Fishery (targeting mainly Clupeidae (herrings & ilishas) including the Australian sardine *Sardinops neopilchardus*), Cockburn Sound Fish Net Fishery (mainly Australian herring *Arripis georgianus* and southern garfish *Hyporhamphus melanochir*), Cockburn Sound Line and Pot Fishery (including blue swimmer crab *Portunus pelagicus*, snapper *Pagrus auratus*, octopus, squid and various skates and rays Rhinobatidae and Myliobatidae) and the West Coast Beach Bait Fishery (mostly sandy sprat *Hyperlophus vittatus*). The two main differences between the two lists of species retained by commercial fishers are due to 1) the permanent closure to trawling in Owen Anchorage and Cockburn Sound resulting in no commercial fishing exploitation of Penaeidae (including western king prawns) and Ballot's saucer scallop *Amusium balloti* and 2) the West Coast Estuarine Fishery that only operates in the Swan/Canning and Peel/Harvey estuaries, *ca* 20 km north and *ca* 50 km south of Cockburn Sound, respectively, despite some of the main target species of this fishery also occurring in Owen Anchorage and Cockburn Sound.

In contrast to the commercially retained species, the species that were caught in this study that are retained by recreational fishers were very similar between the WCB and Owen Anchorage and Cockburn Sound. This is due to no permanent spatial closures for these species (only seasonal for some species) for recreational fishers. Cockburn Sound represents a very popular recreational fishing area within the West Coast Bioregion. In 1996/97, Cockburn Sound and Owen Anchorage had the second highest level of fishing effort in the West Coast Bioregion (Sumner & Williamson 1999). The area with the highest level of fishing effort in that study was adjacent to Hillarys marina. In 2005/06, Cockburn Sound and Owen Anchorage remained one of the most intensely fished areas in the WCB, with the fishing effort estimated to be between 10,000-100,000 boat-based fishing hours per year (Sumner *et al.* 2008).

3.4.3 Blue swimmer crab

A significant increase in the abundance of blue swimmer crab recruits in 2008, compared to 2007, was most likely due to greater recruitment success on account of higher numbers of spawning stock and better environmental conditions. The Cockburn Sound blue swimmer crab fishery was closed to all fishing in December 2006 due to a significant decline in stock levels in preceding years. Recovery of this fishery has been relatively slow with crab recruitment in 2007 very poor due to the very low levels of spawning stock in 2006. However, in the absence of fishing for two years, spawning stock levels in 2007 increased resulting in an improvement in recruitment in 2008. This trend is demonstrated by the significant increase in recruit numbers between 2007 and 2008. Interestingly, there was no significant difference in the abundance of residuals (1+) between 2007 and 2008, suggesting that recovery of juveniles and sub-adults has been slow.

Trends in recruit (0+) abundance have revealed that Mangles Bay, James Point and Jervois Bay are the best recruitment sites sampled in this study. Lack of an interaction between year and site further confirms that these sites in Cockburn Sound are consistently important recruitment areas irrespective of year. However, further validation of this interannual trend is needed using longer-term datasets. Nevertheless, anecdotal evidence has suggested that these areas may drive the recruitment of blue swimmer crabs in Cockburn Sound. Hence sampling regimes targeting recruits in Cockburn Sound should incorporate Mangles Bay, Jervois Bay and James Point to accurately represent this proportion of the crab population.

Site analysis of residuals has revealed that sub-adult (1+) blue swimmer crabs are located throughout Cockburn Sound and do not appear to favour specific areas between years. It is likely that these crabs are transitory and migrate from defined recruitment areas throughout all areas of the Sound. Consequently, future sampling regimes need to include a wide range of sites per year to accurately represent the numbers of residual crabs in the population. Longer-term datasets would be useful in further validating these trends.

3.4.4 Snapper

The unimodal size distribution of snapper in each survey corresponded to the sizes expected of 0+ aged snapper (Lenanton 1974; Wakefield 2006; Wakefield *et al.* 2007). The smallest 0+ snapper were caught during the October/December survey in 2007. This survey coincided with the spawning period of snapper in Cockburn Sound that occurs between September and January each year (Wakefield 2006). Snapper eggs are pelagic and take approximately 24 to 36 hours to hatch depending on water temperature (McGlennon 2004). The snapper larvae then remain pelagic for approximately 17 to 31 days before transitioning to demersal juveniles at a length less than 20 mm (Neira *et al.* 1998). Thus, the fish collected in October/December were most likely progeny from spawning that occurred early in the 2007 spawning period. It is also likely that the majority of early post-settled juvenile snapper were too small for capture by the trawl gear during this period. This would also explain why the numbers of 0+ snapper caught in the October/December survey were markedly lower than those of the February and April surveys for the same cohort. The contrasting abundances of snapper collected in the trawls in 2008 with those of 2007 and historic data (see Section 4.0) suggests that the spawning of snapper in this area in spring/summer in 2007 was highly successful and may have resulted in a strong recruitment year for this population.

The modal size distribution of 0+ snapper from each survey facilitated the estimates of growth of this cohort during this period. The mean size of 0+ age snapper increased by *ca* 18 mm FL between the October/December 2007 and February 2008 surveys, and a further 25 mm FL by the April 2008 survey. Therefore, these juveniles were growing at an overall rate of *ca* 10.8 mm per month over approximately their first four months of life. It is difficult to compare these growth rates of snapper in Cockburn Sound with those found by Lenanton (1974) as the first appearance of 0+ snapper was in April in that study, despite sampling occurring over all calendar months using the same mesh size for the trawl nets as this study. However, the mean size of 0+ snapper in April 1974, from this earlier study, was similar at eight to nine cm FL to that in April 2007 and 2008, from this study.

Snapper were found to occur, without any obvious preference, at all seven sites in Owen Anchorage and Cockburn Sound at various abundances independent of the sampling period. The only site to yield snapper for every sampling period was James Point. There were similarities in the abundances of snapper for some sites between the February and April 2008 surveys, but they were not consistent with the two surveys in 2007. This may suggest there is interannual variation in the temporal and spatial distribution of 0+ snapper, which in this instance, could be a reflection of poor and strong recruitment years. Alternatively, these differences could reflect that the home range of 0+ snapper is extensive in Owen Anchorage and Cockburn Sound, with possibly some connectivity between the two locations.

The substrate at each of the seven sites was predominantly soft sediment (typically silt), which has been found to be the preferred habitat for juvenile snapper that are less than two years of age, at numerous locations in Australia and New Zealand (*e.g.* Francis & Williams 1995; Thrush *et al.* 2002; Fowler & Jennings 2003; Sumpton & Jackson 2005; Wakefield *et al.* 2007). At approximately 18 to 24 months of age snapper are thought to move from areas of predominantly soft sediment to areas closer to reef margins (Moran & Kangas 2003; Wakefield *et al.* 2007). Snapper older than approximately six months were not caught during this study. This was surprising considering Lenanton (1974) found snapper to remain in this area for the first 14 months of their lives. However, their absence may be related to the low abundance of the 0+ age cohort sampled in the April/May 2007 survey, which would have been approximately 15 and 17 months old in the surveys in February and April 2008, respectively.

4.0 Objective 2

C. Wakefield, D. Johnston and D. Harris

Objective 2. Assess changes in the distribution and abundance of blue swimmer crab and snapper by comparison with the Department of Fisheries long-term data set.

4.1 Introduction

The Department of Fisheries has been conducting trawl surveys in Cockburn Sound since the early 1970s (Penn 1975; Penn 1977). The location of these trawl surveys, termed the 'Research Area' by Lenanton (Fig. 1, 1974), is situated in the deeper waters (*ca* 19 m) towards the north end of Cockburn Sound and has remained consistent over the years. However, data on blue swimmer crabs and snapper have only been collected since February 2000, except for that published for snapper from trawls conducted in 1971 and 1972 (Lenanton 1974).

These historic trawls were always *ca* 20 minutes and *ca* 1 nm in duration. Due to the potential range and density of invertebrate species collected during this study it was concluded that 20-minute shots would require a prohibitive timeframe to process and thus were not feasible for a biodiversity study (Kangas *et al.* 2007). It was also important to assess multiple locations within the Sound to examine the distribution of faunal species and identify 'representative' sites for future studies. Therefore, replicated 20-minute trawls at multiple sites would have been logistically difficult in terms of the time that was available for each night of sampling. It was considered that 5-minute trawls would be more appropriate, however, it was unknown whether this time period would provide representative data on blue swimmer crab and snapper abundance and size distributions. Consequently, the abundance and size distributions of crabs collected in three 5-minute trawls were compared to two 20-minute trawls at the RSA site in April 2007 to assess whether 5-minute trawls were an acceptable sampling regime for blue swimmer crabs and snapper. This would also facilitate the comparisons of catch rates from this study with historic trawls to identify any changes in abundance.

Originally the objective for this part of the research was to assess changes in distribution, as well as abundance, from the Department of Fisheries long-term data set. This was not possible, as previous trawling by the Department of Fisheries has only occurred in the Research area. However, the greater number of locations sampled in this study can be used to determine an appropriate spatial scale for future surveys to obtain more useful estimates of, for example, catch rates and natural mortality, that are more representative of the home ranges of blue swimmer crabs and juvenile snapper.

4.2 Methods

4.2.1 Trawl sampling

There have been a total of 12 trawl surveys, in addition to those from this study, over a period of approximately eight years, *i.e.* from February 2000 to April 2008, with at least one survey per year (Table 4.1). The trawl surveys during this period have consisted of between four and eight 20-minute trawls (Table 4.1). The fishing gear used during all trawls has remained constant and is identical to that described in Section 2.1.

Table 4.1. Description of trawl surveys conducted by the Department of Fisheries between February 2000 and April 2008 in the Research Area (RSA) of Cockburn Sound.

Date	Number of trawls	Trawl Duration (mins)
Feb 00	8	20
May 01	4	20
Feb 02	4	20
Feb 03	4	20
Apr 03	5	20
Jul 03	4	20
Feb 04	4	20
Sep 04	5	20
Dec 04	5	20
Dec 05	5	20
May 06	5	20
Nov 06	5	20
Apr 07*	3, 2	5, 20
Dec 07*	3	5
Feb 08*	3	5
Apr 08*	3	5

* Trawl surveys from the current study

4.2.2 Data analysis

Blue swimmer crab

The analysis of modality relating to age cohorts for blue swimmer crabs is outlined in Section 3.2.1. To compare the abundances of blue swimmer crabs from trawls in this study with those from previous years, the differences in abundances of recruits and residuals between five and twenty minute trawls needed to be assessed. During the trawl survey in April 2007 two additional 20-minute trawl shots were added at the RSA site (Fig. 1, Tables 2.1 & 4.1). Only abundances of blue swimmer crabs were compared as insufficient numbers of snapper were caught. Blue swimmer crabs caught in the three 5-minute and two 20-minute trawls were pooled to provide a more robust sample size. The mean catch rates of recruit and residual cohorts were compared, with 5-minute trawls expected to yield abundances *ca* 25 % less than that of 20-minute trawls.

Comparison of blue swimmer crab data from this study with the Department of Fisheries historic data was only possible for the RSA site, as this was the only site sampled historically from May 2001 through to April 2008.

While mature blue swimmer crabs at the RSA site are susceptible to capture by the trawl gear throughout the year, juvenile blue swimmer crabs can only be reliably sampled in this area from April to October. Mature females spawn in Cockburn Sound between September and January. Before April, the juveniles are either too small to be captured in the 2-inch mesh of the cod-ends or have yet to recruit to the RSA site from nursery grounds. By November, the recruits are approximately 12 months old and form part of the residual stock. Consequently, data from surveys carried out in February and December 2004, December 2005, November 2006 and December 2007 were not analysed for recruit abundance. Analysis of data from surveys in February 2002 and 2008, however, produced a distinct and unambiguous recruit mode so these samples have been included. It should nevertheless be noted that these data points are likely to underestimate the overall juvenile abundance for that year, as can be seen by the February and April data points in 2008.

Snapper

The fork lengths of juvenile (0+) snapper caught from each trawl were categorised into sequential 1 cm size classes and their numbers were adjusted to allow for the selectivity of the fishing gear according to Wakefield *et al.* (Table 4.2, 2007). The catch rate for each trawl was calculated as the adjusted number of snapper per m^{-2}. Changes in the abundance of juvenile snapper were analysed from the average catch rates (± 1 SE) for each survey from February 2000 to April 2008, for only those sites that were within the 'Research Area' (RSA, Fig.1.1). However, to facilitate the comparisons of sampling over a wider area of Cockburn Sound, the average catch rates for those surveys from this current study were estimated using all trawl shots from the seven locations sampled.

Estimates of the rate of natural mortality (M.year^{-1}) were obtained and compared from regression analysis of the natural logarithms of the catch rates of juvenile (0+) snapper from the RSA site and all sites combined from the surveys in February and April 2008.

4.3 Results

4.3.1 Blue swimmer crab

20-minute *vs.* 5-minute trawls

A comparison of the numbers of crabs collected in 5-minute versus 20-minute trawls at the RSA site is presented in Table 4.3. The mean abundance of crab recruits and residuals sampled during the 5-minute trawls were 20 % and 27 %, respectively, of the numbers of recruits and residual crabs collected during 20-minute trawls (Table 4.3). The combined mean number of blue swimmer crabs collected during the 5-minute trawls was 25 % of numbers collected during 20-minute trawls. This proportion is the same as was expected for blue swimmer crabs, given that 5-minute trawls are one quarter the length of time and distance of 20-minute trawls.

Size distributions obtained during 5-minute trawls provided significantly lower numbers of crabs compared with 20-minute trawls, with the majority of size categories not sampled (Fig. 4.1). This was particularly evident by the relatively low abundance of blue swimmer crabs less than 130 mm CW in 5-minute than 20-minute trawls.

Table 4.3. Comparison of numbers of recruit (0+, Rec.) and residual (≥ 1+, Res.) blue swimmer crabs caught in three 5-minute and two 20-minute trawls aboard the *RV Naturaliste* at the RSA site in April 2007.

	5-minute trawls			**20-minute trawls**			**Observed proportion**		
	Rec.	**Res.**	**All**	**Rec.**	**Res.**	**All**	**Rec.**	**Res.**	**All**
Trawl 1	5	16	21	20	33	53			
Trawl 2	2	7	9	26	38	64			
Trawl 3	7	6	13	-	-	-			
Mean (SD)	4.67 (2.52)	9.67 (5.51)	**14.33 (6.11)**	23.0 (4.24)	35.5 (5.45)	**58.5 (7.78)**	20 %	27 %	**25 %**
Expected proportion	5 minutes		vs.	20 minutes				**25 %**	

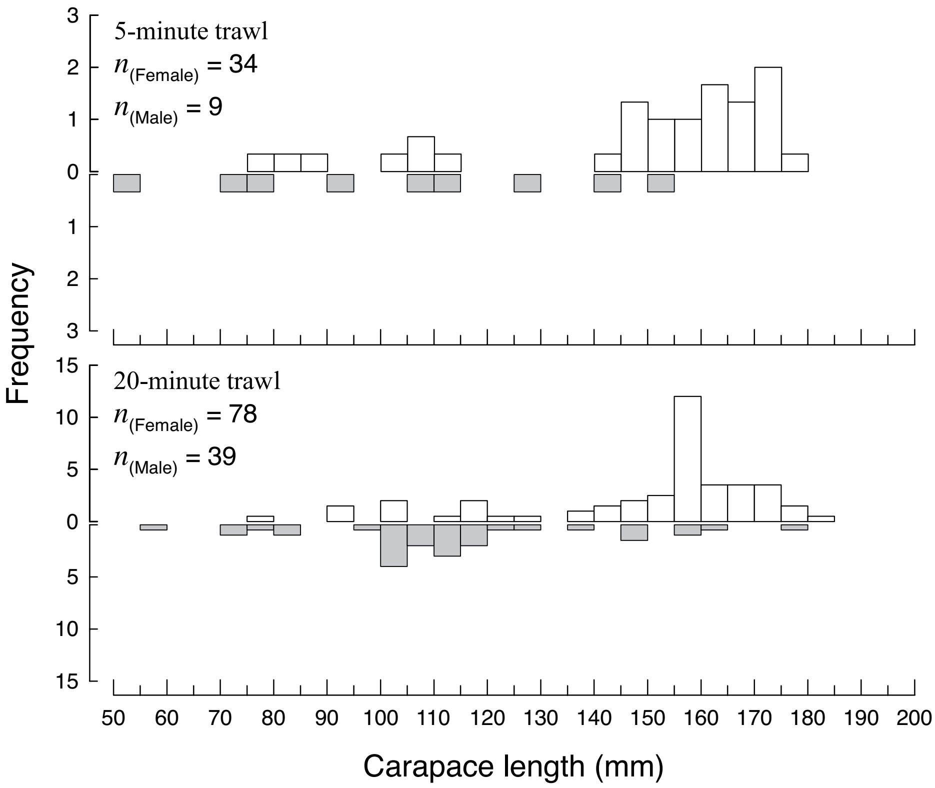

Figure 4.1. Length frequency histograms of the mean number of female (above) and male (below) blue swimmer crabs caught in three 5-minute (above) and two 20-minute (below) trawls at the Research Area (RSA, see Fig. 1.1) in April 2007.

Trends in abundance

The mean abundance of recruitment blue swimmer crabs (0+) sampled from the RSA site was relatively constant between 2001 and 2003 (Fig. 4.2). However, recruit abundance declined significantly between 2003 and 2006, with their abundance in May 2006 the lowest measured between 2001 and 2008. Recruit numbers marginally increased in April 2007 and February 2008 with a more marked improvement in numbers in May 2008. Comparison of recruit abundance between the RSA site and the three highest recruitment sites from this study, *i.e.*

James Point, Jervois Bay and Mangles Bay, revealed that recruit numbers at the RSA site are substantially lower.

A similar pattern in residual (≥ 1+) blue swimmer crab abundance is evident at the RSA site with numbers declining significantly between February 2003 and November 2006 (Fig. 4.2). Residual blue swimmer crab numbers improved marginally in April 2007 with a significant increase in December 2007. However, this point may be anomalous as residual abundance declined in 2008 to numbers similar to 2006. The comparison of residual (≥ 1+) blue swimmer crab abundances between the RSA site and all sites sampled revealed that the numbers of residuals at the RSA site are consistent with, and therefore representative of, residual abundances in Cockburn Sound.

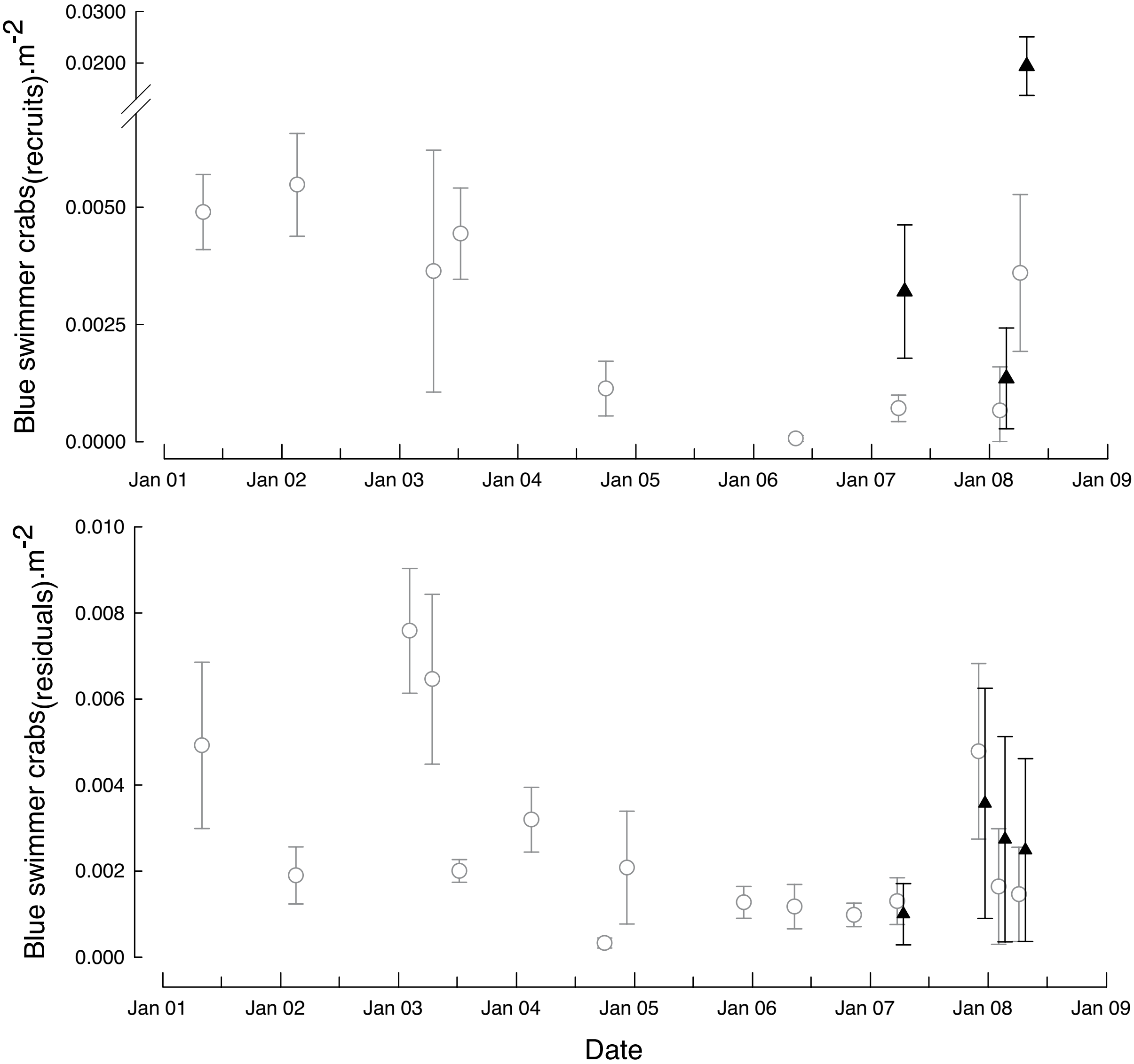

Figure 4.2. Average number of recruit (0+, above) and residual (≥ 1+, below) blue swimmer crabs per m^2 (± 1 SE), for each trawl survey from March 2001 to April 2008 in the 'Research Area' (RSA, white circles), compared with the average number of recruits from the primary recruitment sites of Mangles Bay (MGB), Jervois Bay (JVB) and James Point (JPT, black triangles, above) and the average number of residuals from all sites (black triangles, below) for each of the four trawl surveys from this study.

4.3.2 Snapper

The average catch rates of juvenile (0+) snapper (m^{-2}) were relatively low or zero for all trawl surveys with the exception of one in 2000 and two in 2008 (Fig. 4.3). The average catch rates of snapper, from trawl surveys in this current study, for the RSA site were zero in April/May and October/December 2007. They then increased to 0.0076 snapper (m^{-2}) in February 2008, which was the highest amount recorded for all trawl surveys during this period, before a precipitous decline to 0.00043 snapper (m^{-2}) in April 2008 (Fig. 4.3). In comparison, the average catch rates of the seven trawl locations combined, from this current study, were also relatively low or zero in April/May and October/December 2007. These catch rates then also increased in February 2008, to 0.005 snapper (m^{-2}), but did not decline as rapidly in the following survey, *i.e.* 0.0024 snapper (m^{-2}). This decline in catch rates from the February to April surveys in 2008 is reflected in the estimates of natural mortality (*M*) where, the estimate of *M* was much higher for the RSA trawls than all trawl locations combined, *i.e.* 94.4 %.yr^{-1} compared to 51.8 %.yr^{-1} (Fig. 4.3, inset).

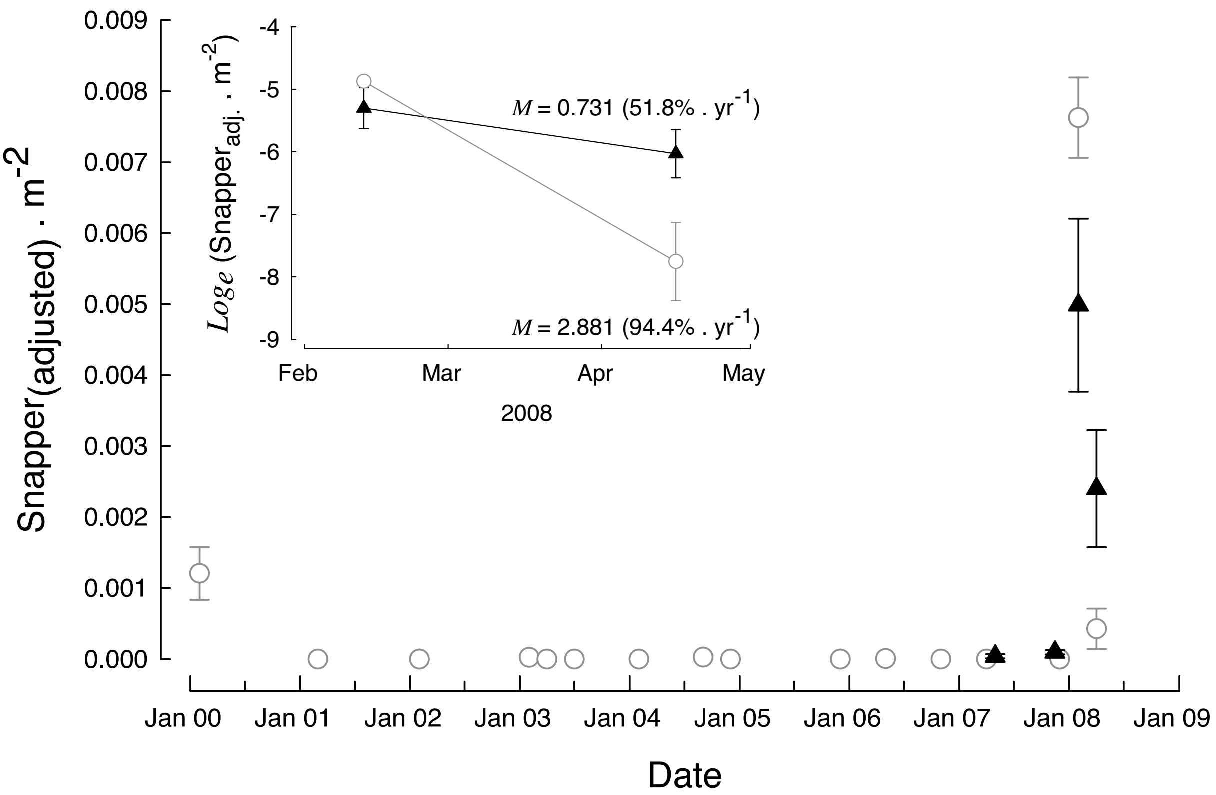

Figure 4.3. Average number of 0+ juvenile snapper per m^2 (± 1 SE), adjusted for each 1 cm size class to allow for selectivity of sampling gear (Table 4.1, Wakefield *et al.* 2007), for each trawl survey from February 2000 to April 2008 in the 'Research Area' (RSA, white circles) and all locations from this study (black triangles). **Inset**, regression of natural logarithms of the catch rates (± 1 SE) from the trawl surveys in February and April 2008, with their respective estimates of rates of natural mortality (M) shown.

4.4 Discussion

4.4.1 Blue swimmer crab

5-minute *vs.* 20-minute trawls

The overall number of recruit and residual blue swimmer crabs combined that were caught in the 5-minute trawls was one quarter (25 %) of the number caught in the 20-minute trawls. This is consistent with the expected value as the time and distances sampled were reduced by approximately three quarters. However, it should be noted that the numbers of blue swimmer crabs from 5-minute trawls were less than expected (20 %) for recruits and more than expected (27 %) for residuals. This could reflect small sample sizes or a patchy distribution resulting from the inherent aggressive behaviour between individuals. Thus, it is likely that 5-minute trawls would show more variation in catch rates.

Although the catch rates of blue swimmer crabs from 5-minute trawls was similar to the expected value, the size distribution data of males and females maybe inadequate for distinguishing modes in age. It is possible that this trend has been exacerbated by the very low levels of crabs in Cockburn Sound at present (refer introduction) and that in years where crab numbers are more typical, a 5-minute trawl may be satisfactory to obtain representative size distribution data. It is clear that future trawling programs will need to take crab stock levels into consideration when determining appropriate sampling strategies and shot lengths. Given that crabs in Cockburn Sound are currently recovering from years of very low recruitment, an acceptable compromise may be to use 10-minute trawls to achieve desired size distribution information for this species, or sampling more areas using 5-minute trawls.

Trends in abundance

Given the sporadic nature of historical sampling at the RSA site it is difficult to ascertain defined trends in recruit and residual abundance (Fig. 4.2). However, with respect to recruits, the marked overall decline in numbers from 2003 to 2006 is consistent with commercial fisheries and research data collected during this time. The slow recovery of recruits in 2007 and 2008, following the closure of the Cockburn Sound blue swimmer crab fishery in December 2006, is also apparent and reflects the overall status of the fishery at this time. Comparison of recruit abundance between the RSA site and known recruitment sites, *i.e.* James Point, Jervois Bay and Mangles Bay, confirms that recruits are less abundant at the RSA site. Consequently, conclusions on abundance based on recruitment data at the RSA site should be cautious, as it is clearly not a favoured location for juvenile crabs. This however, is less of a concern for residual crab abundance where numbers at the RSA site are similar to numbers collected elsewhere in Cockburn Sound. Numbers of residuals (1+) show a marked decline in abundance between 2003 and 2006, with recovery of residuals in 2007 and 2008 less apparent. The comparison of residual (≥ 1+) blue swimmer crab abundances between the RSA site and all study sites sampled in Cockburn Sound revealed that residual numbers at the RSA site are representative of residual abundances in Cockburn Sound. Nevertheless, given the patchy distribution of crabs it is important to sample a large number of sites to ensure that data is representative of the residual crab population. This is consistent with findings from the site analysis where, unlike recruits, residual crabs were found over a wide spatial area and did not appear to favour specific sites.

4.4.2 Snapper

As trawling for snapper in Cockburn Sound occurred in different months each year there are two factors that need to be considered that could influence their catch rates, the selectivity of the fishing gear and natural mortality. There is very little if any associated fishing mortality of juvenile snapper in this area. The selectivity of the fishing gear was accounted for by adjusting the abundances of snapper caught in each trawl with respect to their size, according to the selectivity estimates derived by Wakefield *et al.* (Table 4.2, 2007). Estimates of the rate of natural mortality were not accounted for in the catch rates of snapper; however, it was considered that a decline in catch rates of a single cohort over time would provide these estimates. As the catch rates of snapper from years of relatively poor recruitment were low or zero, estimates of natural mortality could not be obtained. However, two estimates of the rate of natural mortality of snapper were calculated from trawl surveys from February and April 2008, during a year of strong recruitment. These estimates should be treated with caution given the limited number of data points. The two estimates of natural mortality, *i.e.* 51.8 % and 94.4 % year^{-1}, were vastly different and are most likely an artefact of the spatial scale they were derived from. The larger estimate was for the trawls from the RSA site, whereas the smaller estimate was from the mean catch rate of seven locations covering a wide area of Cockburn and Warnbro Sounds. Given the small size of the RSA site, it is highly likely that snapper could move out of this area, which would result in an overestimate of natural mortality. It is thought that the sample area used to derive the smaller estimate of natural mortality is adequate given the relatively small home range of 0+ snapper (Hartill *et al.* 2003), coupled with the fact that Lenanton (1974) found them to occur in this marine embayment for at least the first 14 months of their lives. Notwithstanding this, the larger estimate of the rate of natural mortality is within the range of that found for 0+ snapper from Freycinet Estuary in Shark Bay, W.A., *i.e.* 86 % to 95 % year^{-1} (Wakefield *et al.* 2007). To improve this estimate of natural mortality of 0+ snapper in Cockburn Sound further trawl surveys should be conducted in the last half of 2008.

The catch rates of 0+ snapper from trawling in Cockburn Sound have provided some insight into the relative strength of annual recruitment. As a large majority of the catch rates since February 2000 were relatively low or zero, it appears that these estimates are not useful for comparing recruitment abundances between years. However, given the relatively higher catch rates from trawls conducted in 2000 and 2008 it does appear that these estimates may be useful in identifying years of strong recruitment of juvenile snapper. Given that the spawning period of snapper in Cockburn Sound occurs mainly between October and December (Wakefield 2006), these relatively high catch rates correspond to high levels of survival of progeny that were spawned in 1999 and 2007. Thus, the period between years of strong recruitment of snapper from Cockburn Sound may be as long as eight years.

The marked difference in the abundance between strong and poor recruitment years and the period between strong recruitment years of snapper in Cockburn Sound concurs with that found for snapper from other locations. Variations in annual recruitment have been found to range from four fold in NSW (Ferrell 2004), eight fold in New Zealand (Francis 1993; Francis *et al.* 1997) and twenty fold in South Australia (Fowler & Jennings 2003). These studies have also noted the period between years of strong recruitment is indiscriminate but may be related to water temperatures during early life (Francis 1993; Francis *et al.* 1997; Fowler & Jennings 2003).

Future trawl surveys for juvenile snapper in Cockburn Sound should consider the high rates of natural mortality, and thus be scheduled within the first few months of the calendar year to obtain the highest possible catch rates. Furthermore, to avoid extremely low or zero catch rates that are unable to provide useful values for recruitment abundance, sampling should incorporate a wider area of Cockburn Sound, such as that sampled in this current study.

5.0 Objective 3

C. Wakefield, A. Sampey, D. Johnston and J. Fromont

Objective 3. Establish a system to monitor the abundance and distribution of sub-tidal embayment faunal communities in Cockburn Sound.

5.1 Marine ecosystem targets

5.1.1 Indicator species

Long term monitoring of an entire biological community is rarely undertaken as identifying all species in a community is time consuming, expensive and requires specialised expertise. For this reason the use of indicator species is often suggested as a means to monitor the health of an ecosystem and to act as surrogates for the entire community. The identification of appropriate indicator species can be difficult and frequently requires some prior knowledge of the system to be monitored and some background information on the species that occur there. Before suitable indicator species can be identified the particular attribute of the environment to be monitored needs to be defined as this will determine what species or suite of species are chosen as indicators. For example, indicator species can be used to monitor long-term change in habitat composition or water quality.

Ideally a species needs to have a widespread distribution within the area being monitored and also to be common to ensure sufficient numbers of individuals can be counted so changes in abundance over time can be tracked. Some species that are specific to certain sites are also useful however they need to be in relatively high numbers. Rare species are of limited value as they are too easily missed and the number of replicates required to sample them effectively would be cost prohibitive. The seasonality of variations in abundance needs to be taken into account for many species so monitoring should be scheduled for certain times of the year. Both species that are targeted by commercial and recreational fishers and non-targeted species need to be included to separate the effects of changes in abundances due to natural variation, from variation due to fishing pressure. The species chosen need to capture a range of ecosystem functions such as filter feeders, scavengers, and carnivores.

Based on the analyses done to date some suggested species for ongoing monitoring that fit the above criteria are listed in Table 5.1. All these species were widespread and reasonably common and were able to discriminate between sites and times. They also include a mix of targeted and non-targeted species and a mix of ecosystem function and trophic levels.

Table 5.1. List of some possible indicator species, their trophic level and whether they are targeted by commercial and/or recreational fishers. Species were selected based on the CAP and SIMPER analyses. Snapper and blue swimmer crab are not listed, as ongoing monitoring of these species is assumed due to their importance as species targeted by fishers in the area.

Species	Taxa	Trophic Level	Targeted
Portunus rugosus	crab	detritivore	No
Belosquilla laevis	crustacean	carnivore	Yes
Metapenaeopsis spp.	prawn	carnivore/detritivore	No
Melicertus latisulcatus	prawn	carnivore/detritivore	Yes
Sepia novaehollandiae	cuttlefish	carnivore	Yes
Sepioteuthis australis	squid	carnivore	Yes
Stellaster inspinosus	seastar	detritivore	No
Anoplocapros amygdaloides	fish	omnivore	No
Lepidotrigla papilio	fish	carnivore	Possibly
Pseudocalliurichthys goodladi	fish	carnivore	No

Note, *Melicertus latisulcatus* is not targeted by commercial fishers in Cockburn Sound and Owen Anchorage.

The timeframes of the current project did not allow for all analyses that could have been done on the current dataset to be completed. An example of a potential analysis that was not undertaken is BVStep, a routine available in PRIMER, that is a forward selection backward elimination procedure that examines the entire dataset sequentially removing species to generate a subset of species that provide high correlation (assessed by the Spearman correlation coefficient, ρ) to the entire species dataset (Clarke & Warwick 2001; Mistri *et al.* 2001; Clarke & Gorley 2006). These results are then checked by plotting an MDS ordination to confirm if the patterns are similar to the entire species dataset. This objective process could have been compared with the analyses presented in this report to confirm the adequacy of the selected indicator species. The process can also be applied in conjunction with environmental data to select indicator species for specific environmental conditions.

5.1.2 Species richness and diversity

The structure of the trawled faunal community at each of the seven sites in Cockburn Sound and Owen Anchorage displayed a general decreasing trend in species richness and abundance from north to south. To a much lesser extent there was an east west gradient in the communities. This was predominately due to the community trawled at Jervois Bay (JVB), which encompassed a different habitat from all other sites. JVB was the shallowest site sampled (*ca* 10 m) and the only site located within the NE shelf biotype, compared to the five other sites in Cockburn Sound which were located in the central basin biotype (Devaney 1978; Marsh 1978a; Marsh 1978b; Wells 1978; Wilson *et al.* 1978; Wells & Threlfall 1980). This decrease in species richness from north to south has been reported previously for benthic infaunal invertebrates in Cockburn Sound (Anon. 1996).

Considerable disturbance to the benthic environment in Cockburn Sound has been reported previously (Cambridge *et al.* 1986; Cary *et al.* 1995; Anon. 1996; Walker *et al.* 2001; Kendrick *et al.* 2002). One study on the benthic infaunal invertebrate assemblages in Cockburn Sound described a gradient of increasing levels of environmental disturbance from north to south based on abundance-biomass curves (Cary *et al.* 1995; Anon. 1996). Although this current study did not specifically target benthic infaunal invertebrates and abundance-biomass curves were not included in our analysis, this would certainly be a useful approach to undertake on the existing datasets available for Cockburn Sound. This would enable us to see if the north to south trend is evident for different components of the communities (infaunal versus benthic) and how these might have changed over time. These combined results could then form a framework for suggesting future monitoring programmes.

Disruption to the benthic environment in Cockburn Sound is most obvious from the large-scale loss of seagrass throughout the shallow subtidal areas (depths < 10 m). The largest loss of seagrass occurred predominantly on the eastern and southern margins between 1967 and 1972 (*ca* 46 %, 1587 ha), with further losses of 681 ha up to 1999 (totalling *ca* 77 %, Kendrick *et al.* 2002). The only site sampled in this study that was in a depth ≤ 10 metres was Jervois Bay on the eastern shelf, where the largest loss of seagrass was reported (Kendrick *et al.* 2002). This site was found to be markedly different from all others based on a significant difference in the abundance and diversity of its constituent species. The sediments on the north eastern shelf are different from the central basin being composed of course grained calcareous sand compared to the central basin where sediments ranged from fine calcareous sand in the north of the Sound to thick grey mud in the south (Wilson *et al.* 1978). Whether these differences in this community are merely the result of differences in the habitat, depth or bottom type, or are a result of this seagrass loss cannot be determined from the analyses we have presented in this report. However, the molluscan community on the northeastern shelf was reported as being different from the central basin even in the 1950s prior to the large-scale loss in seagrass (Wilson *et al.* 1978). How the community at Jervois Bay has changed over time and what factors may be driving these changes can only be determined by analysis of historic datasets in conjunction with environmental datasets. Any hypotheses arising from such analyses would need to then be tested from surveys with an appropriate sampling design such as beyond BACI.

It would be beneficial for future monitoring of the trawled community of Cockburn Sound to sample more sites with depths less than 10 metres in both the eastern/southern and northern/western areas, to increase our understanding of the influence of depth and/or habitat (such as sparsely distributed limestone outcrops on the eastern shelf) on the community structure. This study has comprehensively described the structure of the trawled communities of marine fauna throughout Cockburn Sound and Owen Anchorage and therefore provided a relative baseline to enable future monitoring to detect changes in their structure. It is recommended that future monitoring should include the seven sites sampled in this study to facilitate consistent comparisons to generate a useful long-term dataset, which has been lacking for many studies of this nature in Cockburn Sound. Furthermore, to facilitate comparisons of the trawled community structure of the marine fauna between disturbed and undisturbed environments, sampling should include sites in unimpacted areas. Warnbro Sound is a nearshore marine embayment with very similar geomorphology (Seddon 1972; Anon. 1996), water circulation (Steedman & Craig 1983; Gersbach 1993) and benthic habitats to Cockburn Sound, but without historic and current intensive anthropogenic usages, and consequently would be a suitable control site.

5.1.3 Ecological considerations associated with commercially and/or recreationally important species

As species of commercial and/or recreational importance are subjected to additional levels of mortality associated with fishing practices, their biomass may fluctuate in addition to naturally viability caused by environmental fluctuations. A majority of the commercially and/or recreationally important species identified in this study represent medium to high trophic-level species. Thus, changes in their abundance may have broader ecological impacts. Currently, the stock levels of some commercially and recreationally important species are low/ depleted, *e.g.* blue swimmer crab (Johnston *et al.* 2007) and snapper (Wise *et al.* 2007), and for many other species stock levels are unknown, *e.g.* octopus and squid. The descriptions of the trawled faunal community structure presented in this study represent the current levels of the stocks of commercially and/or recreationally important species in this area. Therefore, if any changes in this trawled community structure are identified in future monitoring, the stock levels of commercially and/or recreationally important species need to be considered. Changes may reflect increases or decreases in predators and prey, respectively, or further flow-on effects associated with commercial and/or recreational fishing practices. In recognition of the low stock levels of adult blue swimmer crab and snapper the Department of Fisheries has recently introduced regulations to further reduce the commercial and recreational effort on adults of these species. If these new regulations are successful an increase in abundance of blue swimmer crab and snapper populations may alter the community structure of the marine fauna in this area.

5.1.4 Blue swimmer crab

The findings outlined in this study are based on a low/depleted stock level of adults (≥ 1+, residuals) and a lower than expected recruitment abundance for juveniles (0+, recruits) of blue swimmer crabs. Thus, site selectivity displayed by recruits, *i.e.* consistently higher abundances at Jervois Bay, James Point and Mangles Bay, may be more widespread as the population size increases. Although the Research Area was found to be representative of trends in abundances for residual blue swimmer crab, the larger area sampled in this study provided improved spatial information and allowed for more accurate estimates of abundance for this embayment. In addition, sampling over a wider area will facilitate the assessment of smaller scale localised changes in abundances for future monitoring. This is especially significant given the north/ south and west/east gradient in community structure previously described.

It should also be noted that the preferred locations of recruit blue swimmer crabs were identified to be in the eastern and southern areas of Cockburn Sound, *i.e.* Jervois Bay, James Point and Mangles Bay, where the largest loss of seagrass has been reported (Kendrick *et al.* 2002). This suggests that the large-scale disturbance and subsequent loss of seagrass that occurred in these areas may have been beneficial for recruits of this species. Alternatively, given that seagrass meadows are important nursery areas for blue swimmer crab (Orth & van Montfarns 1987; Lipcius *et al.* 2005; Svane & Cheshire 2005), the large-scale loss of seagrass may have reduced the recruitment capacity from these areas. As there were no sites sampled in seagrass in this study, it is not possible to determine the population structure of blue swimmer crabs associated with this habitat and its influence on recruitment. These are suggestions only and need further investigation.

Recruit (0+) blue swimmer crabs were not fully selected by the trawl gear used in this study until approximately March, *ca* three to four months after spawning. In addition, by the end of June their modal distribution in carapace width, used to define age cohorts, became difficult to distinguish from residual blue swimmer crabs (see Fig. 3.8). This merging of cohort size is most likely due to the slowing of growth of larger/older individuals. In future, sampling to obtain estimates of annual recruitment abundance for this species needs to occur between March and June each year. The analysis of the abundances of residual blue swimmer crabs would therefore need to consider two time periods separately, as overlaps in the size distribution of age cohorts may influence estimates of abundance. These times periods include 1) from January to June when residuals can be easily distinguished from the younger 0+ age cohort and 2) September to December when age cohorts can no longer be distinguished and are all considered to be residuals. This period also coincides with the spawning period of this species in this area.

5.1.5 Snapper

Only juvenile snapper less than six months of age were collected during this study. Trawling has been able to distinguish between poor and strong recruitment years for this species in Cockburn Sound. Estimates of the annual recruitment abundance of snapper in the Sound were more accurate in this study due to sampling occurring over a wider area, which more accurately reflects the home range of juveniles of this species. Populations of snapper commonly display large fluctuations in annual recruitment (Francis 1993; Francis *et al.* 1997; Fowler & Jennings 2003; Ferrell 2004). Presently, the adult stock of snapper are at a low/depleted level along the lower west coast of Western Australia and annual estimates of their recruitment abundance from Cockburn Sound and Owen Anchorage could provide managers with knowledge of expected abundances prior to their vulnerability to fishing, which would be useful information to assess the time required for stock rebuilding. Recent studies on the biology of snapper have identified the relative paucity of recruitment sources for snapper along the lower west coast of Western Australia (Wakefield 2006; St John *et al.* in press). These origins of recruitment are typically associated with protected nearshore embayments, with juveniles from these embayments found to recruit to stocks over a wide area of coastline (Fowler *et al.* 2005; Hamer *et al.* 2005). In South Australia, snapper from a 9+ year old age class collected from > 2000 km of coastline were traced back to two points of origin/nursery areas, *i.e.* the northern waters of Gulf St Vincent and Spencer Gulf, based on their otolith chemistry (Fowler *et al.* 2005). Future trawl studies investigating the recruitment of snapper on the lower west coast of Western Australia should strongly consider including Warnbro Sound as well as Cockburn Sound and Owen Anchorage to assess input to the population from Warnbro Sound.

The decrease in abundance of 0+ snapper from the February to April trawl surveys in 2008 between all sites sampled, and the Research Area only, provided contrasting estimates of natural mortality. It is highly likely that the lower estimate (51.8 %) recorded for all sites better represented the home range of juveniles of this species and incorporated any immigration, and was thus a more accurate assessment. However, the higher estimate (94.4 %) was similar to estimates of natural mortality for 0+ snapper from Freycinet Estuary in Shark Bay, Western Australia (Wakefield *et al.* 2007). To improve the estimate of natural mortality of 0+ snapper, it would be necessary to do an additional trawl survey in the last half of 2008 (which is outside the scope of this report), and in the future at least three surveys a year are needed.

5.2 Future monitoring

5.2.1 Temporal sampling regime

As the structure of the trawled faunal community was only described for autumn (April/May) and spring to early summer (October/December) in 2007 and late summer (February) in 2008, interannual variation in the community structure was not evaluated. There were significant differences in the communities among surveys and it would be useful to track these variations for a few years to determine the consistency of these. However, as long as long term monitoring of the community is undertaken at the same time of the year, interannual variation in the community could be determined for one time period. The frequency required to monitor the trawled community structure in this area would benefit from a periodical approach up to a maximum of every five years, as ecological processes associated with changes in the community structure could occur within this period, *e.g.* the large-scale loss of seagrass from the eastern shelf of Cockburn Sound between 1967 and 1972 (Kendrick *et al.* 2002). Notwithstanding this, sampling of the trawled community structure of the marine fauna should occur sooner in the event of a potential impact/disruption, *e.g.* further industrial development such as the proposed Outer Harbour facility for the Port of Fremantle to be positioned in the area slightly north of James Point.

Monitoring of commercially and/or recreationally important species, such as blue swimmer crab and snapper, would need to be more frequent. The stock assessment of both blue swimmer crab and snapper would benefit from annual estimates of recruitment abundance, for which sampling would need to be undertaken between March and June for both species, considering issues associated with gear selectivity and mortality. Monitoring of the abundance of residual blue swimmer crabs using trawl gear similar to this study, would need to be kept consistent temporally due to the previously mentioned overlap in modal distributions in carapace width from June onwards. However, monitoring of blue swimmer crab during September to December would provide additional information on their reproductive biology. Thus, sampling of blue swimmer crabs should be undertaken at least twice a year between March to June and September to December. If sampling were to be undertaken three times in a single year than estimates of mortality could be obtained for both blue swimmer crab and snapper. For juvenile snapper that are subject to very little if any fishing mortality (and possibly other indicator species), estimates of natural mortality would provide additional information on the environmental health for this area.

5.2.2 Spatial sampling regime

The wider area sampled in this study compared to historic trawl surveys conducted by the Department of Fisheries provided improved estimates of abundances of recruit and residual blue swimmer crabs and recruitment of juvenile (0+) snapper. In addition, it allowed spatial trends in the trawled community structure to be determined. Furthermore, any changes in these species abundances or the community structure in future surveys will be noticeable at a smaller/localised spatial scale.

It is recommended that sampling include Warnbro Sound, located *ca* 5 km south of Cockburn Sound; to 1) describe the trawled community structure of the marine fauna from a very similar nearshore marine embayment that has not had large-scale environmental degradation. This would allow for an improved interpretation of the trawled community structure described in Cockburn Sound. 2) Provide estimates of the recruitment abundance of juvenile snapper from an additional source, as Warnbro Sound is also the location of an annually occurring spawning aggregation (Wakefield 2006), and there is a relative paucity of origins of recruitment of this species along the lower west coast of Western Australia (Wakefield 2006; St John *et al.* in press). 3) Provide additional estimates of natural mortality for snapper and other indicator species, which would allow for an improved interpretation of estimates from Cockburn Sound. Although trawling can be detrimental to benthic habitats, the central basin of Warnbro Sound is very similar to Cockburn Sound, *i.e.* largely flat and comprising soft sediment (silt composition). Thus, the benefits of the information gained about the faunal community through the use of short research trawls in the central basin of Warnbro Sound could outweigh the potential impact to the benthos. However, further analysis of existing datasets should occur first to allow a framework for testing of specific hypotheses to be developed prior to more surveys being undertaken.

6.0 General discussion

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6.1 Summary

This study has provided a description of the trawled faunal community at six sites in Cockburn Sound and one site in Owen Anchorage from autumn and spring/early-summer in 2007 and late summer in 2008. The key indicator species that have statistically described differences among these faunal communities have been identified. This study has also provided information on important aspects of the faunal community associated with commercial and/or recreational species in this area. This information will assist managers in their assessment of future Ecologically Sustainable Development (ESD) in this area through an ecosystem-based fisheries management (EBFM) approach, which considers human impacts on target species, by-catch species and habitats, and any potential indirect impacts of their removal or alteration on the broader ecosystem (Department of Fisheries W.A. 2005).

It is unknown whether the detection of changes in the structure of the trawled faunal community from future surveys will provide sufficient capacity to evaluate levels of environmental disturbance. However, the current status of the structure of the trawled faunal community described in this study provides sound quantitative data for which future comparisons can be made.

The main findings of each objective in this study were as follows.

6.1.1 Objective 1

Describe the trawled community structure associated with the key indicator species, i.e. blue swimmer crabs and snapper, in Cockburn Sound.

Community structure

- The sub-tidal faunal communities sampled by trawls in Cockburn Sound and Owen Anchorage were dominated by small benthic predators and detritivores.
- The majority of the species were well within their known geographic distributions and/or have previously been collected in Cockburn Sound or Owen Anchorage.
- Sites and surveys were significantly different from each other but the differences in the faunal community were more apparent among sites than among surveys.
- With the exception of Jervois Bay, all sites sampled in Cockburn Sound during the current study were located in an area previously identified to have a distinct assemblage, the central basin (Devaney 1978; Marsh 1978a; Marsh 1978b; Wilson *et al.* 1978; Wells & Threlfall 1980).
- The area in Jervois Bay that we sampled had a different community from the other sites due to the presence of sponges and their associated fauna. In previous studies, this area was also identified to have different faunal assemblages.
- Differences in the faunal community structure at Jervois Bay largely caused the east to west gradient in sites evident on the MDS ordinations. This was a result of a different community composition at this site compared with other sites, *i.e.* generally lower total abundance and species richness, but higher abundance of some component species, *e.g.* southern calamari squid *Sepioteuthis australis* and western smooth boxfish *Anoplocapros amygdaloides*.

- A north to south gradient was also evident on the ordinations and this was driven by the higher species diversity, richness and evenness of the faunal communities sampled at Owen Anchorage. All these diversity measures decreased moving southwards into the Sound with the lowest values being recorded at Mangles Bay. These patterns may be related to an environmental impact gradient but this was not investigated in the current study.

Commercially and/or recreationally important species

- Only taxa belonging to three of the six phyla that were collected from trawls in Cockburn Sound and Owen Anchorage were retained by commercial and/or recreational fishers in either the west coast bioregion (WCB) or Cockburn Sound and Owen Anchorage, *i.e.* Arthropoda, Mollusca and Chordata.
- Approximately 13 % (*ca* 28 species from 24 families) of the taxa collected in this study are retained by commercial fishers in the WCB.
- Only *ca* 15 species from 13 families of these taxa are retained by commercial fishers in Cockburn Sound and Owen Anchorage, due to the permanent closure to trawling and the restriction of the West Coast Estuarine Fishery to the Swan/Canning and Peel/Harvey estuaries.
- The number of taxa retained by recreational fishers was slightly higher than that of commercial fishers in the WCB of *ca* 14 %, comprising *ca* 30 species from 24 families.

Blue swimmer crab

- The abundance of blue swimmer crab recruits (0+) differed significantly between sites with recruit numbers highest at James Point, Jervois Bay and Mangles Bay. A lack of significant interaction between year and site further confirmed these sites are important crab recruitment areas, irrespective of year.
- Blue swimmer crab recruit numbers differed significantly between 2007 and 2008, with numbers significantly higher in 2008. This was most likely due to greater recruitment success on account of a slow recovery of spawning stock following the collapse of this fishery in 2006 and subsequent closure to commercial and recreational fishing in Cockburn Sound.
- There did not appear to be any site selectivity by residual (≥ 1+) crabs with abundances highest in 2007 at the Research Area, Garden Island South and Mangles Bay, compared to Jervois Bay, James Point and Mangles Bay in 2008.

Snapper

- Only juvenile snapper less than six months of age, *i.e.* 0+ age cohort, were collected in this study.
- There was a marked difference in the overall abundances of 0+ snapper between the 2006 and 2007 year classes.
- There was no site selectivity displayed by the 0+ snapper between surveys. However, there were some consistencies in abundances between the February and April surveys in 2008, where the numbers of snapper caught were consistently higher for GIN and JPT and consistently lower for GIS and JVB. The remaining three sites, *i.e.* OWA, RSA and MGB, showed large fluctuations in abundance between these two sampling periods.
- The only site where 0+ snapper were collected in each survey was JPT.

- Estimates of growth of 0+ snapper were obtained from the 2007 year-class. The mean growth rate was estimated as 10.8 mm per month for their first four months of life.

6.1.2 Objective 2

Assess changes in the distribution and abundance of blue swimmer crab and snapper by comparison with the Department of Fisheries long-term data set.

Blue swimmer crab

- The total number of blue swimmer crab recruits (0+) and residuals (≥ 1+) sampled during 5-minute trawls was one quarter (25 %) of that in the 20-minute trawls, which was consistent with expected catch rate comparisons (25 %).
- Size distributions obtained during 5-minute trawls provided significantly lower numbers of blue swimmer crabs compared with 20-minute trawls, with the majority of size categories not sampled. This trend may be exacerbated by very low blue swimmer crab abundance in Cockburn Sound at present, so future trawling programs will need to take current stock levels into account when determining appropriate shot lengths.
- Historic trawls undertaken by the Department of Fisheries since 2000 at RSA showed a decline in blue swimmer crab recruitment and residual abundance between 2003 and 2006 which is consistent with commercial fisheries and research data collected during this time. Slow recovery of recruits during 2007 and 2008 is also apparent and reflects the overall status of the fishery at this time.
- Comparison of recruit abundances between the RSA site and known blue swimmer crab recruitment sites, *i.e.* James Point, Jervois Bay and Mangles Bay, confirmed that recruits are less abundant at the RSA site and thus have not provided useful estimates of recruitment historically.
- Trends in the mean abundance of residual blue swimmer crabs at the RSA site are similar to the mean abundance of residuals from all other sites combined in Cockburn Sound.

Snapper

- The mean abundances of juvenile snapper from historic trawls undertaken by the Department of Fisheries since February 2000 at the RSA site were able to distinguish between strong and poor recruitment years.
- There have been two strong years of recruitment of juvenile snapper in Cockburn Sound in recent years, *i.e.* the 1999 and 2007 year-classes.
- The mean abundances of juvenile snapper from these historic trawls during poor recruitment years have been low or zero, most likely resulting from the home range of juvenile snapper being larger than the RSA site, along with this site not being highly selected/preferred by juvenile snapper, evident from relatively low abundances caught at this site during this study.
- Limitations in the historic data being from one site were also evident in two contrasting estimates of natural mortality that were based on two spatial scales for the 2007 year-class. Natural mortality was estimated to be 51.8 % for juvenile snapper using all seven sites in Cockburn and Owen Anchorage compared to 94.4 % using RSA only. Although the spatial scale used for the lower estimate encompasses the home range of juvenile snapper and is therefore considered more accurate, the higher estimate could not be ruled out given

it is within the range for juvenile snapper from Freycinet Estuary in Shark Bay, Western Australia. However, these estimates need to be treated with caution given the limited data used, and need further investigation.

6.1.3 Objective 3

Establish a system to monitor the abundance and distribution of sub-tidal embayment faunal communities in Cockburn Sound.

Temporal sampling regime

- Significant differences were found in the trawled faunal community structure among survey periods in this study. Consequently, trawled community structure needs to be described from surveys conducted at the same time of the year. However, the periodicity of sampling in this study did not allow for interannual variation of the communities to be determined, which would need further investigation.
- The frequency required to monitor the trawled community structure in this area would benefit from a periodical approach of less than five years, given the timeframes of environmental changes, for example the large-scale loss of seagrass witnessed within this time frame, *i.e.* 1967 to 1972. Alternatively, the trawled faunal community structure would need to be described in the event of potential disturbance from a major development in the area, *e.g.* the proposed Outer Harbour facility for the Port of Fremantle.
- Monitoring of commercially and/or recreationally important species would need to be more frequent than monitoring of the faunal community as fishing pressure on these populations is ongoing and also to detect any influence that fisheries management policies being implemented in the area would have on the stocks.
- Sampling needs to be undertaken between March and June each year to obtain useful estimates of the annual abundance of recruits of blue swimmer crab and snapper.
- To monitor the annual abundance and associated reproductive biology of residual blue swimmer crab, sampling would need to be undertaken between September and December each year.
- To estimate the annual rates of mortality (specifically natural mortality where possible) for key indicator species and commercially and/or recreationally important species, *e.g.* blue swimmer crab and snapper, sampling would need to be undertaken at least three times in a single year.

Spatial sampling regime

- The wider area sampled in this study, *i.e.* six sites in Cockburn Sound and one site in Owen Anchorage, than in historic trawl surveys was beneficial and 1) allowed for spatial trends in the trawled community structure to be determined; 2) improved our understanding of the spatial distribution of blue swimmer crab recruits; and 3) improved estimates of abundances of recruit (0+) and residual (≥ 1+) blue swimmer crab and recruitment of juvenile snapper (0+).
- Future sampling regimes would benefit from using the seven sites from this study, as changes in the trawled faunal community structure could be detected at a smaller/localised spatial scale.
- Future monitoring programs should incorporate Jervois Bay, James Point and Mangles Bay to accurately represent crab recruits, whereas a wide range of sites is needed to accurately represent residual crabs.

- Future sampling should consider additional sites in depths less than ten metres in north-western and south-eastern areas of Cockburn Sound to determine the influence of some important factors, *i.e.* depth, habitat, and relative distance from previously identified highly disturbed areas.
- Future surveys should consider sampling in Warnbro Sound to 1) allow an improved interpretation of the trawled faunal community structure described in Cockburn Sound in this study, compared to the faunal community from a similar nearby marine embayment that has not had large-scale environmental disturbance; 2) improve our understanding of recruitment abundances of blue swimmer crab and snapper for the lower west coast, for which the relative paucity of protected nearshore marine embayments are an integral part of their life history, and 3) allow comparisons of the natural mortality rates of key indicator species and juvenile blue swimmer crab and snapper between Cockburn Sound and Warnbro Sound, to provide insight into the probability of survival between an environmentally impacted and non-impacted embayment/recruitment areas.

6.2 Future research

The results from these surveys represent a snapshot of the status of the subtidal faunal communities collected by trawls in Cockburn Sound and Owen Anchorage at this time, but these results alone do not enable us to interpret how the faunal communities may have changed historically. The current project did not allow for incorporation and analysis of historic datasets of the faunal communities of Cockburn Sound. Historic datasets for Cockburn Sound and adjacent areas are available from Department of Fisheries trawl studies (Penn 1977; Dybdahl 1979), Western Australian Museum and Western Australian Naturalist Club invertebrate surveys from the 1950s, 1960s and 1970s (Devaney 1978; Wells 1978; Wilson et al. 1978; Marsh 1978a; Marsh 1978b; Wells and Threlfall 1980), a survey of the deep basin infaunal invertebrates of Cockburn and Warnbro Sounds (Cary *et al.* 1995), and a variety of studies undertaken by environmental consultants. However, these data are not readily accessible as the majority are in unpublished reports, and the older datasets are not digitised. Preliminary reading of these reports indicates that they could provide a useful insight into how the faunal communities may have changed over time, for example the absence of *Stellaster inspinosus* from the southern sites in Cockburn Sound (current study) when previously a widespread distribution had been reported (Marsh 1978b). Compilation and digitisation of these historic datasets would be a very useful exercise. Combining historic information with the data collected from this study would provide a comprehensive and more complete dataset that could be analysed with modern statistical methods. This would provide baseline summary information and suggest a framework for future studies. The problem with comparing species richness and diversity measures from different sampling designs can be ameliorated by calculating a measure of taxonomic distinctness which is a standardised measure of species richness and can be used to compare results from different sampling designs (Warwick & Clarke 1995; Warwick & Clarke 1998; Clarke & Warwick 1999; Price *et al.* 1999; Rogers *et al.* 1999; Clarke & Warwick 2001; Salas *et al.* 2006).

The analyses undertaken in this report only considered components of the fauna that were identified to species, potentially missing out important members of the community including sessile invertebrates such as the orange sea pens *Cavernularia* spp. and colonial and solitary ascidians that could not be identified to species because of lack of expertise. The analyses undertaken could be repeated on the entire dataset at the Class and Phylum levels to determine if the patterns found from the species dataset were also found when all taxa were included.

No effort was made during the current study to rank sites on their perceived level of health or pollution and, due to time constraints, no control site was incorporated into the sampling design to compare the study site with a less impacted embayment. It would be very useful to expand the sites surveyed to include a comparatively undisturbed site with similar environmental conditions and benthic habitat structure such as Warnbro Sound. This would allow an expanded spatial and temporal comparison of the faunal community of Cockburn Sound.

A useful approach for future work would be to have environmental managers give site rankings to areas based on factors such as level of pollution. This approach has been employed for sites and estuaries in the Auckland region with promising results (Hewitt *et al.* 2005). The addition of environmental data to this biological dataset would allow explicit linking of the faunal community to environmental parameters using analyses such as LINKTree and BIOENV (Clarke & Gorley 2006).

Another method not able to be undertaken in this study would be to perform an abundance-biomass comparison (ABC) for the different sites (Warwick & Clarke 1994). ABC plots two curves, one for cumulative abundance and one for cumulative biomass against species rank. For many marine macrobenthic communities a shift occurs from a higher biomass dominated community to a community dominated by higher abundance with increasing disturbance. This shift is based on the ecological theory that in undisturbed communities the species will be large bodied and longer lived (K – selected), and will dominate the community by weight (biomass). In comparison, communities with high disturbance will be dominated by small bodied, short lived species (r-selected) which will dominate the community by abundance. Changes in the abundance biomass relationship over time will also provide information for comparisons with other communities.

It would be very useful to produce a regional field guide to the marine fauna of Cockburn Sound and surrounding areas. This would need to have colour photographs of the species along with a description of the fauna and key diagnostic features. Currently, there is no local field guide available that provides this information, with people interested in identifying the fauna of Cockburn Sound having to access a variety of sources, including specialised taxonomic texts, to be able to identify the species.

The Department of Fisheries has collected population data, *i.e.* counts and carapace widths, for western king prawns (*Melicertus latisulcatus*) from the historic trawls outlined in Section 4.0. Although this species was not recognised as being retained by commercial and recreational fishers in Cockburn Sound and Owen Anchorage, there is a commercial trawl fishery that targets them nearby in Comet Bay, *ca* 13 km south of Cockburn Sound. Thus, information on this species from an unfished population in Cockburn Sound would provide useful comparisons with that of a fished population.

The importance of recruitment of juvenile snapper from Cockburn Sound and Owen Anchorage to the adult stocks along the west coast of Western Australia needs further investigation (*e.g.* age related otolith microchemistry, genetics).

This study has outlined some key indicator species for which little is known on their biology and the importance of Cockburn Sound in terms of their life history strategy. More detailed information on their distribution and abundance with respect to habitat, topography and anthropogenic structures (*e.g.* dredged channels, rock walls) within Cockburn Sound would assist in the interpretation of the faunal communities discussed in this study.

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9.0 Appendices

9.1 Appendix 1

List of invertebrate taxa retained in the WA Museum collections as voucher specimens for this project. Note, '*cf.*' denotes specimens that had some variation in characters from published species descriptions and therefore may not belong to that species, and '?' denotes species with some uncertainty in the validity of the identification, mostly due to insufficient knowledge of the taxa.

Phlya	Taxa	Date	ShotNo	Site	WAM#
Porifera					
	Acanthodendrilla? sp. C1	29-Oct-07	4	JPT	WAM Z49570
	Callyspongia sp. C1	12-Dec-07	5	CSN	WAM Z49537
	Callyspongia sp. MF3	29-Oct-07	1a	MGB	WAM Z49571
	Ciocalypta sp. C1	30-Oct-07	12	GIN	WAM Z49510
		13-Feb-08	17	GIN	WAM Z49508
	Coelosphaera sp. C1	2-May-07	2	JPT	WAM Z49535
	Echinodictyum clathrioides	12-Dec-07	1	JVB	WAM Z49529
	Echinodictyum mesentarium	3-Apr-07	11	CSN	WAM Z49511
		2-May-07	2	JPT	WAM Z49496
	Haliclona (Reniera) sp. C1	30-Oct-07	8	GIS	WAM Z49518
	Haliclona (Haliclona) sp. C2	30-Oct-07	8	GIS	WAM Z49524
	Haliclona (Reniera) sp. C3	30-Oct-07	8	GIS	WAM Z49530
		13-Feb-08	16	GIN	WAM Z49503
	Holopsamma sp. C1	2-May-07	8	GIN	WAM Z49501 & 49514
		12-Dec-07	6	CSN	WAM Z49516
		12-Dec-07	2	JVB	WAM Z49527
		12-Feb-08	5	JPT	WAM Z49534
	Igernella sp. C1	12-Dec-07	1	JVB	WAM Z49517
		13-Feb-08	16	GIN	WAM Z49558
	Ircinia sp. J1	2-May-07	1	JPT	WAM Z49506
		13-Feb-08	16	GIN	WAM Z49509
	Leucosolenida sp. C1	30-Oct-07	12	GIN	WAM Z49502
	Leucosolenida sp. C2	30-Oct-07	10	GIN	WAM Z49532
	Mycale sp. C1	29-Oct-07	4	JPT	WAM Z49495
	Mycale sp. C2	12-Feb-08	5	JPT	WAM Z49498
	Phorbas sp MF3	2-May-07	8	GIN	WAM Z49505
	Phorbas sp MF4	2-May-07	1	JPT	WAM Z49521
	Phorbas sp. C1	2-May-07	2	JPT	WAM Z49536
		12-Feb-08	6	JPT	WAM Z49497
	Phorbas sp. C2	12-Dec-07	2	JVB	WAM Z49513
		13-Feb-08	16	GIN	WAM Z49512
	Sarcotragus sp. C1	12-Dec-07	3	JVB	WAM Z49540
	Sarcotragus sp. C2	12-Dec-07	2	JVB	WAM Z49507
	Semitaspongia sp. C1	12-Dec-07	3	JVB	WAM Z49538
	Spheciospongia cf. papillosa	13-Feb-08	17	GIN	WAM Z49525
	Suberites sp. C1	13-Feb-08	16	GIN	WAM Z49519
	Tedania sp. C1	12-Dec-07	1	JVB	WAM Z49500
	Tethya cf. ingalli	29-Oct-07	1b	MGB	WAM Z49522
		13-Dec-07	10	OWA	WAM Z49523
		12-Feb-08	8	JVB	WAM Z49533
	Tethya cf. robusta	30-Oct-07	10	GIN	WAM Z49526
		12-Dec-07	2	JVB	WAM Z49515
	Tethya sp. C1	12-Dec-07	6	CSN	WAM Z49520
		13-Dec-07	11	OWA	WAM Z49504
	Xestospongia sp. C1	12-Dec-07	2	JVB	WAM Z49528
Cnidaria					
	Sarcoptilus spp.	3-Apr-07	11	CSN	WAM Z49568

Appendix 1. continued

Phlya	Taxa	Date	ShotNo	Site	WAM#
Crustacea					
	Actumnus setifer	12-Dec-07	3	JVB	WAM C39989
	Alpheus cf. rapax	12-Dec-07	3	JVB	WAM C40000
	Alpheus digitalis	12-Dec-07	5	CSN	WAM C39999
		13-Feb-08	15	GIS	WAM C40010
	Alpheus pacificus	13-Dec-07	10	OWA	WAM C40003
	Balanus trigonus	29-Oct-07	1b	MGB	WAM C39985
		29-Oct-07	4	JPT	WAM C39984
	Belosquilla laevis	3-Apr-07	1	MGB	WAM C39974
		3-Apr-07	11	CSN	WAM C40005
	cf. Leptomithrax sternocostulatus	13-Feb-08	17	GIN	WAM C39995
	Diogenes serenei?	12-Dec-07	3	JVB	WAM C39997
	Diogenes sp.	12-Dec-07	2	JVB	WAM C40009
	Dumea latipes	13-Feb-08	14	GIS	WAM C39992
	Ebalia intermedia	13-Dec-07	10	OWA	WAM C40001
	Ephippias endeavouri	12-Dec-07	4	CSN	WAM C40002
	Fultodromia nodipes	2-May-07	2	JPT	WAM C39963 & WAM C39971
		2-May-07	3	JPT	WAM C39977
		2-May-07	8	GIN	WAM C39979
		29-Oct-07	4	JPT	WAM C39964
		30-Oct-07	10	GIN	WAM C39991
		12-Feb-08	5	JPT	WAM C40016
		13-Feb-08	21	OWA	WAM C39996
	Galathea subsquamata?	2-May-07	2	JPT	WAM C39968
	Heteropilumnus sp.	12-Dec-07	2	JVB	WAM C40007
	Hyastenus sebae	29-Oct-07	4	JPT	WAM C39980
		30-Oct-07	12	GIN	WAM C39967
	Metapenaeopsis fusca	3-Apr-07	1	MGB	WAM C39982
		12-Dec-07	2	JVB	WAM C39998
	Naxia aurita	13-Feb-08	19	OWA	WAM C40008
	Nectocarcinus integrifrons	13-Feb-08	17	GIN	WAM C39993
	Pilumnus fissifrons	2-May-07	9	GIN	WAM C39970
		30-Oct-07	8	GIS	WAM C39972
		30-Oct-07	9	GIS	WAM C39986
		30-Oct-07	12	GIN	WAM C39965
		12-Dec-07	1	JVB	WAM C39994
	Pilumnus spp.	12-Dec-07	3	JVB	WAM C39962
	Pisidia dispar	13-Dec-07	10	OWA	WAM C39973
	Portunus rugosus	3-Apr-07	1	MGB	WAM C39983 / WAM C40015
		3-Apr-07	3	MGB	WAM C39976
		3-Apr-07	4	GIS	WAM C40014
		3-Apr-07	5	GIS	WAM C40006
		2-May-07	1	JPT	WAM C39978
	Rochinia cf. fultoni	3-Apr-07	11	CSN	WAM C39987
	Thalamita sima	2-May-07	1	JPT	WAM C39966

Appendix 1. continued

Phlya	Taxa	Date	ShotNo	Site	WAM#
Echinodermata					
	Anthenea australiae	29-Oct-07	5	JPT	WAM Z49547
		13-Feb-08	17	GIN	WAM Z49592
	Archaster angulatus	2-May-07	12	OWA	WAM Z49591
	Astropecten preissi	3-Apr-07	1	MGB	WAM Z49586
		3-Apr-07	4	GIS	WAM Z49564
		2-May-07	2	JPT	WAM Z49567
	Cercodema anceps	3-Apr-07	4	GIS	WAM Z49543
	Cladolabes schmeltzii	13-Dec-07	10	OWA	WAM Z49542
		13-Dec-07	11	OWA	WAM Z49541
	Colochirus quadrangularis	3-Apr-07	4	GIS	WAM Z49559
	Comanthus parvicirrus	2-May-07	9	GIN	WAM Z49552
	Comanthus wahlbergi	12-Feb-08	5	JPT	WAM Z49561
	Comatula purpurea	3-Apr-07	3	MGB	WAM Z49583
		2-May-07	1	JPT	WAM Z49554
		2-May-07	9	GIN	WAM Z49555
		30-Oct-07	11	GIN	WAM Z49560
		30-Oct-07	12	GIN	WAM Z49560
	Coscinasterias muricata	2-May-07	3	JPT	WAM Z49584
	Dorometra nana	3-Apr-07	11	CSN	WAM Z49577
	Dorometra parvicirra	2-May-07	4	JVB	WAM Z49550
	Echinocardium cordatum	2-May-07	2	JPT	WAM Z49566
		29-Oct-07	4	JPT	WAM Z49590
		29-Oct-07	5	JPT	WAM Z49581
	Luidia australiae	2-May-07	11	OWA	WAM Z49594
		13-Dec-07	11	OWA	WAM Z49588
	Macrophiothrix spongicola	3-Apr-07	11	CSN	WAM Z49582
		2-May-07	2	JPT	WAM Z49580 & 49587
		2-May-07	4	JVB	WAM Z49546
	Nepanthia crassa	3-Apr-07	11	CSN	WAM Z49557
	Nudechinus scotiopremnus	13-Feb-08	21	OWA	WAM Z49549
	Ophiopsammus assimilis	12-Dec-07	6	CSN	WAM Z49544
		13-Dec-07	10	OWA	WAM Z49556
	Ophiothrix caespitosa	3-Apr-07	4	GIS	WAM Z49563
	Ophiothrix ciliaris	30-Oct-07	11	GIN	WAM Z49589
	Ophiura kinbergi	2-May-07	5	JVB	WAM Z49569
	Peronella lesueuri	2-May-07	4	JVB	WAM Z49585
	Stellaster inspinosus	3-Apr-07	11	CSN	WAM Z49545
	Stichopus mollis	3-Apr-07	4	GIS	WAM Z49562
		29-Oct-07	6	JPT	WAM Z49553
	Temnopleurus michaelseni	2-May-07	4	JVB	WAM Z49575
		2-May-07	5	JVB	WAM Z49565
		29-Oct-07	4	JPT	WAM Z49551

Appendix 1. continued

Phlya	Taxa	Date	ShotNo	Site	WAM#
Mollusca					
	?Electroma georgiana	30-Oct-07	11	GIN	WAM S49967
	?Grimpella sp.	2-May-07	2	JPT	WAM S34812
	Amusium balloti	3-Apr-07	4	GIS	WAM S34953
		12-Feb-08	8	JVB	WAM S34965
	Aplysia dactylomela	2-May-07	11	OWA	WAM S34920
		30-Oct-07	10	GIN	WAM S34923
	Bedeva paivae	3-Apr-07	1	MGB	WAM S34940
		12-Dec-07	2	JVB	WAM S34919
		13-Dec-07	10	OWA	WAM S34950
		13-Dec-07	11	OWA	WAM S34925
	Berthella stellata	30-Oct-07	8	GIS	WAM S34948
	Chiton sp.	30-Oct-07	10	GIN	WAM S34961
	Crenatula viridis?	2-May-07	7	GIN	WAM S34926
		2-May-07	8	GIN	WAM S34943
		29-Oct-07	5	JPT	WAM S34918
		13-Feb-08	17	GIN	WAM S34968
	Cryptochiton sp.	2-May-07	5	JVB	WAM S34960
	Cymatium (Monoplex) cf. exaratum	30-Oct-07	10	GIN	WAM S34955
	Cymatium (Monoplex) labiosum	13-Feb-08	17	GIN	WAM S34966
	Ensiculus cultellus	30-Oct-07	10	GIN	WAM S34933
	Euprymna tasmanica	3-Apr-07	3	MGB	WAM S34932
		2-May-07	4	JVB	WAM S34938
	Hapalochlaena sp.	2-May-07	12	OWA	WAM S34811
		13-Feb-08	21	OWA	WAM S34962
	Mimachlamys asperrima	13-Feb-08	14	GIS	WAM S34951
		13-Feb-08	19	OWA	WAM S34954
		13-Feb-08	21	OWA	WAM S34947
	Octopus sp.	12-Feb-08	5	JPT	WAM S34964
		13-Feb-08	20	OWA	WAM S34963
	Pecten fumatus	30-Oct-07	11	GIN	WAM S34941
	Phasianella australis	13-Dec-07	10	OWA	WAM S34949
	Philine spp.	3-Apr-07	11	CSN	WAM S34956
	Philinopsis troubridgensis	2-May-07	5	JVB	WAM S34921
	Pleurobranchus peroni	29-Oct-07	7	GIS	WAM S34917
	Pyrene bidentata	29-Oct-07	2	MGB	WAM S34944
	Scaeochlamys lividus	3-Apr-07	9	CSN	WAM S34957
		2-May-07	8	GIN	WAM S34924
		2-May-07	9	GIN	WAM S34922
	Scutus antipodes	2-May-07	3	JPT	WAM S34942
	Sepia braggi	3-Apr-07	1	MGB	WAM S34931
		3-Apr-07	7	CSN	WAM S34936
	Sepia novaehollandiae	2-May-07	7	GIN	WAM S34935 & 34929
		30-Oct-07	11	GIN	WAM S34928
	Sepiadarium austrinum	2-May-07	1	JPT	WAM S34937
		2-May-07	7	GIN	WAM S34958
		30-Oct-07	9	GIS	WAM S34946
		30-Oct-07	12	GIN	WAM S34945
	Sepioloidea lineolata	2-May-07	7	GIN	WAM S34934
	Stylocheilus striatus	30-Oct-07	10	GIN	WAM S34952

9.2 Appendix 2

The total count (Table 1) and weight (Table 2) of each taxa collected during the study from each site and survey are presented. Sites and surveys are abbreviated as follows: Owen Anchorage [OWA]; Research Area [RSA]; Garden Island North [GIN]; Garden Island South [GIS]; Jervois Bay [JVB]; James Point [JPT]; Mangles Bay [MGB], April/May[1]; October/December[2]; February [3].

The streaked goby *Acentrogobius pflaumii* was the only introduced species to be collected during the study (introduced species[I]). Two species captured during the study were considered to be tropical species outside their expected geographic range; further taxonomic investigation would be required to confirm identifications of these species. *Alpheus rapax*[1] is a tropical species only known from NE Australia and Gulf of Carpentaria, *Upeneus asymmetricus* [2] is a tropical species with an Indo-Australian distribution, in Western Australia it is known from Shark Bay north. A number of taxa could not be identified to species either due to a lack of available expertise, *e.g.* ascidians and sea pens, the need for microscopic examination of diagnostic features coupled with insufficient retention of voucher specimens to confirm identification, *e.g. Metapenaeopsis* spp. and *Upeneus* spp., or because the specimens were too damaged to allow confirmation of identifications, *e.g. Arnoglossus* spp. None of these taxa groups[T] were analysed in the community analysis conducted in Chapter 3 of this report

Table 1. Counts of all taxa for each site and survey. Where, 1 refers to April/May 2007, 2 to October/December 2007 and 3 to February 2008.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Porifera		sponges																					
Calcarea																							
Leucosolenida																							
Leucosolenida sp. C1										1												1	
Leucosolenida sp. C2										1													
Demospongiae																							
Hadromerida																							
Clionaidae																							
Spheciospongia cf. *papillosa*	(Ridley & Dendy, 1886)										100												
Suberitidae																							
Suberites sp. C1											38												
Tethyidae																							
Tethya cf. *ingalli*	(Bowerbank, 1858)			1						6	2		1	1		2	1	12				3	
Tethya cf. *robusta*	(Bowerbank, 1858)			1						2						1		1					
Tethya sp. C1				1			1																
Halichondrida																							
Halichondriidae																							
Ciocalypta sp. C1										1	1												
Poecilosclerida																							
Microcionidae																							
Holopsamma cf. *laminaefavosa*	Carter, 1885								1														
Holopsamma sp. C1			1				1		4	5	9					1		2		1			
Raspailiidae																							
Echinodictyum clathrioides	Hentschel, 1911															1							
Echinodictyum mesentarium	(Lamarck, 1814)					1						1						1					
Coelosphaeridae																							
Coelosphaera sp. C1																		1					
Hymedesmiidae																							
Phorbas sp MF3									1														
Phorbas sp MF4																		1					
Phorbas sp. C1																		1		1			
Phorbas sp. C2											1					1							
Tedaniidae																							
Tedania sp. C1																1							
Mycalidae																							
Mycale sp. C1													1						1				
Mycale sp. C2																				1			

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Porifera Continued																							
Haplosclerida																							
Callyspongiidae																							
Callyspongia sp. C1							1																
Callyspongia sp. MF3																						1	
Chalinidae																							
Haliclona (*Haliclona*) sp. C2										1			1										
Haliclona (*Reniera*) sp. C1										1			1										
Haliclona (*Reniera*) sp. C3											1		1										
Petrosiidae																							
Xestospongia sp. C1																1							
Dictyoceratida																							
Irciniidae																							
Ircinia sp. J1											1							1					
Sarcotragus sp. C1																1							
Sarcotragus sp. C2																1							
Thorectidae																							
Semitaspongia sp. C1				1												2	1						
Dendroceratida																							
Dictyodendrillidae																							
?*Acanthodendrilla* sp. C1																			1				
Igernella sp. C1											1					1							
unidentified sponge spp.[T]			1												2			11			1		

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Cnidaria																							
Anthozoa																							
Actiniaria		anemones																					
unidentified anemone sp.[T]																				2			
Alcyonacea		soft corals																					
unidentified soft coral spp.[T]																					1		
Ceriantharia		tube anemones																					
Cerianthidae																							
Pachycerianthus sp.												1								2	15	3	3
Pennatulacea		sea pens																					
Pennatulidae																							
Sarcoptilus grandis	Gray, 1848						5	1															5
Sarcoptilus spp.[T]						3																	
Veretillidae																							
Cavernularia spp.[T]		orange sea pen	5	17	39	19	351	231	11	1		2	24	3	86	290	357	43	314	343	12	43	178
Scyphozoa		jellyfish																					
Rhizostomeae																							
Mastigiidae																							
Phyllorhiza punctata	Von Lendenfeld, 1884	Swan River Jellyfish							1														

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Arthropoda: Crustacea																							
Cirripedia		barnacles																					
Thoracica																							
Balanidae																							
Balanus trigonus																			1			1	
Malacostraca																							
Decapoda	(Darwin, 1854)																						
Penaeidae		prawns																					
Metapenaeopsis fusca	Manning, 1988				3		8	2		1	6	4	23	16		9	1		80	7	1	45	34
Metapenaeopsis lindae	Manning, 1988			2	4		49	75		55	19		117	13		10	3	1	121	19		50	4
Metapenaeopsis spp.[T]		velvet prawns	1			15			13						270			37					
Melicertus latisulcatus	(Kishinouye, 1896)	Western King Prawn	167	24	55	457	156	72	146	301	95	145	118	158	31		6	495	67	218	169	180	162
Alpheidae		snapping shrimps																					
Alpheus cf. *rapax*[1]	Fabricius, 1798															1			1				
Alpheus digitalis	De Haan, 1844						10	3		2			4	2					5	2		3	3
Alpheus pacificus	Dana, 1852			1																			
Galatheidae		squat lobsters																					
Galathea subsquamata?	Stimpson, 1858																	1					
Porcellanidae		porcelain crabs																					
Pisidia dispar	(Stimpson, 1858)			1																			
Diogenidae		hermit crabs																					
Calcinus dapsiles	Morgan, 1989						1																
Diogenes serenei?	Forest, 1956															1							
Diogenes sp.																1							
Dromiidae		sponge crabs																					
Fultodromia nodipes	(Guérin-Méneville, 1832)				1		2		1	1	4					1		3	1	3			
Leucosiidae		pebble crabs																					
Ebalia intermedia	Miers, 1886			1						1						1							
Majidae		decorator & spider crabs																					
cf. *Leptomithrax sternocostulatus*	(H. Milne Edwards, 1851)										1												
Dumea latipes	(Haswell, 1880)													1									
Ephippias endeavouri	Rathbun, 1918						1																
Hyastenus sebae	White, 1847			4						1						3			1				
Naxia aurita	(Latreille, 1825)				1																		
Rochinia cf. *fultoni*	(Grant, 1905)					1																	
Hymenosomatidae		spider crabs																					
Halicarcinus ovatus	Stimpson, 1838															1							

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Crustacea Continued																							
Portunidae		swimming crabs																					
Nectocarcinus integrifrons	(Latreille, 1825)										1												
Portunus pelagicus	(Linnaeus, 1758)		5	25	46	97	105	37	50	89	34	64	158	32	67	71	188	117	24	84	73	185	133
Portunus rugosus	(A. Milne Edwards, 1861)		58		14	381	121	26	99	34	75	135	38	58	277	63	64	211	71	21	48	99	72
Thalamita sima	H. Milne Edwards, 1834			7	5		8	11			5		15	1		26	24	3	9	7		22	3
Pilumnidae																							
Actumnus setifer	(De Haan, 1835)															1							
Heteropilumnus sp.																1							
Pilumnus fissifrons	Stimpson, 1858			2			1		1	3	8		2			4							
Pilumnus spp.[T]																1							
Stomatopoda		mantis shrimps																					
Squillidae																							
Belosquilla laevis	(Hess, 1865)			1	5	4	14	6		1	5	54	16	45		15	6	17	47	67	41	79	227
Mollusca																							
Polyplacophora		chitons																					
Neoloricata																							
Chitonidae																							
Chiton sp.										1													
Acanthochitonidae																							
Cryptochiton sp.															1								
Bivalvia																							
Mytiloida																							
Mytilidae		mussels																					
Amygdalum glaberrima	(Dunker, 1856)					1		1															
Pterioida																							
Pteriidae		wing shells																					
Electroma georgiana ?	(Quoy & Gaimard, 1834)									1													
Pteria sp.									1														
Malleidae		hammer oysters																					
Malleus sp.									1									1					
Isognomonidae																							
Crenatula viridis?	Lamarck, 1819	false pearl oyster							10		2								1				

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Mollusca Continued																							
Ostreoida																							
Pectinidae		scallops																					
Amusium balloti	(Bernardi, 1861)	Ballot's saucer scallop			1		1		1			1			1		1						
Mimachlamys asperrima	(Lamarck, 1819)	Doughboy Scallop			2									1									
Pecten fumatus	Reeve, 1852	Commercial Scallop			1					2													
Scaeochlamys livida	(Lamarck, 1819)				1	1			2		1			1			2						
Anomiidae																							
Monia sp.									1														
Veneroida																							
Pharidae		razor clams																					
Ensiculus cultellus	(Linnaeus, 1758).			5			1			1					1								
Gastropoda																							
Vetigastropoda																							
Fissurellidae		shield limpets																					
Scutus antipodes	Montfort, 1810																	1					
Turbinidae		pheasant shells																					
Phasianella australis	(Gmelin, 1791)			1																			
Sorbeoconcha																							
Ranellidae		triton shells																					
Cymatium (Monoplex) cf. *exaratum*	(Reeve, 1844)			1	1					2			1										
Cymatium (Monoplex) labiosum	(Wood, 1828)										3												
Cymatium parthenopeum	(von Salis, 1793)									1													
Muricidae		oyster drills																					
Bedeva paivae	(Crosse, 1864)			2			1	1		1	1			1		4	2				1		
Columbellidae		dove shells																					
Pyrene bidentata	(Menke, 1843)																					1	
Cephalaspidea		sea slugs																					
Philinidae																							
Philine spp.					1	1											1						
Aglajidae																							
Philinopsis troubridgensis	(Verco, 1909)														1								
Anaspidea																							
Aplysiidae		sea hares																					
Aplysia dactylomela	Reng, 1828		3	9						5													
Stylocheilus striatus	(Quoy & Gaimard, 1832)									1													

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Gastropoda continued																							
Notaspidea																							
Pleurobranchidae		side gill slugs																					
Berthella stellata	(Risso, 1826)												1										
Pleurobranchus peroni	Cuvier, 1804									3			1										
Nudibranchia		nudibranchs																					
Chromodorididae																							
Ceratosoma brevicaudatum	Abraham, 1876																			1			
Cephalopoda																							
Sepiida		cuttlefishes																					
Sepiidae																							
Sepia apama	Gray, 1849	Giant Cuttlefish					1										2						
Sepia braggi	Verco, 1907	Bragg's cuttlefish	19		2	7	1	3	5	3	5	7		6	15	1	4	7	3	3	3		3
Sepia novaehollandiae	Hoyle, 1909		12	1	23	35	4	47	24	5	55	5		27	1	3	10	10	1	11	3		5
Sepiolida																							
Sepiolidae		bobtail squids																					
Euprymna tasmanica	(Pfeffer, 1884)	Southern Bobtail Squid	3		3	2	11	11	1	1	11		1	6	7	1		3	2	7	4	1	5
Sepiadariidae		bottletail squids																					
Sepiadarium austrinum	Berry, 1921	Southern Bottletail Squid				2	5	3	3	1	1	1	1		3			3			1	2	
Sepioloidea lineolata	(Quoy & Gaimard, 1832)	Striped Pyjama Squid	1			1		3	2	2	2				9	1			1				
Teuthida																							
Loliginidae																							
Sepioteuthis australis	Quoy & Gaimard, 1832	Southern Calamari Squid	54	11	44	6	15	12	6	2	34		3	40	37	51	56	5	19	18	2		13
Octopoda		octopuses																					
Octopodidae																							
?*Grimpella sp*.																		1					
Hapalochlaena sp.		blue ring octopus	1	1	1																		
Octopus sp.					1			1								2	1			1			
unidentified mollusc spp.[T]				1						1						1			1		1		

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Echinodermata																							
Crinoidea		featherstars																					
Comatulida																							
Antedonidae																							
Dorometra nana	(Hartlaub, 1890)					2																	
Dorometra parvicirra	(Carpenter, 1888)														1			17					
Comasteridae																							
Comanthus parvicirrus	(Müller, 1841)								1														
Comanthus wahlbergi	(Müller, 1843)																			2			
Comatula pectinata	(Linnaeus, 1758)			3	1		5		1	1													
Comatula purpurea	(Müller, 1843)			3	3	6	1	2	2	4	2			2		1		23		6	1		
Asteroidea		seastars																					
Paxillosida																							
Luidiidae																							
Luidia australiae	Döderlein, 1920		4	21	16	10	4	5	1	7	8	3	1	1	10				1	1	2		
Astropectinidae																							
Astropecten preissi	Müller & Troschel, 1843		1	30	18	8	4	4	1	6	10	9	6	7	3		3	2	3	8	31	12	20
Valvatida																							
Archasteridae																							
Archaster angulatus	Müller & Troschel, 1842		1				1																
Goniasteridae																							
Stellaster inspinosus	H.L. Clark, 1916		10	10	15	15	3	2	14	23	21												
Oreasteridae																							
Anthenea australiae	Döderlein, 1915										1								1				
Goniodiscaster seriatus	(Müller & Troschel, 1843)			1	1						1			1									
Asterinidae																							
Meridiastra gunnii	(Gray, 1840)			1			1																
Nepanthia crassa	(Gray, 1847)					2																	
Forcipulatida																							
Asteriidae																							
Coscinasterias muricata	Verrill, 1867							1			2	1				3		5					

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Echinodermata continued																							
Ophiuroidea		brittlestars																					
Ophiurida																							
Ophiotrichidae																							
Macrophiothrix spongicola				4	3	5	4	3	4	6	11	3	2		1	24	1	70	16	5		4	
Ophiothrix caespitosa												1											
Ophiothrix ciliaris										1										1			
Ophiodermatidae																							
Ophiopsammus assimilis				5	2		1																
Ophiuridae																							
Ophiura kinbergi				1	3	2	1	4		5	3		4	14	2				1	1			
Echinoidea		urchins																					
Clypeasteroida																							
Laganidae																							
Peronella lesueuri	(Valenciennes, 1841)		1	3	1		1			1					14	102	8						
Echinoida																							
Temnopleuroida																							
Temnopleuridae																							
Temnopleurus michaelseni	(Döderlein, 1914)			3	14	6	4	12		25	6	5	24	165	24	50	1	10	55	3			
Toxopneustidae																							
Nudechinus scotiopremnus	H.L. Clark, 1912				1																		
Spatangoida																							
Loveniidae																							
Echinocardium cordatum	(Pennant, 1777)			1		1				4			4					1	24				
Holothuroidea		sea cucumbers																					
Dendrochirotida																							
Cucumariidae																							
Cercodema anceps	Selenka, 1867		10	74	6	15	36	21	40	24	33	11	18	3	2	7		9					
Colochirus quadrangularis	Troschel, 1846		20	265	84	4	30	7	49	44	24	37	2			1		4		1			
Sclerodactylidae																							
Cladolabes schmeltzii	(Ludwig, 1875)			2																			
Aspidochirotida																							
Stichopodidae																							
Stichopus mollis	(Hutton, 1872)											2				3	1	6	1	5			

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Chordata																							
Ascidiacea		ascidians																					
Pleurogona																							
Pyuridae																							
Herdmania sp.[T]				6	5		1			13	5	8	16			7		10		6	8		
ascidian spp. - colonial[T]				3	1	1		2	4	2	4	5	3	4		1		3	3			1	
ascidian spp. - solitary[T]			2	13	1	8	3	3	3	9	16	6	8	3	1	2		10	5	7		3	
Pisces		fishes																					
Heterodontiformes																							
Heterodontidae																							
Heterodontus portusjacksoni	(Meyer, 1793)	Port Jackson Shark	25	6	16	2	3	1	2	7	5	4	1	3	19	3		13	2			1	6
Rhinobatiformes																							
Rhinobatidae																							
Aptychotrema vincentiana	(Haacke, 1885)	Western Shovelnose Ray									1												
Trygonorrhina fasciata	Müller & Henle, 1841	Southern Fiddler Ray	2		2	3		2	1	1	3	1	3	3		1				1		2	
Rajiformes																							
Dasyatidae																							
Dasyatis brevicaudata	(Hutton, 1875)	Smooth Stingray								1					2			3		1			
Dasyatis thetidis	Ogilby, 1899	Black Stingray	1				1						1										
Urolophidae																							
Trygonoptera mucosa	Müller & Henle, 1841	Western Shovelnose Stingaree			1																		1
Trygonoptera testacea	Whitley, 1939	Common Stingaree		1	3																		
Urolophus paucimaculatus	Dixon, 1969	Sparsely-spotted Stingaree	12		5		1		3	1	3	1											
Myliobatidae																							
Myliobatis australis	Macleay, 1881	Southern Eagle Ray			1	3	1	2		2	2	3	1	1	1	2	3	2	1	1		3	3
Clupeiformes																							
Clupeidae																							
Sardinops neopilchardus	(Ogilby, 1897)	Australian Sardine							2														
Spratelloides robustus	(Jenyns, 1842)	Blue Sprat								2													
Engraulidae																							
Engraulis australis	(Shaw, 1790)	Australian Anchovy				8		4	14		3	21	2	4			1	6		3	22	2	
Siluriformes																							
Plotosidae																							
Cnidoglanis macrocephalus	(Valenciennes, 1840)	Estuary Cobbler		1																			
Plotosus lineatus	(Thunberg, 1791)	Striped Catfish																5					
Lophiiformes																							
Antennariidae																							
Antennarius striatus	(Shaw, 1794)	Striate Anglerfish									1												

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Pisces Continued																							
Gadiformes																							
Moridae																							
Eeyorius hutchinsi	Paulin, 1986	Finetooth Beardie							1														
Beloniformes																							
Hemiramphidae																							
Hyporhamphus melanochir	(Valenciennes, 1847)	Southern Garfish				1			1	1			2		3		2	3	1	1	1	1	4
Atheriniformes																							
Atherinidae																							
Atherinomorus vaigiensis	(Quoy & Gaimard, 1825)	Common Hardyhead											1										
Lampriformes																							
Veliferidae																							
Metavelifer multiradiatus	(Regan, 1907)	Common Veilfin	7		4			2	1		6	2		2							1		
Gasterosteiformes																							
Pegasidae																							
Pegasus volitans	Linnaeus, 1758	Slender Seamoth	6	10	31	5	39	2	1	6	2		2	2	2	12	7	24	64	6	19	7	1
Syngnathidae																							
Hippocampus subelongatus	Castelnau, 1873	West Australian Seahorse			1				1	1			1		3			1		1			
Scorpaeniformes																							
Aploactinidae																							
Kanekonia queenslandica	Whitley, 1952	Deep Velvetfish																		2			1
Triglidae																							
Chelidonichthys kumu	(Lesson, 1826)	Red Gurnard	1		2	1	2		1		2											1	
Lepidotrigla papilio	(Cuvier, 1829)	Spiny Gurnard	52	3	29	160	212	237	238	142	217	58	15	72	91	49	60	52	39	68	60	34	15
Neosebastidae																							
Maxillicosta scabriceps	Whitley, 1935	Little Gurnard Perch	1		3		1	1	3	4	7			1	4	3	6	1	2	1		1	
Neosebastes pandus	(Richardson, 1842)	Bighead Gurnard Perch	1	2																			
Platycephalidae																							
Inegocia japonica	(Tilesius, 1812)	Rusty Flathead	1	1	11	19	5	21	20	11	30	8	9	41	1			6	7	10	5	9	28
Onigocia spinosa	(Temminck & Schlegel, 1843)	Midget Flathead	8		27	8	22	12	22	30	45	4	14	21	9	4	3	3	9	4	7	43	52
Platycephalus endrachtensis	Quoy & Gaimard, 1825	Yellowtail Flathead		1	3																		
Platycephalus longispinis	Macleay, 1884	Longspine Flathead	7			3	4	7	19	196	33							2					
Platycephalus speculator	Klunzinger, 1872	Southern Bluespotted Flathead					1			2											1		
Tetrarogidae																							
Gymnapistes marmoratus	(Cuvier, 1829)	Soldier	2	16	22	14	4	7		9	43	1	2	17				1	1			4	9

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Pisces Continued		fishes																					
Perciformes																							
Apogonidae																							
Apogon rueppellii	(Ogilby, 1886)	Western Gobbleguts	223	29	74	72	82	36	324	221	97	146	195	157	13	6	15	63	25	93	180	275	413
Siphamia cephalotes	(Castelnau, 1875)	Wood's Siphonfish																					1
Siphamia roseigaster	Günther, 1859	Pinkbreast Siphonfish																					1
Callionymidae																							
Dactylopus dactylopus	(Valenciennes, 1837)	Finger Dragonet													1								
Pseudocalliurichthys goodladi	(Whitley, 1944)	Longspine Dragonet	389	49	246	331	818	514	731	621	1939	371	172	884	85	33	15	208	216	30	252	384	296
Carangidae																							
Pseudocaranx georgianus	(Cuvier, 1833)	Sand Trevally	71		54	60		11	1	1	24	2		39	2		28	2		7	1		8
Pseudocaranx wrighti	(Whitley, 1931)	Skipjack Trevally	208		18	614	189	243	46	136	457	170	258	383	2		2	8	24	41	15		51
Seriola hippos	Günther, 1876	Samsonfish	2				1								1	1		2					
Trachurus novaezelandiae	Richardson, 1843	Yellowtail Scad	1								2						1						
Clinidae																							
Cristiceps australis	Valenciennes, 1836	Southern Crested Weedfish		1																			
Gerreidae																							
Parequula melbournensis	(Castelnau, 1872)	Silverbelly	815	30	98	5			49	19	12				4		21	1		2	15	2	1
Gobiidae																							
Acentrogobius pflaumii[1]	(Bleeker, 1853)	Streaked Goby					1			1													
Labridae																							
Notolabrus parilus	(Richardson, 1850)	Brownspotted Wrasse																2					
Mullidae																							
Upeneichthys vlamingii	(Cuvier, 1829)	Bluespotted Goatfish	52	5	36	1			23	5	17			7	2		1		1				1
Upeneus asymmetricus ?[2]	Lachner, 1954	Asymmetric Goatfish			3				1														
Upeneus spp.[T]		Goatfish species	27	3	4		2		2	1	6						1	1		1		5	
Upeneus tragula	Richardson, 1846	Bartail Goatfish							2														

Table 1. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Pisces Continued		fishes																					
Nemipteridae																							
Pentapodus vitta	Quoy & Gaimard, 1824	Western Butterfish	224	31	16	2	3	2	56	27	15	8	4	1		2	1	2	3		1	6	
Odacidae																							
Neoodax balteatus	(Valenciennes, 1840)	Little Weed Whiting		2	1		1			1	1		2	1							5	2	
Pempheridae																							
Pempheris klunzingeri	McCulloch, 1911	Rough Bullseye	1		5			1	1			37			2			4					
Pinguipedidae																							
Parapercis haackei	(Steindachner, 1884)	Wavy Grubfish	2	1	1	5	12	3	2	2	2		5		11	7		1	1		1	8	2
Pomatomidae																							
Pomatomus saltatrix	(Linnaeus, 1766)	Tailor			1		1			1				1					2				
Sillaginidae																							
Sillago bassensis	Cuvier, 1829	Southern School Whiting	50	2	26			49	19			5			29		14	1					
Sillago burrus	Richardson, 1842	Western Trumpeter Whiting	14	6	47	45	71	82	101	25	277	90	3	75	1			19	4	9	31	7	80
Sillago vittata	McKay, 1985	Western School Whiting	1				1		1	1		1			1								
Sparidae																							
Pagrus auratus	(Bloch & Schneider, 1801)	Snapper	2		5			158			294		1	23		3	12	4	4	123		2	108
Terapontidae																							
Pelates octolineatus	(Jenyns, 1840)	Western Striped Grunter		1	2						1												
Pelsartia humeralis	(Ogilby, 1899)	Sea Trumpeter													1								
Pleuronectiformes																							
Bothidae																							
Arnoglossus spp.[T]		Left Eye Flounder	2		1	22	23	13	11	15	12	4	5		1	1		3	2	1		1	1
Cynoglossidae																							
Cynoglossus broadhursti	Waite, 1905	Southern Tongue Sole											4										
Paralichthyidae																							
Pseudorhombus jenynsii	(Bleeker, 1855)	Smalltooth Flounder	8	1	6	3	2	3	7	4	9	4	4	2	9	3	8	12	2	5	20	12	14
Pleuronectidae																							
Ammotretis elongatus	McCulloch, 1914	Elongate Flounder																	1				
Soleidae																							
Zebrias cancellatus	(McCulloch, 1916)	Harrowed Sole			1																		
Tetraodontiformes																							
Diodontidae																							
Diodon nicthemerus	Cuvier, 1818	Globefish	2	3	4					2		9	2	5	21	9	1	13	2	4	2	7	5

Table 1. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Pisces Continued		fishes																					
Monacanthidae																							
Acanthaluteres spilomelanurus	(Quoy & Gaimard, 1824)	Bridled Leatherjacket	1	3	10				4		2											2	
Acanthaluteres vittiger	(Castelnau, 1873)	Toothbrush Leatherjacket	352	6	1		1	2			1				1								
Brachaluteres jacksonianus	(Quoy & Gaimard, 1824)	Southern Pygmy Leatherjacket	1					1		1	3									1			1
Eubalichthys mosaicus	(Ramsay & Ogilby, 1886)	Mosaic Leatherjacket					2			4			3						3			3	
Monacanthus chinensis	(Osbeck, 1765)	Fanbelly Leatherjacket	7	15	6		1	1	3	6	17	2	3		2	2			1			1	1
Scobinichthys granulatus	(Shaw, 1790)	Rough Leatherjacket	23						2		4				1							2	
Ostraciidae																							
Anoplocapros amygdaloides	Fraser-Brunner, 1941	Western Smooth Boxfish	44	22	54	7	3	6	11	5	6	7	6	3	44	24	15	16	3	9		3	9
Aracana aurita	(Shaw, 1798)	Shaw's Cowfish	2		1				2		2	2		1							1	1	
Tetraodontidae																							
Omegophora armilla	(Waite & McCulloch, 1915)	Ringed Toadfish	5	1	2			1	2		3			1		3	1				1	3	
unidentified - indeterminant[T]										2		1											

Appendix 2. continued

Table 2. Weights (g) of all taxa for each site and survey. Where, 1 refers to April/May 2007, 2 to October/December 2007 and 3 to February 2008.

			OWA			RSA			GIN			GIS			JVB			JPT			MGB		
Taxa	**Authority**	**Common Name**	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Porifera		sponges																					
Calcarea																							
Leucosolenida																							
Leucosolenida sp. C1										20												10	
Leucosolenida sp. C2										15													
Demospongiae																							
Hadromerida																							
Clionaidae																							
Spheciospongia cf. *papillosa*	(Ridley & Dendy, 1886)									1													
Suberitidae																							
Suberites sp. C1										1													
Tethyidae																							
Tethya cf. *ingalli*	(Bowerbank, 1858)			30						165	52		30	8		230	16	460				230	
Tethya cf. *robusta*	(Bowerbank, 1858)			50						25						170		60					
Tethya sp. C1				15			32																
Halichondrida																							
Halichondriidae																							
Ciocalypta sp. C1										2000	2100												
Poecilosclerida																							
Microcionidae																							
Holopsamma cf. *laminaefavosa*	Carter, 1885								50														
Holopsamma sp. C1			15				50		710	1080	1116					350		60		175			
Raspailiidae																							
Echinodictyum clathrioides	Hentschel, 1911															150							
Echinodictyum mesentarium	(Lamarck, 1814)					150						15						1350					
Coelosphaeridae																							
Coelosphaera sp. C1																		50					
Hymedesmiidae																							
Phorbas sp MF3									5														
Phorbas sp MF4																		200					
Phorbas sp. C1																		1100		200			
Phorbas sp. C2											750					150							
Tedaniidae																							
Tedania sp. C1																24							
Mycalidae																							
Mycale sp. C1													20						20				
Mycale sp. C2																				175			

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Porifera Continued																							
Haplosclerida																							
Callyspongiidae																							
Callyspongia sp. C1							250																
Callyspongia sp. MF3																						8	
Chalinidae																							
Haliclona (*Haliclona*) sp. C2										5			55										
Haliclona (*Reniera*) sp. C1										40			70										
Haliclona (*Reniera*) sp. C3											1390		3050										
Petrosiidae																							
Xestospongia sp. C1																200							
Dictyoceratida																							
Irciniidae																							
Ircinia sp. J1											1100							1400					
Sarcotragus sp. C1																1800							
Sarcotragus sp. C2																50							
Thorectidae																							
Semitaspongia sp. C1				700												1314	350						
Dendroceratida																							
Dictyodendrillidae																							
?*Acanthodendrilla* sp. C1																			10				
Igernella sp. C1											32					23							
unidentified sponge spp.[T]			10												22			3575			185		

Table 2. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Cnidaria																							
Anthozoa																							
Actiniaria		anemones																					
unidentified anemone sp.[T]																				10			
Alcyonacea		soft corals																					
unidentified soft coral spp.[T]																					50		
Ceriantharia		tube anemones																					
Cerianthidae																							
Pachycerianthus sp.												50								35	450	90	100
Pennatulacea		sea pens																					
Pennatulidae																							
Sarcoptilus grandis	Gray, 1848																						300
Sarcoptilus spp.[T]						225																	
Veretillidae																							
Cavernularia spp.[T]		orange sea pen	152.5	270	1825	675	5450	7582	156.5	2		30	370	37	1900	4550	9800	695	4900	8450	305	660	455
Scyphozoa		jellyfish																					
Rhizostomeae																							
Mastigiidae																							
Phyllorhiza punctata	Von Lendenfeld, 1884	Swan River Jellyfish							200														

Appendix 2. continued

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Arthropoda: Crustacea																							
Cirripedia		barnacles																					
Thoracica																							
Balanidae																							
Balanus trigonus																			10			1	
Malacostraca																							
Decapoda	(Darwin, 1854)																						
Penaeidae		prawns																					
Metapenaeopsis fusca	Manning, 1988				14		35	2		5	15	12	71	31		15	1		180	9	3	149	32
Metapenaeopsis lindae	Manning, 1988			10	10		143	118		155	43		252	18		22	3	1	265	25		180	4
Metapenaeopsis spp.[T]		velvet prawns	0.5			23			10.5						580			65					
Melicertus latisulcatus	(Kishinouye, 1896)	Western King Prawn	4900	1000	1450	13190	4689	1600	3900	10050	2250	4550	3500	3550	800		75	9900	1400	1950	3450	4450	1900
Alpheidae		snapping shrimps																					
Alpheus cf. *rapax*[1]	Fabricius, 1798															5			10				
Alpheus digitalis	De Haan, 1844						77	16		20			33	15					50	10		40	12.5
Alpheus pacificus	Dana, 1852			2																			
Galatheidae		squat lobsters																					
Galathea subsquamata?	Stimpson, 1858																	3					
Porcellanidae		porcelain crabs																					
Pisidia dispar	(Stimpson, 1858)			1																			
Diogenidae		hermit crabs																					
Calcinus dapsiles	Morgan, 1989						1																
Diogenes serenei?	Forest, 1956															1							
Diogenes sp.																1							
Dromiidae		sponge crabs																					
Fultodromia nodipes	(Guérin-Méneville, 1832)				6		8		2	25	11					50		12	20	150			
Leucosiidae		pebble crabs																					
Ebalia intermedia	Miers, 1886			2						5						5							
Majidae		decorator & spider crabs																					
cf. *Leptomithrax sternocostulatus*	(H. Milne Edwards, 1851)										6												
Dumea latipes	(Haswell, 1880)													2									
Ephippias endeavouri	Rathbun, 1918						1																
Hyastenus sebae	White, 1847			20						1						4			6				
Naxia aurita	(Latreille, 1825)				4																		
Rochinia cf. *fultoni*	(Grant, 1905)					5																	
Hymenosomatidae		spider crabs																					
Halicarcinus ovatus	Stimpson, 1838															0.5							

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Crustacea Continued																							
Portunidae		swimming crabs																					
Nectocarcinus integrifrons	(Latreille, 1825)										4												
Portunus pelagicus	(Linnaeus, 1758)		1350	8000	10350	13250	20650	10900	7900	24650	8500	14150	30250	6800	12700	11950	32850	11600	2850	8825	14750	22950	18890
Portunus rugosus	(A. Milne Edwards, 1861)		280		79	1750	650	203	520	190	509	648	180	210	1450	470	430	1050	399	113	258	520	540
Thalamita sima	H. Milne Edwards, 1834			40	43		48	100			73		122	11		340	283	50	76	55		256	10
Pilumnidae																							
Actumnus setifer	(De Haan, 1835)															2							
Heteropilumnus sp.																2							
Pilumnus fissifrons	Stimpson, 1858			5			1		0.5	3	11		2			5							
Pilumnus spp.[T]																1							
Stomatopoda		mantis shrimps																					
Squillidae																							
Belosquilla laevis	(Hess, 1865)			26	73	44	167	18		10	45	580	250	347		310	65	215	695	443	370	773	1650
Mollusca																							
Polyplacophora		chitons																					
Neoloricata																							
Chitonidae																							
Chiton sp.										2													
Acanthochitonidae																							
Cryptochiton sp.															2								
Bivalvia																							
Mytiloida																							
Mytilidae																							
Amygdalum glaberrima	(Dunker, 1856)	mussel				1		1															
Pterioida																							
Pteriidae		wing shells																					
Electroma georgiana ?	(Quoy & Gaimard, 1834)									10													
Pteria sp.									15														
Malleidae		hammer oysters																					
Malleus sp.									5									150					
Isognomonidae																							
Crenatula viridis ?	Lamarck, 1819	false pearl oyster							55		100								25				

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Mollusca Continued																							
Ostreoida																							
Pectinidae		scallops																					
Amusium balloti	(Bernardi, 1861)	Ballot's Saucer Scallop			13		100		30			40			200		15						
Mimachlamys asperrima	(Lamarck, 1819)	Doughboy Scallop			7									2									
Pecten fumatus	Reeve, 1852	Commercial Scallop			200					5													
Scaeochlamys livida	(Lamarck, 1819)				2	3			11		6			2			22						
Anomiidae																							
Monia sp.									5														
Veneroida																							
Pharidae		razor clams																					
Ensiculus cultellus	(Linnaeus, 1758).			22			10			2					2								
Gastropoda																							
Vetigastropoda																							
Fissurellidae		shield limpets																					
Scutus antipodes	Montfort, 1810																	5					
Turbinidae		pheasant shells																					
Phasianella australis	(Gmelin, 1791)			2																			
Sorbeoconcha																							
Ranellidae		triton shells																					
Cymatium (Monoplex) cf. *exaratum*	(Reeve, 1844)			5	14					10			2										
Cymatium (Monoplex) labiosum	(Wood, 1828)										7												
Cymatium parthenopeum	(von Salis, 1793)									1													
Muricidae		oyster drills																					
Bedeva paivae	(Crosse, 1864)			2			1	5		1	5			2		4	5				1		
Columbellidae		dove shells																					
Pyrene bidentata	(Menke, 1843)																					0.5	
Cephalaspidea		sea slugs																					
Philinidae																							
Philine spp.					7	5											4						
Aglajidae																							
Philinopsis troubridgensis	(Verco, 1909)														10								
Anaspidea																							
Aplysiidae		sea hares																					
Aplysia dactylomela	Reng, 1828		70	1150						220													
Stylocheilus striatus	(Quoy & Gaimard, 1832)									2													

Table 2. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Gastropoda continued																							
Notaspidea																							
Pleurobranchidae		side gill slugs																					
Berthella stellata	(Risso, 1826)												1										
Pleurobranchus peroni	Cuvier, 1804									450			450										
Nudibranchia		nudibranchs																					
Chromodorididae																							
Ceratosoma brevicaudatum	Abraham, 1876																			40			
Cephalopoda																							
Sepiida		cuttlefish																					
Sepiidae																							
Sepia apama	Gray, 1849	Giant Cuttlefish					4										150						
Sepia braggi	Verco, 1907	Bragg's Cuttlefish	285		30	115	2	21	60	40	59	180		47	130	50	11	185	78	26	60		38
Sepia novaehollandiae	Hoyle, 1909		540	50	563	1175	136	1350	1400	450	1800	270		1094	90	200	600	520	24	688	350		308
Sepiolida																							
Sepiolidae		bobtail squids																					
Euprymna tasmanica	(Pfeffer, 1884)	Southern Bobtail Squid	40		16	20	54	57	5	15	89		10	27	147	5		7	16	53	40	10	17
Sepiadariidae		bottletail squids																					
Sepiadarium austrinum	Berry, 1921	Southern Bottletail Squid				40	20	10	3	15	6	15	10		3			20			20	7	
Sepioloidea lineolata	(Quoy & Gaimard, 1832)	Striped Pyjama Squid	20			20		24	7	60	28				29	1			10				
Teuthida																							
Loliginidae																							
Sepioteuthis australis	Quoy & Gaimard, 1832	Southern Calamari Squid	1900	148	1180	232	193	190	71	60	759		30	504	375	895	850	65	181	116	34		117
Octopoda		octopuses																					
Octopodidae																							
?*Grimpella sp*.																		45					
Hapalochlaena sp.		blue ring octopus	10	20	2																		
Octopus sp.					150			250								210	50			200			
unidentified mollusc spp.[T]				2						1						3200			1		1		

Table 2. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Echinodermata																							
Crinoidea		featherstars																					
Comatulida																							
Antedonidae																							
Dorometra nana	(Hartlaub, 1890)					0.5																	
Dorometra parvicirra	(Carpenter, 1888)														5			111					
Comasteridae																							
Comanthus parvicirrus	(Müller, 1841)								0.5														
Comanthus wahlbergi	(Müller, 1843)																			300			
Comatula pectinata	(Linnaeus, 1758)			10	7		17		1	1													
Comatula purpurea	(Müller, 1843)			10	21	26	2	7	0.5	14	5			2		5		435		21	1		
Asteroidea		seastars																					
Paxillosida																							
Luidiidae																							
Luidia australiae	Döderlein, 1920		450	3700	3300	1490	755	1200	150	900	1950	580	300	250	1200				400	100	300		
Astropectinidae																							
Astropecten preissi	Müller & Troschel, 1843		20	2150	935	420	400	375	50	500	750	480	550	600	180		221	100	150	450	1240	750	1290
Valvatida																							
Archasteridae																							
Archaster angulatus	Müller & Troschel, 1842		4				100																
Goniasteridae																							
Stellaster inspinosus	H.L. Clark, 1916		750	900	1500	1550	236	175	1350	1930	1950												
Oreasteridae																							
Anthenea australiae	Döderlein, 1915										100								250				
Goniodiscaster seriatus	(Müller & Troschel, 1843)			30	21						100			50									
Asterinidae																							
Meridiastra gunnii	(Gray, 1840)			20			2																
Nepanthia crassa	(Gray, 1847)					30																	
Forcipulatida																							
Asteriidae																							
Coscinasterias muricata	Verrill, 1867							2			1	2				11		11					

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Echinodermata continued																							
Ophiuroidea		brittlestars																					
Ophiurida																							
Ophiotrichidae																							
Macrophiothrix spongicola				12	14	11	8	5	2.5	23	13	3	4		5	162	5	51	32	7		10	
Ophiothrix caespitosa												0.5											
Ophiothrix ciliaris										1										1			
Ophiodermatidae																							
Ophiopsammus assimilis				21	11		5																
Ophiuridae																							
Ophiura kinbergi				2	4	1	1	4		5	3		5	8	1.5				1	1			
Echinoidea		urchins																					
Clypeasteroida																							
Laganidae																							
Peronella lesueuri	(Valenciennes, 1841)		50	270	150		100			100					1200	8750	800						
Echinoida																							
Temnopleuroida																							
Temnopleuridae																							
Temnopleurus michaelseni	(Döderlein, 1914)			7	15	10	7	5		30	7	9	51	62	32	100	1	16	77	7			
Toxopneustidae																							
Nudechinus scotiopremnus	H.L. Clark, 1912				5																		
Spatangoida																							
Loveniidae																							
Echinocardium cordatum	(Pennant, 1777)			10		5				12			13					5	93				
Holothuroidea		sea cucumbers																					
Dendrochirotida																							
Cucumariidae																							
Cercodema anceps	Selenka, 1867		175	1750	135	350	1050	600	1570	1160	1554	199	805	96	50	255		490					
Colochirus quadrangularis	Troschel, 1846		500	10100	3250	200	1050	300	3000	2365	1498	1915	90			100		450		150			
Sclerodactylidae																							
Cladolabes schmeltzii	(Ludwig, 1875)			275																			
Aspidochirotida																							
Stichopodidae																							
Stichopus mollis	(Hutton, 1872)											350				150	250	900	100	650			

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Chordata																							
Ascidiacea		ascidians																					
Pleurogona																							
Pyuridae																							
Herdmania sp.[T]				1600	479		350			2340	1109	1970	5550			2300		1200		850	750		
ascidian spp. - colonial[T]				45	14	20		6	24	11	27	130	43	32		1		90	190			14	
ascidian spp. - solitary[T]			100	100	14	360	45	34	6	760	247	610	102	24	400	130		26650	2050	425		3275	
Pisces		fishes																					
Heterodontiformes																							
Heterodontidae																							
Heterodontus portusjacksoni	(Meyer, 1793)	Port Jackson Shark	3897	469	2650	650	600	650	750	1220	1750	950	350	1200	4650	950		6450	1000			1200	4850
Rhinobatiformes																							
Rhinobatidae																							
Aptychotrema vincentiana	(Haacke, 1885)	Western Shovelnose Ray									250												
Trygonorrhina fasciata	Müller & Henle, 1841	Southern Fiddler Ray	900		550	3600		1400	2000	900	3350	5400	3900	3200		250				300		3400	
Rajiformes																							
Dasyatidae																							
Dasyatis brevicaudata	(Hutton, 1875)	Smooth Stingray								150000					12650			9900		4360			
Dasyatis thetidis	Ogilby, 1899	Black Stingray	17950				1100						25200										
Urolophidae																							
Trygonoptera mucosa	Müller & Henle, 1841	Western Shovelnose Stingaree			450																		450
Trygonoptera testacea	Whitley, 1939	Common Stingaree		350	450																		
Urolophus paucimaculatus	Dixon, 1969	Sparsely-spotted Stingaree	2400		315		350		400	400	750	550											
Myliobatidae																							
Myliobatis australis	Macleay, 1881	Southern Eagle Ray			5550	16350	650	7150		5150	10	11250	19150	4000	13050	5150	12100	4650	16450	6700		42850	21790
Clupeiformes																							
Clupeidae																							
Sardinops neopilchardus	(Ogilby, 1897)	Australian Sardine							86														
Spratelloides robustus	(Jenyns, 1842)	Blue Sprat								17													
Engraulidae																							
Engraulis australis	(Shaw, 1790)	Australian Anchovy				46		22	102		36	84	23	20			10	36		13	81	20	
Siluriformes																							
Plotosidae																							
Cnidoglanis macrocephalus	(Valenciennes, 1840)	Estuary Cobbler		27																			
Plotosus lineatus	(Thunberg, 1791)	Striped Catfish																11					
Lophiiformes																							
Antennariidae																							
Antennarius striatus	(Shaw, 1794)	Striate Anglerfish									-												

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Pisces Continued																							
Gadiformes																							
Moridae																							
Eeyorius hutchinsi	Paulin, 1986	Finetooth Beardie							29														
Beloniformes																							
Hemiramphidae																							
Hyporhamphus melanochir	(Valenciennes, 1847)	Southern Garfish				7			1	12			45		21		14	16	15	7	4	17	35
Atheriniformes																							
Atherinidae																							
Atherinomorus vaigiensis	(Quoy & Gaimard, 1825)	Common Hardyhead											10										
Lampriformes																							
Veliferidae																							
Metavelifer multiradiatus	(Regan, 1907)	Common Veilfin	225		45			8	11		38	19		9							24		
Gasterosteiformes																							
Pegasidae																							
Pegasus volitans	Linnaeus, 1758	Slender Seamoth	21	31	83	10	89	4	4	17	4		4	4	4	31	17	43	126	12	40	31	2
Syngnathidae																							
Hippocampus subelongatus	Castelnau, 1873	West Australian Seahorse			5				1	2			3		3			1		5			
Scorpaeniformes																							
Aploactinidae																							
Kanekonia queenslandica	Whitley, 1952	Deep Velvetfish																		2.38			2
Triglidae																							
Chelidonichthys kumu	(Lesson, 1826)	Red Gurnard	129		1850	142	171		181		236											4	
Lepidotrigla papilio	(Cuvier, 1829)	Spiny Gurnard	373	18	199	754	1038	1020	1206	771	1050	298	64	335	601	279	326	280	156	348	95	162	87
Neosebastidae																							
Maxillicosta scabriceps	Whitley, 1935	Little Gurnard Perch	8		24		3	5	13	30	37			4	32	309	101	4	3	2		6	
Neosebastes pandus	(Richardson, 1842)	Bighead Gurnard Perch	450	1250																			
Platycephalidae																							
Inegocia japonica	(Tilesius, 1812)	Rusty Flathead	34	46	347	518	117	549	1022	239	685	254	321	1021	31			133	164	162	200	238	553
Onigocia spinosa	(Temminck & Schlegel, 1843)	Midget Flathead	81		203	62	232	113	194	275	358	33	98	187	154	32	24	20	49	33	57	271	318
Platycephalus endrachtensis	Quoy & Gaimard, 1825	Yellowtail Flathead		87	786																		
Platycephalus longispinis	Macleay, 1884	Longspine Flathead	338			126	125.23	327	882	2215	1629							58					
Platycephalus speculator	Klunzinger, 1872	Southern Bluespotted Flathead					98			40											21		
Tetrarogidae																							
Gymnapistes marmoratus	(Cuvier, 1829)	Soldier	18	114	161	100	30	51		72	367	10	14	139				7	5			21	38

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Pisces Continued		fishes																					
Perciformes																							
Apogonidae																							
Apogon rueppellii	(Ogilby, 1886)	Western Gobbleguts	906	114	311	216	342	166	1341	836	407	349	594	390	45	22	65	277	95	374	463	922	1477.8
Siphamia cephalotes	(Castelnau, 1875)	Wood's Siphonfish																					1
Siphamia roseigaster	Günther, 1859	Pinkbreast Siphonfish																					0.51
Callionymidae																							
Dactylopus dactylopus	(Valenciennes, 1837)	Finger Dragonet													7								
Pseudocalliurichthys goodladi	(Whitley, 1944)	Longspine Dragonet	3262	432	1634	1768	3756	4993	4289	3272	11374	1806	725	4039	319	194	61	826	1062	135	1316	1956	1287.8
Carangidae																							
Pseudocaranx georgianus	(Cuvier, 1833)	Sand Trevally	2519		937	1171		134	22	8	307	68		493	47		497	31		104	9		106.8
Pseudocaranx wrighti	(Whitley, 1931)	Skipjack Trevally	9025		711	11287	4419	5081	751	3223	8258	4379	5681	5432	59		13	125	141	234	292		833.5
Seriola hippos	Günther, 1876	Samsonfish	83				16								40	20		43					
Trachurus novaezelandiae	Richardson, 1843	Yellowtail Scad	82								56						65						
Clinidae																							
Cristiceps australis	Valenciennes, 1836	Southern Crested Weedfish		3.1																			
Gerreidae																							
Parequula melbournensis	(Castelnau, 1872)	Silverbelly	6901	404	993	27			578	279	167				58		107	5		38	110	21	2
Gobiidae																							
Acentrogobius pflaumii[1]	(Bleeker, 1853)	Streaked Goby					6.5			4													
Labridae																							
Notolabrus parilus	(Richardson, 1850)	Brownspotted Wrasse																200					
Mullidae																							
Upeneichthys vlamingii	(Cuvier, 1829)	Bluespotted Goatfish	1769	262	436	6			386	118	194			64	49		7		21				5
Upeneus asymmetricus ?[2]	Lachner, 1954	Asymmetric Goatfish			72				8														
Upeneus spp.[T]		Goatfish species	584	54	101		37		35	13	143						1	10		4		46	
Upeneus tragula	Richardson, 1846	Bartail Goatfish							24														

Table 2. continued.

Taxa	Authority	Common Name	OWA 1	OWA 2	OWA 3	RSA 1	RSA 2	RSA 3	GIN 1	GIN 2	GIN 3	GIS 1	GIS 2	GIS 3	JVB 1	JVB 2	JVB 3	JPT 1	JPT 2	JPT 3	MGB 1	MGB 2	MGB 3
Pisces Continued		fishes																					
Nemipteridae																							
Pentapodus vitta	Quoy & Gaimard, 1824	Western Butterfish	2484	511	365	14	27	45	537	380	353	145	41	66		28	2	22	33		8	46	
Odacidae																							
Neoodax balteatus	(Valenciennes, 1840)	Little Weed Whiting		25	19		18			14	16		20	15							20	31	
Pempheridae																							
Pempheris klunzingeri	McCulloch, 1911	Rough Bullseye	13		62			9	12			935			22			139					
Pinguipedidae																							
Parapercis haackei	(Steindachner, 1884)	Wavy Grubfish	13	9	3	22	63	15	14	13	12		24		57	34		4	8		3	37	9
Pomatomidae																							
Pomatomus saltatrix	(Linnaeus, 1766)	Tailor			300		88			47				149					190				
Sillaginidae																							
Sillago bassensis	Cuvier, 1829	Southern School Whiting	3166	82	1658			506	258			55			1112		646	12					
Sillago burrus	Richardson, 1842	Western Trumpeter Whiting	599	303	2009	686	722	1280	1716	532	5587	1528	66	1279	24			204	85	121	454	124	1066.9
Sillago vittata	McKay, 1985	Western School Whiting	75				25		9	25		11			25								
Sparidae																							
Pagrus auratus	(Bloch & Schneider, 1801)	Snapper	25		48			1672			3692		4	175		7	105	83	25	1270		14	873
Terapontidae																							
Pelates octolineatus	(Jenyns, 1840)	Western Striped Grunter		93	144						114												
Pelsartia humeralis	(Ogilby, 1899)	Sea Trumpeter													50								
Pleuronectiformes																							
Bothidae																							
Arnoglossus spp.[T]		Left Eye Flounder	44		18	171	194	99	82	143	80	26	30		16	7		24	10	8		11	4
Cynoglossidae																							
Cynoglossus broadhursti	Waite, 1905	Southern Tongue Sole											16										
Paralichthyidae																							
Pseudorhombus jenynsii	(Bleeker, 1855)	Smalltooth Flounder	1289	150	562	291	285	53	1013	824	324	512	718	27	421	350	333	1019	49	62	1120	1400	438.2
Pleuronectidae																							
Ammotretis elongatus	McCulloch, 1914	Elongate Flounder																	26				
Soleidae																							
Zebrias cancellatus	(McCulloch, 1916)	Harrowed Sole			21																		
Tetraodontiformes																							
Diodontidae																							
Diodon nicthemerus	Cuvier, 1818	Globefish	900	2100	2150					1100		2250	400	852	13350	3759	500	7600	1500	1600	525	4300	2950

Table 2. continued.

Taxa	Authority	Common Name	OWA			RSA			GIN			GIS			JVB			JPT			MGB		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Pisces Continued		fishes																					
Monacanthidae																							
Acanthaluteres spilomelanurus	(Quoy & Gaimard, 1824)	Bridled Leatherjacket	7	15.34	88				56		14											24	
Acanthaluteres vittiger	(Castelnau, 1873)	Toothbrush Leatherjacket	3291	29.27	3.14		11	28			12				6								
Brachaluteres jacksonianus	(Quoy & Gaimard, 1824)	Southern Pygmy Leatherjacket	6					2		14	15									1			4
Eubalichthys mosaicus	(Ramsay & Ogilby, 1886)	Mosaic Leatherjacket					21			95			46						34			32	
Monacanthus chinensis	(Osbeck, 1765)	Fanbelly Leatherjacket	77	144	71		50	23	27	156	98	19	43		6	36.3			12			9	14
Scobinichthys granulatus	(Shaw, 1790)	Rough Leatherjacket	151						34		87				46							24	
Ostraciidae																							
Anoplocapros amygdaloides	Fraser-Brunner, 1941	Western Smooth Boxfish	12090	5450	16250	2470	550	2450	3750	1950	1767	2350	2250	1300	13400	6250	4650	5700	750	2650		975	2650
Aracana aurita	(Shaw, 1798)	Shaw's Cowfish	700		450				500		327	33		119							45	150	
Tetraodontidae																							
Omegophora armilla	(Waite & McCulloch, 1915)	Ringed Toadfish	281	56	88			23	350		108			40		55	27				83	114	
unidentified - indeterminant[T]										70		1											