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Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary

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Fish for the future

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Fisheries Research in Western Australia

The Fisheries Research Division of the Department of Fisheries is based at the Western Australian Fisheries and Marine Research Laboratories, PO Box 20, North Beach (Perth), Western Australia, 6920. The Fisheries and Marine Research Laboratories serve as the centre for fisheries research in the State of Western Australia.

Research programs conducted by the Fisheries Research Division and laboratories investigate basic fish biology, stock identity and levels, population dynamics, environmental factors, and other factors related to commercial fisheries, recreational fisheries and aquaculture. The Fisheries Research Division also maintains the State data base of catch and effort fisheries statistics.

The primary function of the Fisheries Research Division is to provide scientific advice to government in the formulation of management policies for developing and sustaining Western Australian fisheries.

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Summary

This report synthesises data from the commercial and recreational fisheries of the Swan-Canning Estuary (hereafter Swan Estuary), as well as relevant biological and environmental data. This information is used to provide an overview of the fisheries, assess the current status of important stocks and highlight changes in the abundances of various fish species in the estuary over recent decades.

Blue swimmer crab is currently the largest component of both commercial and recreational landings and the most valuable component of commercial landings in the Swan Estuary. From 1995 to 2004, commercial crab catches averaged 19 t per year. The 2000/01 recreational crab catch was estimated to be 33 t. This suggests that the recreational sector has recently taken ~63% of the total annual crab catch (by weight). The recreational crab catch has probably been of a similar or greater magnitude to the commercial crab catch in the Swan Estuary since the 1970s.

From 1995 to 2004, commercial finfish catches averaged 36 t per year. The 2000/01 recreational catch of finfish was estimated to be 28 t. This suggests that the recreational sector has recently taken ~45% of the total finfish catch (by weight) in the Swan Estuary. However, over this 10 year period, commercial landings of finfish declined considerably, and so in latter years the recreational catch of finfish has been >50%. Black bream is currently the most commonly retained finfish species in the recreational fishery. The majority (>80% by weight) of black bream in the Swan Estuary are taken by recreational fishers.

From 2000 to 2004, the commercial fishery in the Swan Estuary had 4 licensees. In these years, the commercial fishery retained about 15 species per year. The main species in commercial landings were blue swimmer crabs, sea mullet, Perth herring, black bream, yellow-eye mullet and tailor. Minor commercial species included yellowfin whiting, Australian herring, mulloway, bar-tail flathead, small-tooth flounder, yellowtail scad, tarwhine and yellowtail trumpeter.

Recreational fishery landings in the Swan Estuary are more diverse than commercial landings, although there were also about 15 common species retained in recent catches (not including blowfish which is the most commonly caught species). The main species in recreational landings were blue swimmer crabs, black bream, Australian herring, tailor and bar-tail flathead. Minor recreational species included yellowfin whiting, small-tooth flounder, tarwhine, yellowtail trumpeter, six-lined trumpeter, garfish, mulloway, cobbler, yellowtail scad, pink snapper and trevally. Many of the yellow eye-mullet, mulloway and yellowtail scad retained by recreational fishers are juveniles. Limited data is available on the discarded component of the recreational catch, but it is likely to include juveniles of various other species including trevally, tailor and black bream.

Although many species are common to both recreational and commercial landings, there appear to be few sources of conflict over the current allocation of fishery resources in the estuary. The vast majority of the recent commercial catch comprised crabs, sea mullet, Perth herring and black bream. Of these species, only black bream and crabs are targeted by recreational fishers. Since 1990, the catch rate of black bream has increased and the catch rate of crabs has been stable which suggests that availability of these species to each sector is adequate.

Commercial and recreational fishery catch trends suggest marked changes in the abundance of numerous fish species in the Swan Estuary since 1990 or earlier. The annual commercial finfish catch steadily declined between 1975 and 2000. Catch declines are partly due to declines in effort and declines in targeting of certain species. However, environmental factors and fishing pressure

are also likely to have impacted on stocks and led to real declines in fish abundance in the Swan Estuary. After 1990 the total annual finfish commercial CPUE declined, the species composition of the finfish catch changed considerably and crabs became the main focus of the fishery.

Commercial and recreational fishery catch trends suggest that cobbler, Western school prawn and Perth herring stocks in the Swan Estuary have declined significantly over a period of decades. Sea mullet, yellow-eye mullet, Australian herring and yellowtail trumpeter may also have declined in abundance in the estuary.

Fishery catch trends suggest that blue swimmer crabs, black bream, tarwhine, yellowtail scad and blowfish have increased in abundance in the Swan Estuary since 1990. Bar-tail flathead, tailor, flounder and six-lined trumpeter appear to have experienced stable or fluctuating long-term abundance. The catch rates of these latter three species, and also Australian herring, appear to be influenced by strong fluctuations in recruitment.

The impact of environmental factors are likely to be at least as significant as the impact of fishing pressure on stock abundances in the Swan Estuary. The estuary and its catchment have been highly modified since European settlement. Often the ecological impacts of these changes are unclear, but it is reasonable to assume that widespread losses of aquatic habitat, the input of contaminants, reduced freshwater flows and deepening of the estuary mouth have altered the composition of the fish community and been detrimental to numerous estuarine-dependant species. A reduction in water quality has caused many recent 'fish kills' and probably also had other less obvious impacts on fish.

In 2003, a persistent bloom of the toxic dinoflagellate, Karlodinium micrum*, resulted in widespread kills of fish and invertebrates in the upper Swan Estuary. This was the largest recorded fish kill in the estuary. Affected species included black bream, Perth herring, Swan River goby, flathead, mulloway, flounder and mullet. Anecdotal reports suggested that various juvenile fish, crabs, prawns and bait worms were also affected. In 2004 and 2005, K. micrum blooms again caused fish kills in the estuary, suggesting that these may be regular events in the near future.*

Fish kills in the Swan Estuary have tended to occur during summer/autumn in the upper estuary. Therefore, fish that typically occur in this season/location are at highest risk. Fish kills are likely to impact most severely on species that exist as discrete, self-replenishing populations within the estuary and spend a significant part of their life cycle (including eggs, larvae, juveniles and/or adults) in the upper estuary. Species that aggregate to breed in the upper estuary in summer/autumn are particularly vulnerable, including black bream, Perth herring, bar-tailed flathead and yellowtail trumpeter. Other species are likely to be indirectly affected through loss of prey and forced redistribution within the estuary.

Historically, assessments of fish stocks in the Swan Estuary have relied on catch and effort data from the commercial fishery. A significant reduction in the number of commercial fishers has reduced the amount of annual data now available, although the fishery still yields valuable information for stock assessments of some species. Cessation of commercial fishing in the estuary in the near future would be problematic because an alternative, ongoing data source is yet to be established. In future, annual data on the relative abundance and size structure of many stocks could be provided by recreational fishers, from either angling club catch records or angler logbooks. Such data is complementary to creel/phone survey estimates of total catch and effort in the estuary.

Future monitoring of fish communities in the Swan Estuary should include a combination of methods including annual fishery catch and effort data, regular recreational fishery surveys and occasional fishery-independent surveys. Independent surveys would be a desirable component of any future monitoring strategy, providing validation of fishery data and also collecting information about juveniles of target species and the status of non-fishery species, which are important to the ecological function of the estuary.

1.0 Introduction

Assessments of fish stocks in the Swan-Canning Estuary (hereafter Swan Estuary) have historically relied on catch and effort data from the commercial fishery. However, there have been very significant changes in recent decades that have made commercial data less useful for this purpose. Since 1975, commercial catch and effort levels in the estuary have steadily declined, while recreational catches have increased. Recreational catches of many species now exceed commercial catches of the same species. Although data from the commercial fishery are still valuable because they provide a long time series of information and are the only available index of abundance for some species, the commercial catch is no longer representative of total fishery landings and is no longer the major source of fishing mortality in the Swan Estuary. Recreational catch and effort data must now be included in stock assessments in the Swan Estuary.

Recreational catch and effort data in this estuary have mainly become available since the mid-1990s and a significant amount of recreational data is now available from various sources (Malseed and Sumner 2001, Henry and Lyle 2003, this report). The inclusion of recreational data in assessments not only provides a more representative picture of total catch, but also overcomes some of the historical limitations of commercial data, such as being restricted to the middle estuary (the commercial fishery area) and being restricted to commercial target species.

In the interpretation of recreational and commercial fishery catch trends, consideration must be given to the impact of environmental factors, which are likely to be at least as significant as the impact of fishing pressure in the Swan Estuary. The estuary and its catchment have been highly modified since European settlement. Unfortunately, the lack of long-term biological monitoring in the estuary makes it very difficult to separate the impacts of fishing and non-fishing factors on fish stocks. Many physical changes (e.g. dredging) are well documented in the historical literature (e.g. Riggert 1978), although the ecological impacts of these changes are less clear. It is reasonable to assume that widespread losses of aquatic habitat, the input of contaminants, reduced freshwater flows and deepening of the estuary mouth have altered the composition of the fish community and been detrimental to numerous estuarine-dependant species. A reduction in water quality has caused many ‘fish kills’ over a period of decades and probably also had other less obvious impacts on fish.

Section 2 of this report summarises some of the environmental factors that are likely to have impacted on fish stocks in the Swan Estuary in recent decades. Eutrophic conditions in the estuary have caused numerous algal blooms and several major fish kills recently and so this report focuses particularly on the impacts of these factors on fish stocks. Sections 3-5 summarise catch and effort data from the commercial and recreational fisheries of the estuary, with an emphasis on data collected since 1975. Some of these data have not previously been reported. A summary of catch and effort prior to 1975 can be found in Lenanton (1978, 1984). Section 6 includes an assessment of the status of the key fishery stocks in the Swan Estuary, using environmental and biological information together with fishery catch and effort trends.

2.0 Environmental factors affecting fish in the Swan-Canning Estuary

2.1 Environmental changes since European settlement

The Swan-Avon River drains the largest catchment in Western Australia (~121,000 km^2) (Pen 1999). The 'estuary' (i.e. tidal sections) occupies an area of approximately 53 km^2 (SRT 2001).

The Swan Estuary and its catchment have been highly modified since European settlement in 1829. Upstream of the estuary, much of the catchment and freshwater environments are now in poor condition. 'River training' (straightening and dredging of channels) along 187 km of the Avon River was conducted from the mid-1950s to early 1970s to increase maximum flow rates and reduce flooding (Harris 1996). As a result, much sediment was mobilised and fish habitat was lost (instream and bank vegetation was cleared, woody debris was removed, river pools filled with sediment). The Avon catchment is ~70% cleared. This has led to rising groundwater, increased runoff, higher maximum flows, sedimentation, eutrophication and salinisation. Most sections of the Avon River and its tributaries are now brackish or saline (Pen 1999).

Freshwater input to the Swan Estuary has been dramatically reduced since settlement. In particular, Mundaring Weir (Helena River) was completed in 1902 and the Canning Dam was completed in 1940. Climate change has further reduced freshwater input to the estuary, with a marked reduction in annual rainfall since the 1970s. The average annual inflow to Perth dams from 1975 to 2003 was equal to only 49% of the average inflow from 1911 to 1974 (Water Corporation data). In future, the pressure to divert surface and groundwater resources away from the river is likely to increase with human population growth and continuing low rainfall.

In addition to reduced rainfall and diversion of flows, both of which have reduced freshwater input, entrance modifications have acted to create a more 'marine' (saline) environment within the estuary. Increased flushing and tidal range resulted after a limestone bar at the entrance was removed to construct Fremantle Harbour in 1897. The entrance is now dredged to a depth of 13 m, although the original entrance depth was only 2 m. For >100 years, a railway bridge at North Fremantle inadvertently functioned as a weir, restricting outflow, but this was removed in 1968 (Riggert 1978). Before removal of the bar, most of the estuary was fresh or brackish (Thomson *et al.* 2001).

The Swan Estuary has been affected by various contaminants including pesticides, petroleum products and heavy metals. Heavy metals tend to remain in sediments for long periods and also bioaccumulate (Gerritze *et al.* 1998). Past and present sources of metal contamination include urban and agricultural runoff, rubbish tip leachate and antifouling paints (Riggert 1978). Recently, the disturbance of acid-sulphate soils along the foreshore of the upper estuary has emerged as another potential source of heavy metal contamination (Department of Environment 2004).

Eutrophication is a major environmental problem in the Swan Estuary and has been occurring since settlement. Past and present anthropogenic sources of nutrients include seepage from foreshore rubbish tips and septic tanks, urban stormwater runoff, nutrients from agricultural and urban fertilisers, effluent from tanneries, abattoirs, breweries, laundries and fertiliser factories (Riggert 1978). Treated sewage effluent was discharged from Burswood Island from 1912 to 1936. The symptoms of eutrophication (poor water quality, macroalgal blooms) were most evident during the 1950s and 60s and have since lessened. However, nutrient input remains relatively high and blooms of phytoplankton, macroalgae and exotic weeds continue to occur. The Ellen Brook catchment is currently one of the major sources of nutrients to the estuary (Gerritse *et al*. 1998, SRT 2000a).

The problem of eutrophication has been exacerbated by the loss of foreshore and aquatic vegetation, which would otherwise absorb some of the nutrients. Approximately half of the foreshore of the middle estuary has been altered (Riggert 1978). Extensive areas of mudflats along the shoreline have been reclaimed; creeks and swamps have been replaced by channels and pipes; many areas have been dredged to improve navigation or provide spoil for reclamation; wash from boat traffic has eroded river banks; many retaining walls have been built (mostly prior to the 1940s) to reclaim land, build roads, bridges, etc. All of these works have contributed to a loss of natural vegetation and fish habitat.

2.2 Phytoplankton blooms and fish kills

Although eutrophication and algal blooms are not the only environmental threats to fish in the Swan Estuary, special consideration is given to these issues here because of the potentially large and immediate impacts on some stocks from associated fish kills. Recent changes in catchment management have attempted to reduce nutrient input to the catchment but, even if successful, eutrophic conditions in the estuary are likely to continue for decades. Therefore, major algal blooms and fish kills, such as occurred in 2003, are likely to reoccur.

Bloom-forming species of phytoplankton, including green algae, diatoms, dinoflagellates and blue-green algae, are typically present in the river at low densities and only form blooms under favourable conditions. Some species bloom predictably on a seasonal basis, while others tend to bloom only occasionally. Not all blooms are harmful to fish or other organisms.

Nuisance blooms (and resultant fish kills) tend to occur shortly after storm events in summer or autumn, when organic material is transported from the catchment into the estuary. This creates favourable bloom conditions, i.e. high nutrients, warm water and low flow. The intensity and frequency of nuisance blooms and fish kills may have increased in recent decades due to the input of anthropogenically-derived nutrients from the catchment. However, comprehensive records of the timing and magnitude of fish kills in south-western Australian estuaries were not kept until quite recently (T. Rose, Department of Environment, pers. comm.). Therefore, the cause of previous fish kills and trends in frequency are unclear.

Asphyxiation is the typical cause of fish deaths during a bloom, via several mechanisms including i) anoxic or hypoxic conditions arising from consumption of dissolved oxygen during bloom development and/or decomposition; ii) physical clogging of gills by algal cells; iii) damage to gill surfaces by toxins, particularly those produced by dinoflagellates and blue-green algae.

To date, no comprehensive, quantitative surveys of fish kills have been conducted in the Swan Estuary. The available data about recent fish kills focuses on larger species of fish, with little data available to assess impacts on small fish or invertebrates. Lack of data should not be interpreted as evidence for a lack of impact. Anoxic conditions and algal toxins, which are common causes of local fish kills, are likely to kill a wide range of gill breathing organisms including many small fish and invertebrates. For example, a quantitative survey of a fish kill in the nearby Serpentine River (Peel-Harvey Estuary) in February 2004, found that anoxic conditions killed at least 17 species of finfish and at least 1 species of crustacean. Dead finfish ranged from <10 mm to >400 mm in length (Smith *et al*. 2004).

A summary of recorded fish kills associated with algal blooms in the upper Swan Estuary, from 1978 to 1994, can be found in Hosja and Deeley (1994). A summary of more recent fish kills is listed in Table 1. The main causes of fish kills have been algal blooms and chemical spills. Regardless of cause, major fish kills have tended to occur during summer/autumn (January to May) in the upper estuary (i.e. upstream of Heirisson Island in the Swan River and in the upper Canning River) (Fig. 1). Therefore, this season/location has the highest likelihood of future kills and species that occur here are at the highest risk.

2.3 *Karlodinium micrum* bloom and fish kill, April-June 2003

From April to June 2003, a persistent bloom of the toxic dinoflagellate, *Karlodinium micrum*, resulted in widespread kills of fish and invertebrates in the upper Swan Estuary. To date, this is the largest recorded fish kill in the estuary.

K. micrum is a marine species well adapted to estuarine conditions. Cells possess a flagella (tail-like structure) that assists them to migrate vertically through the water column. This allows them to exploit optimum conditions of light, temperature, salinity and nutrients at various depths. *K. micrum* photosynthesises, and so uses sunlight to convert nutrients to energy. When nutrients (mainly N or P) are in short supply, it can also prey on other algal species to obtain energy. *K. micrum* may also produce a toxin that prevents other algal species from consuming it. The environmental cue that prompts toxin production is unclear.

K. micrum blooms have been recorded at various locations around the world and are characterised by an oily scum floating on the surface and a fishy smell. Under bloom conditions, *K. micrum* is harmful to fish because cells clog the gills and the toxin destroys blood vessels, especially in the gills. Both effects result in asphyxiation of fish. In smaller fish, other areas of the body are also damaged by the toxin. *K. micrum* is likely to also affect other gill-breathing organisms such as crustaceans and molluscs.

K. micrum was not detected in the Swan Estuary until 2003. However, this species may previously have been present in the estuary at low levels, not detectable in routine phytoplankton monitoring. In April 2003, a *K. micrum* bloom commenced in the Maylands area of the estuary. It spread upstream and also spread downstream to Perth Water and the Canning River. Unusual background conditions contributed to the bloom – several rainfall events between February and May transported pulses of nutrients (particularly soluble oxidised nitrogen) into the river. A large rainfall event in April triggered the bloom. A period of calm, sunny weather from April to June provided ideal conditions for algal growth. May was unusually warm. The bloom ended in mid-June, when several weeks of rain reduced salinity levels in the estuary and caused the bloom to collapse. *K. micrum* has a low tolerance to freshwater.

During the 2003 bloom, an estimated 200,000 individuals of black bream (*Acanthopagrus butcheri*) were collected by the Swan River Trust Cleanup Program. Public reports about the fish kill focused on black bream because individuals are relatively large, conspicuous and of high fishery value, but other species were also affected. Large numbers of Perth herring (*Nematolosa vlaminghi*) and Swan River gobies (*Pseudogobius olorum*), and smaller numbers of bar-tailed flathead (*Platycephalus endrachtensis*), mulloway (*Argyrosomus japonicus*), small-toothed flounder (*Pseudorhombus jenynsii*) and mullet (*Mugilidae*) were reported dead but not collected. Anecdotal reports suggested that juvenile fish, crabs, prawns and bait worms were also killed. A total of 7.8 t of dead fish were collected during the clean up operation. This figure is an underestimate of the total quantity of fish affected, because only those fish that floated to the surface or to the sides of the river were collected. Significant quantities may have remained in deeper water, or been consumed by scavenging birds and crabs. Also, small fish are likely to have decomposed before the opportunity arose to collect them. Therefore, semi-quantitative data collected during the clean up operation provided an underestimate of the total species and number of fish affected.

Annual blooms of *K. micrum* in the Swan Estuary and regular fish kills now appear likely, as evidenced by the high cell densities of *K. micrum* that were recorded in summer/autumn of 2004 and 2005 (Swan River Trust data). Cell densities in 2004 and 2005 were higher than in 2003 and, although a toxic bloom did not form in these years, fish kills still occurred due to de-oxygenation of the water.

Other south-west estuaries are also at risk of regular fish kills due to *K. micrum*. A bloom of *K. micrum* was responsible for fish deaths in the Collie River in early June 2003, at approximately the same time as the bloom in the upper Swan Estuary.

Many fish species are likely to be directly or indirectly impacted by *K. micrum* blooms. Mortality of prey species may subsequently reduce food availability for other species not directly killed by the bloom. Alternatively, mortality of predators may benefit some prey species. Also, many fish swim away from, or avoid, areas of high *K. micrum* cell densities (F. Valesini, Murdoch University, unpubl. data). Therefore, phytoplankton blooms not resulting in fish kills may still impact on fish and fisheries. For example, fishery catch rates in bloom-affected areas may be reduced while catch rates in unaffected areas may be elevated.

2.4 Seasonal patterns in water quality and phytoplankton

A major factor affecting the abundance and distribution of phytoplankton in the Swan Estuary, and also the migration and distribution patterns of many fish, is the movement of a salt wedge, which underlies fresh surface waters and extends furthest upstream in summer (Kurup *et al.* 1998). Coinciding with the movement of the salt wedge are seasonal changes in river flow, temperature, salinity, turbidity and nutrient levels.

Water quality parameters and phytoplankton abundance are measured monthly by the Swan River Trust (SRT) (SRT 2000b). Seasonal patterns in nutrients, water quality and phytoplankton in the Swan Estuary are described by Hosja and Deeley (1994), Gerritse (1999) and SRT (2000c), and are summarised below.

Middle and upper estuary. In winter, high rainfall washes organic material from the catchment into the estuary, which results in fresh, surface waters containing elevated levels of nitrogen. Biologically-available phosphorus is low at this time. Phosphorus tends to bind to suspended particles and sink to the bottom (from where it is released in summer). In winter, low temperatures, low light levels and high rates of flushing prevent phytoplankton blooms from establishing, despite high nitrogen levels. Low light levels are due to short day lengths and high turbidity, mainly due to tannins in the water.

In spring, rainfall and river flushing rates decrease, and temperatures rise. Under these conditions, the elevated levels of nitrogen that still persist in the system facilitate phytoplankton blooms. Spring blooms tend to occur as a succession of blooms by different species. The decomposition of one bloom releases nutrients back into the water and facilitates a new bloom by a different phytoplankton species. Spring blooms of green algae typically occur in the middle and upper estuary in October-November. Spring blooms are often significant in scale, but are part of the natural cycle in the system and are typically harmless.

In response to declining river flow, the location of the salt wedge begins to move upstream in spring and penetrates furthest upstream in summer. This saline water underlies a shallow, fresh, surface layer in the middle and upper estuary. There is limited vertical mixing between layers. The saline water is typically low in oxygen and high in nutrients. Biological activity (from bacteria, etc) rapidly removes oxygen from bottom waters, resulting in hypoxic or anoxic conditions. These conditions cause the release of ammonium and soluble phosphate from sediments, further increasing nutrient levels in bottom waters of the middle and upper estuary. Under such stratified conditions, blooms of dinoflagellates can occur because these cells can migrate vertically between the oxygen-rich surface layer and the nutrient-rich bottom layer.

'Summer' conditions prevail in the Swan Estuary until the onset of autumn rains, the timing and magnitude of which can vary among years. Nuisance blooms, especially by dinoflagellates, are most likely to occur under 'summer' conditions and are generally restricted to the middle and upper estuary. During summer and early autumn, warm water and high light levels are ideal for rapid algal growth, although bloom events will not occur if nutrients are limited. Episodic rainfall events at this time can add a pulse of nutrients to the system and allow a phytoplankton bloom to occur. A bloom is more likely to occur if a rainfall event in summer/autumn is followed by a dry period. If rains fall over an extended period, a bloom is unlikely to develop because increased flows will flush the river and prevent blooms from establishing. Blooms in summer/autumn are unpredictable, due to the erratic timing of rainfall and nutrient input during that period.

Lower estuary. Phytoplankton and nutrient cycles in the lower estuary are distinct from the middle and upper estuary. The lower estuary system is dominated by marine species and tends to be nitrogen limited. Spring blooms occur earlier in the lower estuary, from August to September. During summer/autumn, the lower estuary is generally well flushed by low nutrient, ocean water. Phytoplankton growth occurs at these times, but generally does not result in a bloom. Occasional minor algal blooms can occur when summer or autumn rain events wash a pulse of nutrients (especially nitrogen) into the lower estuary.

3.0 Swan Estuary commercial fishery

3.1 Early years of fishing

'Commercial' fishing in the Swan Estuary undoubtedly commenced shortly after European settlement in 1829. Unfortunately, annual records of commercial catch and effort are incomplete prior to 1939 and so little is known of the catch in these early years. A significant quantity of locally caught fish was presumably needed to supply a Perth population of almost 30,000 in 1880 and almost 50,000 by 1890. Also, the proclamation of the first Fisheries Act and the issue of the first fishing licence in 1899 suggest that considerable fishing effort was occurring by this time (Lenanton 1978, 1984). From 1899 until 1940, any person who caught fish for sale or used a seine net to catch fish was required to hold a licence. From 1940-1949, any person catching fish by any type of net was required to hold a licence. However, the distinction between commercial and recreational fishing was not made until 1949, when separate 'professional' and 'amateur' licences were introduced.

3.2 Commercial fishery catch and effort statistics

Historically, catch and effort statistics supplied by commercial fishers via compulsory monthly returns have been the main (and often only) source of information for fish stock assessments in the Swan Estuary. Commercial fishery catch and effort data are valuable for this purpose because they are long-term, continuous time-series. At the same time, the utility of commercial fishery catch and effort data to provide an index of fish abundance is limited by several factors, which are outlined below. Catch trends must always be interpreted with consideration of these factors.

Changes in market demand for key target species have had a major influence on catch levels in the fishery. Peaks in catch and effort in the estuary occurred around 1920 and again around 1940 to alleviate local food shortages after World War 1 and during World War 2, respectively (Fig. 2). At certain times during 1919, up to 130 men (mainly returned soldiers) were engaged in commercial fishing (Lenanton 1978). Many fish from the Swan Estuary (and adjacent Peel-Harvey Estuary) were canned or smoked for human consumption, a practice that occurred from the late 1800s until the 1950s (Lenanton 1978, 1984). The demand for canned fish (especially Perth herring, but also sea mullet (*Mugil cephalus*), yellow-eye mullet (*Aldrichetta forsteri*), garfish (Hemiramphidae), pilchards (*Sardinops sagax*) and cobbler (*Cnidoglanis macrocephalus*) was greatest in the 1940s. During the 1960s and 1970s, Perth herring, sea mullet and yellow-eye mullet were targeted to supply the western rock lobster fishery with local bait, and were the dominant species in the Swan Estuary catch in these decades. During the 1980s, markets for these species as bait or for human consumption declined. Perth herring is no longer caught for human consumption and now supplies a minor recreational bait market only.

After 1969 the Department of Fisheries (DoF) adopted a policy to i) not issue any new commercial licences and ii) limit transferability of licences. In subsequent years, a 'Voluntary Fishery Adjustment Scheme' (VFAS) significantly reduced fishing effort in the Swan Estuary commercial fishery. The number of registered vessels declined from approximately 30 vessels operating annually throughout the 1960s and 1970s to only 4 vessels operating per year from 2000 to 2004. The departure of certain fishers (especially those that fished part-time) from the fishery and the greatly reduced competition between fishers may have altered the overall targeting practices of the fishery, leading to a change in the composition of the catch.

Various changes in formatting of compulsory monthly fishing returns are likely to have altered the quality and quantity of reported catch and/or effort data. Significant changes in the format of compulsory monthly fishing returns occurred in July 1989 (Appendices 1, 2). New returns provided additional data about fishing effort and location. Various extra minor changes were made to the format of returns after 1989.

Compulsory monthly commercial catch and effort statistics from July 1975 onwards are held in the Department of Fisheries Catch and effort statistics (CAES) database. Catches of each species in the CAES database are recorded as both "landed weight" and "live weight". In the Swan Estuary commercial fishery, there is negligible difference between total annual "landed" and "live" weights, indicating that most species are landed whole (Fig. 3).

3.3 Commercial fishing effort and CPUE

Currently, the following 4 measures of monthly commercial fishing effort can be calculated from compulsory monthly catch and effort returns:

1) Number of boats = the total number of boats registered in the fishery. This is the only type of effort data consistently available between 1912 and 1976. However, it may overestimate actual effort expended because it includes inactive boats.
2) Mean monthly number of active boats = the average number of boats that fished (i.e. recorded some catch) per month.
3) Fishing day = a day spent fishing, regardless of what gear type or how many gear types were used on that day. This may underestimate actual effort expended, particularly when multiple gear types are fishing simultaneously.
4) Gear day = a day spent using a particular gear type. The number of gear days may exceed the number of fishing days per month because a fisher may use >1 gear type per day.

In general, catch-per-unit-effort (CPUE) derived from any of the above units of effort does not provide a precise index of abundance for any species because actual (real) effort cannot be determined. Also, monthly catch returns cannot be used to determine the actual effort used to target each species, due to the multi-species nature of the fishery. This can be illustrated with a hypothetical example – in January 2003, a fisher reported 20 days of gill netting and a total catch of 500 kg of black bream and 200 kg of sea mullet. From this limited data, the number of days spent specifically targeting each species cannot be determined. In the absence of any other information, 20 days of effort could be (and usually is) allocated to each species, and the estimated monthly catch rates would be (500 ÷20 =) 25 kg/day and (200 ÷20 =) 10 kg/day, respectively. However, if 19 days was actually spent targeting bream and only 1 day spent targeting mullet, then the actual catch rates would be (500 ÷19 =) 26 kg/day and (200 ÷1 =) 200 kg/day, respectively. This problem with the measurement of actual effort may be largely overcome in future by implementation of a daily or trip logbook.

Not withstanding these problems, commercial CPUE is the best available index of abundance for many species and is still widely used as an indicator in stock assessments.

All of the above measures of effort follow similar annual trends (Fig. 4a). However, there are minor differences and the choice of effort used to calculate CPUE has an effect on the trend in CPUE, especially after 1989 (Fig. 4b). For example, CPUE calculated from "kg/gear day" and "kg/fishing day" both suggest a decline in catch rate since 1989. By contrast, CPUE calculated from "kg/registered boat" or "kg/active boat" suggests that catch rate has been stable since 1990. In summary, an assessment of the status of the fishery based on CPUE trends in recent years is most optimistic if CPUE is estimated by "kg/ registered boat" and least optimistic if CPUE is estimated by "kg/ gear day". This report uses "kg/ gear day" to estimate CPUE after 1975 because 'gear day' is considered to be the best available approximation of actual effort.

3.4 Seasonality of commercial landings

The commercial catch of each key target species in the estuary is highly seasonal (Fig. 5). Environmental factors (e.g. fluctuations in salinity) and behavioural factors (e.g. spawning migrations) affect the distribution of fish in the estuary and determine their abundance (and hence availability) within the commercial fishery zone. Preferential targeting can also result in seasonal catches - lower value species may only be targeted during months when higher value species are not available. These factors mean that monthly trends in commercial catch rates of particular species do not always reflect trends in overall estuarine abundance.

Commercial landings of Perth herring, Australian herring (*Arripis georgianus*), tailor (*Pomatomus saltatrix*), bar-tailed flathead, whiting (*Sillago schombergkii*), small-toothed flounder and sea mullet typically peak in spring (Fig. 5). Cobbler and black bream are mostly caught in winter. Yellow-eye mullet is mostly caught in autumn/winter. Yellowtail scad and blue swimmer crab are mostly caught in summer/autumn.

3.5 Commercial catches from 1921 to 1974

Incomplete records of annual catch in the Swan Estuary commercial fishery are available for the period 1912 to 1939. Annual landings appear to have been relatively high in these years, as suggested by a total catch of 252 t (including 227 t of finfish) that was recorded in 1921 (Fig. 2). Notably, historic peaks in annual landings of yellow-eye mullet and tailor of 44 t and 16 t, respectively, were recorded in 1921 (Fig. 6).

From 1939 to 1960, landings were dominated by finfish, but also contained significant quantities of blue swimmer crabs (*Portunus pelagicus*) and prawns (*Metapeneas dalli* and *Penaeus latisulcatus*). Over this period, annual catches of finfish, crabs and prawns varied markedly but averaged 58 t, 11 t, 3 t per year, respectively. The total fishery catch was dominated by Perth herring from 1942 to 1946 and by sea mullet from 1947 to 1959 (Fig. 6).

After 1959, the catches of finfish increased dramatically and peaked at 322 t in 1973 (Fig. 2). The increase was mainly due to landings of Perth herring, although sea mullet, cobbler and yellow-eye mullet were also abundant in the catch (Fig. 6). Peak catches of Perth herring occurred in 1968 (178 t), 1972 (147 t), 1973 (159 t) and 1975 (138 t). Sea mullet landings averaged 61 t per year from 1960 to 1974, including an historic peak of 116 t in 1961. Cobbler landings averaged 33 t per year from 1960 to 1974, including peaks of 57 t in 1960 and 50 t in 1970. Yellow-eye mullet landings averaged 15 t per year from 1960 to 1974, including peaks of 29 t in both 1960 and 1970. These values were similar to a later peak in yellow-eye mullet landings of 30 t, which occurred in 1988 (Fig. 6).

From 1939 to 1974, tailor, bar-tailed flathead, yellowtail trumpeter (*Amniataba caudavitatta*) and mulloway also made small but significant contributions to the total commercial catch in some years. Annual landings of tailor were <5 t, except for landings of 5-9 t per year in 1943-51 and in 1961. Annual landings of flathead averaged 2 t, with a peak of 5 t in 1945. Annual landings of yellowtail trumpeter averaged 1 t, with a peak of 7 t in 1964. Mulloway incurred a period of relatively high annual commercial catches (averaging 2.7 t) from 1963 to 1986 (Fig. 6). However, after peaking at 8 t in 1965, the mulloway catch and CPUE trend was downward, with the exception a relatively high catch in 1975.

From 1939 to 1974, annual crab catches fluctuated greatly (ranging from <1 t to 24 t), although the overall trend was stable (Fig. 2). In contrast, prawn catches occurred within two main periods, with peaks of 11 t in 1948 and 14 t in 1959, respectively. After 1959, prawn landings declined. The last significant commercial catch (3 t) of prawns was recorded in 1975.

3.6 Commercial catches from 1975 to 2004

From 1975 to 2004, six species comprised the majority of annual commercial landings, namely Perth herring, sea mullet, yellow-eye mullet, cobbler, black bream and blue swimmer crabs. In this period, annual landings of tailor, bar-tailed flathead, yellowtail trumpeter and mulloway were relatively low (mostly <5 t each) compared with landings of these species prior to 1975 (Fig. 6). Minor catches of small-toothed flounder, white bait (*Hyperlophus vittatus*) and Australian herring were also taken between 1975 and 1999.

From 1975 to 2004, the total annual catch of the fishery declined significantly due to a steadily decline in finfish landings over this period (Figs. 7, 8). For example, finfish landings from 1995-99 equalled only 27% (by weight) of the landings from 1975-79.

Between 1975 and 2004, annual landings of each major finfish target species declined markedly. The annual catch of Perth herring declined from 137 t to <10 t, sea mullet declined from 54 t to <5 t, yellow-eye mullet declined from 24 t to <5 t, and cobbler declined from 31 t to <100 kg.

Between 1975 and 1999, annual effort also declined due to a reduction in the number of licensees (via a voluntary fishery adjustment scheme) (Fig. 7). As a result, the total annual CPUE increased from 1975 to 1990 but then declined gradually after 1990 (Fig. 7). This downward trend was driven by the catch of finfish. The annual finfish CPUE steadily declined from ~70 kg/gear day in 1990 to ~40 kg/gear day in 1999, despite the reduction in fishing effort (Fig. 8). In particular, the annual CPUEs of Perth herring, yellow-eye mullet, small-toothed flounder and cobbler each declined in this period.

The only major finfish species to exhibit an increase in annual catch and CPUE after 1990 was black bream (Fig. 6). Annual catches of black bream increased markedly between 1980 and 1999, despite sharply declining effort levels over this period.

Between 1975 and 2004, blue swimmer crabs became an increasingly important component of the total commercial fishery catch. In contrast to finfish trends, annual landings of crabs were relatively stable from 1975 to 2004 and the crab CPUE increased markedly after 1990 (Fig. 8). Crab CPUE showed a strong inverse relationship with effort, i.e. CPUE increased as effort decreased. Crab CPUE rose from approximately 5kg/day in the 1980s to approximately 25 kg/day in the late 1990s.

From 1975 to 1990, crabs contributed approximately 10% (by weight) to total annual landings, but this proportion increased significantly during the 1990s and was approximately 40% in 1999. Since 1975, annual crab catches have ranged from 4 to 35 t. Catches averaged 19 t from 1995 to 2004 (Table 2).

The period from 2000 to 2004 represented a period of stable commercial effort levels in the Swan Estuary, following many years of declining numbers of licensees (Fig. 7). From 2000 to 2004, four licensees operated in the fishery.

In 2004, crabs contributed 41% to the weight and 58% to the value of the total annual catch. The finfish catch contained about 15 taxa although ~90% of the weight and value of the total finfish catch comprised only 7 species (sea mullet, Perth herring, black bream, yellowfin whiting, yellowtail trumpeter, yellow-eye mullet and tarwhine (*Rhabdosargus sarba*).

4.0 Swan Estuary recreational fishery

4.1 Recreational fishery catch and effort statistics

Recreational anglers and netters were reported to have been very active in the Swan Estuary as early as 1912 (Lenanton 1978). Even in the early years of the fishery, the total recreational catch was substantial and possibly exceeded the commercial catch in some years. Lenanton (1978) suggested that the recreational crab catch was equal to the commercial catch in the 1970s.

Estimates of annual recreational catch in the Swan Estuary are not available prior to the late 1990s, although the number of recreational netting licences issued by the Department of Fisheries gives some indication of earlier effort levels. From 1971 to 1976, the total number of recreational net licences issued at Perth and Fremantle increased from 5,624 to 11,948 (Lenanton 1978). At this time, the primary target species of net fishers were prawns (50-60% of fishers), finfish (25%) and rock lobster. This licenced component of the recreational catch was probably much less than the unlicenced component, which comprised line-caught finfish and crabs (Lenanton 1978).

Recreational catch and effort levels are likely to have increased significantly since the 1970s, in proportion to the growth of Perth's human population from 832,760 in 1976 to >1.4 million in 2004. Available data suggests that recreational catches of many species exceeded commercial catches of the same species in recent years.

The following four major sources of data on the recreational fishery are currently available:

1) A creel survey was conducted in the lower Swan Estuary in 1998-99 (Malseed and Sumner 2001).
2) A national phone survey collected data from the entire Swan Estuary in 2000-01 (Henry and Lyle 2003).
3) 'Swanfish' is a recreational angling tournament hosted by the Melville Amateur Angling Club (MAAC) and is held annually on the last weekend in February. It is open to the general public and fishing effort is spread throughout the Swan Estuary. Since 2000, competitors have been asked to return a 'catch card' with numbers of each species retained and discarded during the event and details of their fishing location.
4) Monthly catch records have been kept by the MAAC since 1986. They are the only available time-series of recreational catch for the Swan Estuary, including trends in CPUE and average fish size. Records kept by the club include the number of participating anglers and the numbers and total weights of each species presented at the 'weigh-in' after each estuary fishing day held by the club.

4.2 Composition of the recreational fishery catch

4.2.1 Creel and phone surveys

The 1998-99 creel survey and the 2000-01 phone survey both indicated that blue swimmer crab was the species most frequently retained by recreational fishers in the estuary (Table 3). However, there was a considerable difference in the total annual crab catch estimated by the two surveys. In 1998-99, an estimated 20,875 crabs (~ 7.3 t) were retained. In 2000-01, an estimated 148,341 crabs (~ 33.1 t) were retained. The 2000-01 survey may have over-estimated boat-based catches of all species (N. Sumner, DoF, pers. comm.). However, the shore-based component of the catch suggested that at least 17,357 crabs (~3.9 t) were caught in 2000-01 and the 1998-99 survey indicated that the shore-based catch is much smaller than the boat-based catch in the Swan Estuary. Also, recent annual landings of crabs by recreational fishers are believed to be considerably larger than recent commercial landings (~ 16.5 t, in Table 2) (L. Bellchambers, DoF, pers. comm.). Therefore, a total estimated crab catch of 33.1 t in 2000-01 is not unrealistic.

The 1998-99 survey was focused on crabs (hence its location in the lower estuary) and provided incomplete data about finfish catches (especially catches in the upper estuary). The limited data from 1998-99 indicated that tailor, whiting, black bream, Australian herring, flathead and yellowtail trumpeter were the most frequently retained target finfish species in the lower estuary. Minor quantities of small-toothed flounder, butterfish (*Pentapodus vita*), tarwhine, trevally (*Pseudocaranx spp.*), mulloway, yellow-eye mullet and yellowtail scad (*Trachurus novaezelandiae*) were also retained. The 2000-01 survey indicated that black bream was the main target species throughout the entire estuary. Other major species in the 2000-01 catch were Australian herring, tailor, whiting and flathead. Minor species in the catch were flounder, tarwhine, 'baitfish', garfish, yellowtail trumpeter, cobbler, mulloway, pink snapper (*Pagrus auratus*) and yellowtail scad.

Although not targeted, blowfish (*Torquineger pleurogramma*) was the most frequently caught finfish in both surveys, indicating that this species was extremely abundant in the estuary in 1998-99 and 2000-01. A total of 116,079 blowfish were reported in 2000-01.

Catch weight was not measured in either survey but can be estimated from known average weights of each species. The estimated catch weight of black bream in 2000-01 was 16,273 kg (= 35,334 fish), which was considerably greater than the reported catch of any other individual finfish species (Table 3). Some uncertainty is associated with the estimation of boat-based catches in 2000-01. However, since black bream are mainly caught from the shore and sample sizes were high, the estimated catch for this species is reasonably reliable.

The weight of the total recreational finfish catch in 2000-01 was estimated to be ~28.2 t, but there is considerable uncertainty associated with this value due to the likely over-estimation of boat-based catches.

4.2.2 'Swanfish' fishing tournament

The MAAC have been collecting catch cards from competitors in the annual 'Swanfish' tournament since 2000. A high proportion of competitors return their catch cards, partly because it entitles them to entry into a random prize draw. In 2004, the format of the catch cards was altered to include slightly more detail about fishing location and more details of discarded fish, especially blowfish. About 50% of competitors recorded blowfish catches in 2004. Blowfish catches were usually not recorded in previous years.

In 2004, over half of the total reported catch (retained + discarded fish) at the 'Swanfish' tournament comprised only 2 species - blowfish (37%) and black bream (21%) (Table 4). Excluding blowfish, black bream represented 29-60% of the total reported catch each year. On average, 9 species (black bream, yellowtail trumpeter, flathead, tarwhine, yellowfin whiting, six-lined trumpeter (*Pelates sexlineatus*), tailor, flounder, cobbler) comprised 90% of the total catch each year (excluding blowfish).

4.2.3 Melville Amateur Angling Club (MAAC)

From 1986 to 2003, the MAAC catch included approximately 40 taxa of finfish. Twelve species comprised 90% of the total catch over this period (yellowfin whiting, cobbler, Australian herring, black bream, yellowtail trumpeter, flathead, yellow-eye mullet, trevally, tailor, six-lined trumpeter, flounder, tarwhine) (Table 5). However, the catch composition differed considerably among years. In particular, the catches of cobbler, yellow-eye mullet and flounder progressively declined over this period. From 2000 to 2003, 11 species comprised 90% of the total catch (Australian herring, black bream, flathead, yellowfin whiting, tarwhine, six-lined trumpeter, trevally, yellowtail trumpeter, tailor, wrasse/groper, sea garfish (*Hyporhamphus melanochir*). Recent MAAC annual catches contained more trumpeter and tarwhine and less tailor than the overall Swan Estuary recreational catch estimated by the 1998-99 creel survey or the 2000-01 phone survey. However, despite differences in the proportions of each species in the total catch, the MAAC data are in reasonable agreement with the creel and phone surveys as to the main species retained by recreational fishers in the Swan Estuary.

4.3 MAAC catch and effort trends, 1986 to 2003

Catches recorded by the MAAC at 'weigh-in' events following each Estuary Field Day may underestimate the total catch per day because some retained fish may not have been included. Also, discarded fish are not recorded by the Club. In all years, some 'high-grading' of catch may have occurred to maximise competition points. The Club allocates competition points to members on the basis of the number and weight of fish caught, and the number of species in the catch. For these reasons, the data from 'weigh-ins' may slightly under-estimate the actual daily catch and slightly over-estimate the average weight of all captured fish. Also, due to the competitive nature of the club, the MAAC daily catch rates and average fish sizes may be higher than those for all recreational fishers in the Swan Estuary.

From 1986 to June 1991, the MAAC had a self-imposed bag limit of 2 fish per species per fisher. From July 1991 onwards the bag limit was increased to 3. After mid-1991, the Club catch rates of several key species increased and the average size of several key species decreased, probably as a result of the increase in Club bag limits.

4.3.1 Total catch and effort

From 1986 to 2003, total annual MAAC effort ranged from 414 to 3,560 angler days, while total annual catch ranged from 112 fish (64 kg) to 1,013 fish (257 kg) (Fig. 9a). After peaking in 1994, there was a slight downward trend in the average annual CPUE (Fig. 9b). The average size of retained fish (regardless of species) was anomalously high in 1987 due to two large mulloway in the catch. The reported number of species in the total catch ranged from 9 to 25 per year, and was relatively stable after 1991, with approximately 20 species retained per year.

From 1986 to 2003, MAAC Estuary Field Days typically occurred monthly. Monthly catch and effort tended to peak during warmer months and so the main fishing season each year was generally summer/autumn.

4.3.2 Catches of key species

Black bream. The MAAC annual CPUE of black bream peaked in 1994 (0.7 fish/angler day) and again in 2003 (0.5 fish/angler day) (Fig. 10a). The higher catch rates after mid-1991 were greater than might be expected from the effect of the change in bag limit alone, suggesting an increase in the abundance of black bream in the estuary since 1992. From 1992 to 2003, the average size of black bream was stable at approximately 0.5 kg (Fig. 11a).

Tarwhine. From 1992 to 2003, the annual CPUE of tarwhine steadily increased, suggesting a steady increase in abundance of this species in the estuary over this period. A peak (0.3 kg) in the average size of retained fish occurred in 2002, followed by a peak in CPUE in 2003 (~0.5 fish/angler day).

Cobbler. The annual CPUE of cobbler steadily declined from 1990 to 2000, despite the increase in bag limit in mid-1991. The trend almost certainly reflects a severe decline in abundance in the estuary over this period. Since 2000, MAAC members have chosen to release any cobbler caught, although the number caught since this time has been minimal. Despite the change in bag limit, the average size of cobbler increased after 1992 (peaking at ~0.7 kg), suggesting recruitment failure.

Bar-tailed flathead. From 1992 to 2003, the annual CPUE of flathead fluctuated considerably although the overall trend was stable. The CPUE tended to be higher (0.6-0.7 fish/angler day) between 1994 and 2000, suggesting higher abundances during the late 1990s. The average size of flathead peaked (0.4 kg) in 1999, consistent with higher CPUE and the possibility of a strong recruitment event around this time.

Small-toothed flounder. The annual CPUE of flounder declined from 1988 to 2003, despite the increase in bag limit in mid-1991. There was a minor increase in CPUE during the late 1990s. The long-term trend suggests a decline in abundance in the estuary since 1987. CPUE was particularly low after 2000. Anecdotal reports from MAAC members also suggest that flounder has been relatively rare in the estuary in recent years. The average size of flounder was relatively stable across all years (~0.26 kg), except for a slight decrease (minimum ~0.18 kg) in the late 1990s, consistent with higher CPUE and the possibility of a weak recruitment event at this time.

Australian herring. The annual CPUE of Australian herring fluctuated considerably between 1986 and 2003, with peaks in 1993 (0.5 fish/angler day), 1999 (0.9 fish/angler day) and 2003 (0.5 fish/angler day). The average size of Australian herring retained by the MAAC also fluctuated over this period, peaking at 0.19 kg in 1999. There appears to be an inverse relationship between CPUE and average fish size, suggesting recruitment-driven variations in the catch of this species.

Yellow-eye mullet. The annual CPUE and average fish size of yellow-eye mullet each peaked during the early 1990s. From 1999 to 2003, CPUE and fish size have been relatively low, suggesting a lower abundance of this species and smaller average size in the estuary in recent years.

Yellowtail scad. This species was not retained by MAAC members until 1992. Since then annual CPUE has fluctuated between zero and 0.08 fish/angler day and the average fish size has been stable (~0.09 kg).

Tailor. The annual CPUE of tailor ranged from 0.1 to 0.6 fish/angler day from 1986 to 2003. CPUE did not increase after mid-1991, despite the increase in bag limit. CPUE was relatively low from 2001 to 2003. Overall, trends suggest a slight decline in tailor abundance in the estuary since 1986. The average size of tailor was stable from 1986 to 1997. The average size then increased sharply to a peak of ~0.4 kg in 2000 before declining to ~0.25 kg in 2003.

The 2000 peak in average fish size corresponded to a minimum in CPUE, suggesting poor recruitment (i.e. an absence of small fish) at this time.

Trevally. (*Psuedocaranx wrighti* and *P. dentex*). The annual CPUE of trevally ranged from 0.1 to 0.6 fish/angler day and the average fish size ranged from 0.1 to 0.3 kg. The annual CPUE peaked at 0.6 fish/angler day in 1997, followed three years later by a peak in average fish size (0.3 kg) in 2000. Variations in the catch rate and average size of trevally retained by MAAC since 1987 appear to have been mainly influenced by changes in bag and size limits. CPUE was relatively high from 1991 to 1997, following an increase in the self-imposed MAAC bag limit in 1991. The CPUE was slightly lower from 1997 to 2003, following an increase in the legal minimum size in 2003. The average fish size increased after 1997.

Six-lined trumpeter. The annual CPUE of six-lined trumpeter was relatively low (~0.15 fish/angler day) until 1993. CPUE then increased and peaked at 0.9 fish/angler day in 1998, before steadily declining until 2003. The average fish size peaked at 0.17 kg in 1991, and a lesser peak of 0.14 kg occurred in 1999 and 2000. A peak in CPUE during the mid-1990s followed by a peak in fish size in 1999-2000 is suggestive of strong recruitment in the mid-1990s.

Yellowtail trumpeter. The annual CPUE of yellowtail trumpeter was relatively low (~0.2 fish/angler day) until 1993. The CPUE then increased dramatically and peaked at 0.7 fish/angler day) in 1994. From 1994 to 2003, annual CPUE trended downwards. The average fish size decreased in 1991 (coinciding with an increase in the bag limit) but was then stable until 1999. From 1999, the average fish size declined and reached a minimum of 100 g in 2003 (Fig. 11). Overall, data suggest that yellowtail trumpeter became progressively smaller and less abundant in the estuary after 1994.

Whiting. Three species of whiting are caught by the MAAC, the most common being yellowfin whiting. A period of relatively high annual CPUE occurred from 1991 to 1998, including a peak of 1.3 fish/angler day in 1998. CPUE from 1999 to 2003 were considerably lower (0.2-0.4 fish/angler day). Trends in CPUE suggest that yellowfin whiting were more abundant in the estuary from 1991 to 1998 than in subsequent years. From 1986 to 2003, the average fish size was relatively stable, ranging from 0.1 to 0.3 kg.

Between 1986 and 2004, King George whiting (*Sillaginoides punctata*) and trumpeter whiting (*Sillago maculata*) were caught intermittently in the estuary by the MAAC, mainly during the early 1990s.

5.0 Discussion

5.1 Commercial and recreational catch composition and catch shares

The period 1975-2004 encompassed a marked shift in the composition of the commercial catch in the Swan Estuary. The proportion of the total catch represented by finfish declined and crabs became the main focus of the fishery. Also, the species composition of the finfish catch changed considerably. Most notably, the proportion of cobbler declined to almost zero while the proportion of black bream increased. After 1999, the proportion of species previously considered as minor or non-target species increased significantly. These species included yellowtail scad, tarwhine, roach (*Gerres subfasciatus*) and whiting (mainly *Sillago* *schombergkii*). Elasmobranch (sharks and rays) catches also increased slightly in recent years, although they remained a very minor (<500 kg) component of the annual catch (Fig. 8).

Long-term records of total annual recreational catch in the Swan Estuary are not available but records of MAAC catch since 1986 suggest that some of the changes in the composition of the commercial catch also occurred in the composition of the recreational catch. In particular, the proportion of cobbler in the MAAC catch declined while the proportion of black bream increased.

In recent years, commercial fishers in the Swan Estuary retained ~15 species per year. The primary species in recent commercial catches were blue swimmer crabs, sea mullet, Perth herring, black bream, yellow-eye mullet and tailor. Secondary commercial species included yellowfin whiting, Australian herring, mulloway, bar-tailed flathead, small-toothed flounder, yellowtail scad, tarwhine and yellowtail trumpeter.

The recreational catch in the Swan Estuary is more diverse than the commercial catch, although there are also ~15 common species retained (not including blowfish which is the most commonly caught species). The primary species in recent recreational catches were blue swimmer crabs, black bream, Australian herring, tailor and bar-tailed flathead. Secondary recreational species included yellowfin whiting, small-toothed flounder, tarwhine, yellowtail trumpeter, six-lined trumpeter, garfish, mulloway, cobbler, yellowtail scad, pink snapper and trevally.

Blue swimmer crabs is currently the largest component of both commercial and recreational landings and the most valuable component of commercial landings in the Swan Estuary. From 1995 to 2004, commercial crab catches averaged 19 t per year. The 2000/01 recreational crab catch was estimated to be 33 t. This suggests that the recreational sector has recently taken ~63% of the total crab catch (by weight). The recreational crab catch has probably been of a similar or greater magnitude to the commercial crab catch in the Swan Estuary since the 1970s (Lenanton 1978).

The 2000/01, the recreational catch of finfish was estimated to be 28 t. From 1995 to 2004, commercial finfish catches averaged 36 t per year. This suggests that the recreational sector has recently taken ~45% of the total finfish catch (by weight) in the Swan Estuary. However, over this 10 year period, the commercial landings of finfish declined considerably, and so in latter years the recreational catch of finfish has been >50%.

Although many species are common to both recreational and commercial catches, there appear to be few sources of conflict over the current allocation of fishery resources in the estuary. The vast majority of the recent commercial catch comprised crabs, sea mullet, Perth herring and black bream. Of these species, only black bream and crabs are targeted by recreational fishers. Since 1990, the CPUE of black bream has increased and the CPUE of crabs has been stable which suggests that availability these species to each sector is adequate.

5.2 Catch trends and changes in species abundance

Annual commercial catch rates were not consistently available until ~1950 and annual recreational catch rates were not consistently available until ~1990. Therefore, fishery records provide very limited information about changes in fish abundance that occurred in the Swan Estuary prior to these dates. Importantly, the absence of catch and effort data from the earliest years of the fishery means that quantitative information about the ‘virgin state’ of the fish stocks and the initial impacts of fishing in the estuary is not available. Early reports by Department of

Fisheries and others suggest that early fishing had a significant impact on local fish abundance and that at least some estuarine stocks were already depleted by the time commercial fishery catch records were introduced (Colebatch 1929).

Trends in commercial and recreational catches suggest the abundances of many fishery species in the estuary have changed over the last 2-3 decades (Table 6). While some species exhibited stable or increasing abundance, of most concern are the various species that appear to have declined in abundance over this period.

In the commercial fishery, there was a continuous decline in the total annual finfish catch after 1975 and a decline in the annual finfish CPUE after 1990. The decline in annual commercial catch and CPUE after 1990 was the combined effect of declines in the catches of Perth herring, sea mullet, yellow-eye mullet and cobbler. Historically, these were the main target species in the fishery and were known to be relatively abundant in the estuary at least until the 1980s (Loneragan *et al*. 1989). Declines in commercial catches of these species were likely to be due to a combination of factors. Firstly, total effort in the fishery was significantly reduced (Fig. 7). Secondly, targeting of some species was reduced. Thirdly, the abundance of the major target species may have declined.

There is a body of evidence to suggest that the abundances of Perth herring, sea mullet, yellow-eye mullet and cobbler in the estuary have declined. The evidence includes trends in commercial and recreational catches, trends in catches from fishery-independent sampling (I. Potter, Murdoch University, unpubl. data) and anecdotal reports from commercial and recreational fishers.

In addition to declines in the primary species mentioned above, commercial fishery catch trends since ~1940 suggest declines in the abundances of school prawns, tailor, bar-tailed flathead and mulloway, and recreational catch trends since 1990 suggest declines in the abundances of yellowtail trumpeter and small-toothed flounder.

Commercial and recreational catch trends indicate that five fishery species may have increased in abundance in the Swan Estuary since 1990. Recreational catch rates suggest an increase in black bream, tarwhine and Australian herring, while commercial catch rates suggest an increase in black bream, blue swimmer crabs, tarwhine and yellowtail scad. Black bream and blue swimmer crabs each fetch a relatively high market price and are likely to be targeted by commercial fishers whenever available. Hence, marketability is not likely to have been a major factor influencing catch trends of these species. However, the higher commercial catch of yellowtail scad may reflect the increased marketability of this species rather than higher abundance (R.J. Bales, commercial fisher, pers. comm.). Commercial and recreational catches of tarwhine have increased in many south-west estuaries recently, suggesting a widespread regional increase in abundance of this species (DoF, unpubl. data).

The increasing trend in the recreational CPUE of Australian herring was probably an artefact of a localised peak in recruitment in 1999-2000, rather than a long-term increasing trend in stock abundance. A localised peak also occurred in the commercial CPUE in 2000. However, the longer-term commercial catch trend since 1975 in the Swan Estuary was decreasing. Commercial and recreational catch rates of Australian herring elsewhere along the west coast of Western Australia (where the same stock is targeted) have declined over recent decades.

Marked fluctuations in the catch rates and/or average fish weight of several species suggest strong variations in annual recruitment. In 2001, a relatively low recreational CPUE and a peak in average fish size suggest poor juvenile recruitment by tailor to the estuary in this year. In 1991, the recreational CPUE of King George whiting peaked, followed by a peak in average fish size in 1993, suggesting strong juvenile recruitment and subsequent growth in the estuary. A period of elevated CPUE followed by a peak in average body size of six-lined trumpeter suggest strong recruitment in the mid-1990s.

Annual catches of bar-tail flathead and small-toothed flounder have been highly variable, probably as a result of highly variable recruitment. Since 1939, there have been several discrete periods of high commercial landings for both species (Fig. 6). Peaks in flounder catches were followed by peaks flathead in catches a few years later, suggesting that pulses of recruitment in these two species were driven by the same environmental factors. Commercial catch trends suggested strong recruitment by flounder and flathead in the late 1950s. Commercial and recreational catch trends suggested strong recruitment by flounder in the late 1980s and strong recruitment by flathead in the early 1990s. Catch rates of flounder and flathead have declined since the early 1990s and late 1990s, respectively. These species are of high value to each sector, and so low catches are probably not market driven and are likely to reflect low abundance in the estuary in recent years.

5.3 Future fishery assessments

Historically, stock assessments in the Swan Estuary have relied on catch and effort data from the commercial fishery. A significant reduction in the number of commercial fishers has reduced the amount of annual data and has eroded the usefulness of commercial data currently being collected. However, any continuation of this long-term data series will still yield valuable information for stock assessments of primary species. Cessation of commercial fishing in the estuary in the near future would be problematic because an alternative, ongoing data source is yet to be established. This situation has already arisen in another west coast estuary – commercial fishing in the Leschenault Inlet ceased in June 2001 and no annual data for assessments have since been available.

In future, annual data on the relative abundance and size structure of many stocks could be provided by recreational fishers, from either club catch records or angler logbooks. Agreement between MAAC CPUE trends and commercial and/or fishery-independent survey catch rate trends for various species, suggests that recreational catch rates can provide useful indices of fish abundance. Such data is highly complementary to creel/phone survey estimates of total catch and effort in the estuary.

At present, commercial and recreational fishery data from the Swan Estuary work in concert. The commercial fishery provides information about species that are not often caught recreationally (e.g. sea mullet, yellow-eye mullet and Perth herring), while the recreational fishery provides information about species that are not often caught commercially (e.g. six-lined trumpeter, blowfish). For species that are caught by both sectors, comparisons of catch trends provides some validation of the data. In the absence of commercial data, fishery-independent surveys would be required to provide information about non-recreational species. In any case, independent surveys would be a desirable component of any future monitoring strategy, providing validation of fishery data in general. Independent surveys also collect information about the status of non-fishery species, which are important to the ecological function of the estuary. It has been demonstrated in similar estuarine systems that baseline fish community data provide an index of general estuary health, and so have broad applications in estuary and fishery management (e.g. Harrison and Whitfield 2004).

Future monitoring of fish communities in the Swan Estuary should include a combination of methods including annual fishery catch and effort data, regular recreational fishery surveys and occasional fishery-independent surveys.

6.0 Status of key fishery stocks

This section assesses the status of the key fishery stocks in the Swan Estuary, including comments on various environmental factors that are likely to have impacted on stocks in the estuary in recent decades. Environmental factors (including habitat modification, input of pollutants and climate change) are likely to be at least as significant as the impact of fishing pressure on stocks in the Swan Estuary. Unfortunately, the lack of long-term biological monitoring in the estuary makes it difficult to precisely determine the impacts of most environmental factors on fish stocks.

In discussing environmental factors, this section focuses on the risk to stocks from algal blooms because the frequency of harmful blooms and associated fish kills in the Swan Estuary has been relatively high in recent years. In summer/autumn of 2003, a bloom of *Karlodinium micrum* resulted in the largest recorded fish kill in the estuary and smaller blooms of *K. micrum* occurred again in 2004 and 2005. Such events pose a high risk to certain stocks, especially estuarine-dependent species. Major fish kills have tended to occur during summer/autumn (January to May) in the upper estuary (i.e. upstream of Heirisson Island in the Swan River and in the upper Canning River) (Fig. 1). Therefore, this season/location has the highest likelihood of future kills and species that occur here are at the highest risk.

6.1 Major target species

6.1.1 Blue swimmer crab

Biology: Blue swimmer crabs (*Portunus pelagicus*) are distributed throughout the Indo-west Pacific. They occur across northern Australia from Cape Naturalist (WA) to Eden (NSW), and also in some areas of South Australia (Kailola *et al*. 1993). A number of discrete regional stocks occur along the Western Australian coast. Individuals in the Swan Estuary are believed to belong to a stock which also occurs in Cockburn Sound, but which is separate to populations in more southern estuaries (Chaplin *et al*. 2001, S. de Lestang, pers. comm.).

The main source of crab recruitment to the Swan Estuary is probably from spawning activity in nearby Cockburn Sound (S. de Lestang, pers. comm.). The majority of spawners in Cockburn Sound are believed to be residents of local coastal waters, with relatively few individuals from estuaries. Some crabs from the Swan Estuary may migrate to Cockburn Sound to spawn, but the size of the blue swimmer crab population in the Swan Estuary is relatively small compared to those of other estuaries in the region, and the contribution to regional recruitment by Swan Estuary females is likely to be minor. Hence, recruitment to the Swan Estuary fishery is independent of population size within the estuary.

The blue swimmer crab is essentially a marine species and can be found in coastal waters and the lower reaches of estuaries throughout the year. Adults will move into the middle and upper reaches of estuaries if waters in these areas become sufficiently saline, with a preference for salinities of 30-40‰ (Potter *et al*. 1983). In the Swan Estuary, this typically occurs during summer when freshwater input is low. Therefore, crabs can be found as far upstream as the middle reaches of the Swan River and lower reaches of the Canning River during warmer periods of the year (S. de Lestang, DoF, pers. comm).

Mating by blue swimmer crabs occurs during summer in estuarine waters (Potter *et al*. 1983). After mating, females migrate to ocean waters (or possibly the lower estuary) to spawn while males remain in estuaries. Females may remain in ocean waters for extended periods, where they can spawn several batches of eggs from a single mating event. The low abundance of females in estuaries during summer results in estuarine fishery landings that are dominated by male crabs. In the Swan Estuary, males are estimated to comprise 94% of the recreational catch (Malseed and Sumner 2001).

Blue swimmer crabs are relatively short-lived, with a maximum age of approximately 3 years and maximum carapace width of 200 mm (Kailola *et al*. 1993). Maturity is reached at approximately 1 year, and recruitment to the Swan Estuary fishery occurs at an age of approximately 18 months. In general, blue swimmer crab populations have relatively fast rates of replacement and can recover quickly from depletion, which allows each stock to sustain moderately heavy levels of fishing.

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills appear to be a low risk to blue swimmer crabs in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would probably be downstream or in ocean waters at this time and not be directly affected. Any loss of stock would be replenished by juvenile recruitment to the estuary in the following spring.

Algal blooms pose a lower risk to crabs than to most finfish. Crabs have a lower oxygen demand than most finfish species and so may be less impacted by hypoxic (low oxygen) conditions than finfish, although they could be impacted by anoxic (zero oxygen) conditions (S. de Lestang, DoF, pers. comm.). Also, crabs are scavengers and consume dead fish. In the event of a fish kill, the surviving crab population may benefit from enhanced food availability.

The main source of crab recruitment to the Swan Estuary is from spawning in nearby Cockburn Sound. Therefore, environmental impacts in Cockburn Sound may affect the breeding stock and affect recruitment to the Swan Estuary.

Trophic links: Blue swimmer crabs are bottom-dwelling carnivores and scavengers (Kailola *et al*. 1993). They mainly consume various slow-moving or sessile invertebrates including worms, bivalve molluscs and crustaceans, and may also consume small amounts of seagrass and algae. They will scavenge on dead fish and larger invertebrates.

Fishery: Blue swimmer crabs are currently the largest and most valuable component of commercial and recreational fishery landings in the Swan Estuary. In recent years, crabs contributed 34% by weight and 57% by value to total commercial landings and 52% by weight to total recreational landings (Tables 2, 3, 4). Catches in both fisheries are seasonal, reaching a maximum in summer and a minimum in winter (Fig. 5). This pattern reflects the seasonal movement of adult crabs into estuaries during warmer months.

A minimum legal size of 127 mm carapace width and a daily bag limit of 20 crabs applies to recreational fishers in the Swan Estuary.

Stock assessment: Commercial fishery trends suggest that the abundance of crabs in the estuary has been stable over many decades and possibly increased since 1990. Since the 1970s, the annual commercial catch of blue swimmer crabs in the Swan Estuary has been highly variable but exhibited an overall stable trend. In the 1990s, the CPUE of crabs increased dramatically and then stabilised at a relatively high level after 1996. Interpretation of this trend is confounded by a major reduction in total commercial effort over the same period and changes in the marketability of other target species, both of which may have increased the targeting of crabs by the fishery. A record of annual crab catches is not available from the recreational fishery for comparison and so it is not known whether recreational CPUE also increased after 1990.

The main source of crab recruitment to the Swan Estuary is a breeding stock in Cockburn Sound. Therefore, recruitment to the Swan Estuary fishery is not dependent on population size within the estuary and the fishery is likely to be sustainable at relatively high levels of catch and effort within the estuary. Fishing mortality in the Swan Estuary probably has little impact on total stock size or recruitment. The fact that a) the fishery does not target breeding females and b) males are mainly caught after mating each year, further limits the impact of the Swan Estuary fishery on the regional crab stock.

6.1.2 Western school prawn

Biology: Western school (or river) prawns (*Metapenaeus dalli*) occur in the Indo-west Pacific, in Indonesia and along the west Australian coast, from Mandurah (WA) to Darwin (NT) (Grey *et al*. 1983). School prawns (*Metapenaeus* spp.) generally occur over sand and sand-mud bottoms in rivers, estuaries and inshore waters to 50 m (Kailola *et al*. 1993). They bury themselves in the sand during day (and on bright moonlit nights) and emerge at night to feed. In the Swan Estuary, school prawns are restricted to the middle and lower estuary in winter but spread to the upper estuary in summer, corresponding to intrusion of the salt wedge and more saline conditions in upper estuary. They are associated with approximately oceanic salinities in the Swan Estuary, but occur at much lower salinities in the adjacent Peel-Harvey estuary (Potter *et al*. 1986, 1989).

The entire life cycle of school prawns, including spawning, is completed in estuaries. Each estuarine population is a discrete breeding stock. Spawning in the Swan Estuary tends to occur where salinity is >30 ppt (i.e. in the middle and lower estuary). Fecundity is ~300,000 eggs (Potter *et al*. 1986). The larval stages are pelagic and feed near surface for ~2 weeks before settling into shallow waters. Most small prawns are found in shallow (<1.2 m) water and tend to move into deeper water as they approach maturity (Potter *et al*. 1986). School prawns mature at 1 year of age and spawn soon after, during summer (November-April, but mainly January-March). They reach a maximum age of ~2 years and length of 190 mm TL.

Fish kills and environmental impacts on stock: Past fluctuations in the abundance of school prawns in the Swan Estuary have been attributed to variations in rainfall. It has been suggested that several, consecutive dry winters may increase the survival of young prawns (Potter *et al*. 1986). Hence, seasonal or annual rainfall patterns and the rate of freshwater runoff from the catchment may impact on this stock.

Given that juvenile and adult prawns are consumed by a wide range of predators, increases in the abundance of various predatory species could impact on prawn abundance. It has been speculated that relatively high numbers of blowfish in the last 1-2 decades years has impacted on school prawn abundance in the Swan Estuary (R. Lenanton, pers. comm.).

Harmful algal blooms and other factors causing fish kills appear to be a medium risk to school prawns in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary. School prawns are most common in the middle and lower estuary (from Fremantle to the Narrows Bridge) but do occur in the upper estuary (up to Maylands and in the Canning River) in summer. Also, spawning occurs during summer and algal blooms at this time could affect pelagic larval and benthic juvenile stages. Therefore, an algal bloom or other event resulting in poor water quality during summer in the upper estuary may affect a small proportion of the total population in the estuary, but this proportion could include spawning adults, larvae and juveniles.

Although only a minority of the stock is likely to be directly affected by a harmful algal bloom, any threat to this stock should be considered serious, given the very low abundance in recent years.

Trophic links: School prawns are bottom-dwelling omnivores and consume small invertebrates and detritus. Prawns are eaten by many fish, including key fishery species.

Fishery: School prawns are targeted by recreational fishers in the shallow waters of the middle estuary (i.e. Melville water) during summer. King prawns (*Penaeus latisulcatus*) are also targeted in this area. Recreational fishers are restricted to catching prawns by hand-trawl nets (length ≤ 4m, mesh ≥16mm) or hand-scoop nets only. A personal daily bag limit of 9 litres and a minimum legal size of 50 mm applies to recreational fishers in the Swan Estuary.

School prawns become vulnerable to capture at ~50 mm length, which is reached at 9-10 months of age (i.e. in spring). Hence, they are vulnerable to capture prior to reaching maturity. A closed fishing season is enforced in the Swan Estuary from July 31 to November 1 to allow prawns to reach maturity prior to capture. To provide habitat protection, there are several areas permanently closed to the use of hand trawl nets (dragnets). This includes the waters of the Swan River within 100 metres of the Pelican Point Nature Reserve and the Milyu Nature Reserve (Como).

Stock assessment: Previous catches of school prawns in the estuary have been highly variable, reflecting annual fluctuations in spawning and recruitment success. Relatively high catches occurred in 1977-80 and 1984-85, possibly as a result of two or more consecutive dry winters, which may increase the survival of young prawns. Very low catches were recorded in 1982 (Potter *et al*. 1986).

The current abundance of school prawns in the Swan Estuary appears to be very low relative to historic levels. The last significant commercial catches of school prawn occurred in 1975. Significant recreational catches were last taken in the late 1990s, suggesting that abundance in the estuary has been very low since then (Maher 2002). Recreational fishers reported a slight increase in abundance of school prawns in 2003 and 2004.

This population inherently has limited capacity to recover because it is an isolated breeding unit and reliant on self-replenishment.

6.1.3 Perth herring

Biology: Perth herring (*Nematolosa vlaminghi*) are endemic to WA, occurring from Broome to Bunbury (Kailola *et al*. 1993). Available data suggest that each estuarine population may be a discrete stock (Chubb *et al*. 1984). This notion is supported by the fact that, in some related species, adults return to spawn each year in their natal river. In the Swan Estuary, adult Perth herring migrate from ocean waters to the upper reaches of the estuary to spawn in summer. The movement of adults while in marine waters has not been examined. However, commercial catches of Perth herring in coastal waters near the Swan Estuary have been mainly restricted to within a few kilometres of the estuary mouth, suggesting limited movement away from the estuary.

Mature fish enter the Swan Estuary during spring and move rapidly through the lower and middle estuary towards spawning areas in the upper estuary (Chubb and Potter 1984). Spawning locations are upstream of the commercial fishery area in the Swan Estuary. Hence, the primary peak in commercial catches occurs prior to spawning (September/October) when adults are migrating upstream through the fishery area to spawning areas. A secondary peak in catches occurs after spawning (February), when adults are moving downstream through the fishery area on their return to the ocean. Recreational anglers report that Perth herring form large aggregations at night under the Narrows Bridge (apparently attracted to the bridge lights) in September-November, roughly corresponding to the timing of upstream migration. At these times, mulloway also aggregate under the Narrows Bridge to feed on the Perth herring.

Spawning by Perth herring occurs in the upper estuary (sites 5-8 in Chubb *et al*. 1984) in December, and to a lesser extent in January. After spawning, eggs and larvae are likely to experience limited dispersal downstream due to low flow rates at this time of year (Neira *et al*. 1992). Small juveniles start to appear in the upper estuary in January and gradually disperse throughout the upper, middle and lower estuary over the next 1-2 months.

The overall distribution of Perth herring in the Swan Estuary is related to variations in salinity. The upstream migration of adults coincides with the easing of freshwater flows and the intrusion of the salt wedge into the upper estuary. At the onset of autumn rains, Perth herring abundance declines rapidly in the upper estuary. Both juveniles and adults are absent from the upper estuary from approximately July to September, corresponding to periods of low salinity. While adults return to ocean waters in winter, juveniles reside in the estuary all year. Juveniles are most common in the middle estuary, where they occur in all months (Chubb and Potter 1984).

The Swan Estuary population is dominated by individuals aged 0-4 y (Chubb and Potter 1986). Maturity and recruitment to the commercial fishery occurs at age 2-3 y, and length >160 mm. The maximum age and length of Perth herring is reported to be 8 y and 360 mm TL (Chubb and Potter 1986). However, this maximum age was determined by an examination of scale increments. A preliminary examination of otolith increments suggests a maximum age of at least 18 years (K. Smith, DoF, unpubl. data).

Fish kills and environmental impacts on stock: A harmful algal bloom or other factor resulting in a fish kill in the upper estuary during the December/January, or shortly after, could have a major impact on this stock. Such an event could affect a large proportion of eggs, larvae, juveniles and breeding adults. In the Swan Estuary, fish kills tend to occur in summer/autumn in the upper estuary, coinciding with the timing and location of spawning by Perth herring. Therefore, there is a high likelihood of a major impact on this stock in the near future. Indeed, during fish kills in April-June 2003, hundreds of dead Perth herring were collected and many more were observed in the Swan and Canning Rivers (Swan River Trust, unpubl. data). Locations of dead fish included the Swan River between Ascot and Perth Water and the lower Canning River near Coffee Point.

In summary, harmful algal blooms resulting in fish kills represent a high risk to this stock. Major fish kills in summer/autumn in successive years could significantly lower spawning stock size and reduce annual recruitment by Perth herring.

Trophic links: Perth herring are a small (<300 mm), schooling species. As such, they are likely to be a component of the diet of some larger predatory species including birds, sea lions, dolphins and important fishery species such as mulloway and tailor. Recreational fishers report that small Perth herring are also consumed by large black bream. Depletion of the Perth herring stock is likely to reduce prey available to various species in the estuary.

Fishery: Perth herring contributed approximately 24% by weight and 4% by value to recent annual commercial finfish catches in the Swan Estuary (Table 2, 3). Catches occur during all months of the year, but are generally lowest in May-July when adults migrate downstream of the fishing area and become unavailable to commercial fishers (Fig. 5). Recreational fishers do not catch this species in the estuary (Tables 4-6).

Recruitment by Perth herring to the commercial fishery occurs at approximately the same age/length as maturity (2-3 y / 160 mm). Hence, many individuals are vulnerable to capture in Swan Estuary before they have an opportunity to breed.

From 1963 to 1988, the annual commercial catch of Perth herring in the Swan Estuary was >40 t. This relatively lengthy period of stable catches suggests that annual catches of 40 t in the estuary may have been sustainable under the environmental conditions that existed at that time. In the 1960s and early 1970s, some annual catches exceeded 100 t, including a peak of 150 t in 1968-69. However, the lower catches around 1970 and during the late 1970s, following these peaks, suggest that catches of >100 t were unsustainable.

Annual catches of Perth herring from Cockburn Sound were >40 t during the 1970s and averaged ~15 t per year during the 1990s (DoF unpubl. data). No catches were reported from Cockburn Sound after 2000.

Stock assessment: The magnitude of past catches and data from previous fishery-independent surveys (e.g. Loneragan *et al*. 1989) indicate that Perth herring was formerly one of the most abundant fish in the estuary. However, commercial catch trends suggest that the abundance of this species has been declining since the 1980s. All available evidence, including simultaneous catch declines in adjacent coastal waters where the same stock was commercially targeted until recently (D. Gaughan, DoF, pers. comm.), anecdotal reports from fishers and low catches in recent fishery-independent surveys (I. Potter, Murdoch University, unpubl. data), suggests that the current stock size of Perth herring is very low relative to historic levels and possibly still declining. Since this species has been subject to relatively low fishing pressure in recent years, the decline in abundance of this species is probably now being driven by environmental factors rather than fishing pressure.

Environmental changes over the last 20 years or so may have reduced the 'carrying capacity' of the estuary in relation to Perth herring. In particular, poor water quality in the middle/upper estuary may have affected growth and mortality at all life history stages of this species. If so, then the relatively low recent (<10 t) annual catches may actually be unsustainable, despite (apparently) sustainable annual catch levels of 40 t in the Swan Estuary (plus landings in Cockburn Sound) in earlier years of the fishery.

This population inherently has limited capacity to recover because it is an isolated breeding unit and reliant on self-replenishment. All available evidence suggests that the current stock size of Perth herring is already very low relative to historic levels and possibly still declining.

6.1.4 Cobbler

Biology: Cobbler (C*nidoglanis macrocephalus*) are endemic to temperate Australia, occurring in southern Queensland, New South Wales, South Australia and Western Australia, but not occurring in Tasmania or Victoria. In WA, they occur southwards from the Houtman-Abrolhos Islands. Adults and juveniles inhabit estuarine and coastal waters to approximately 30 m depth (Kailola *et al*. 1993). The Swan Estuary population is a discrete stock and is self-replenishing. Genetic and morphological differences indicate that there are low levels of mixing between marine and estuarine populations and among estuarine populations of cobbler (Kowarsky 1975, Ayvazian *et al*. 1994). Therefore, movement of fish between the Swan Estuary and adjacent marine waters, or adjacent estuaries, is probably negligible.

In the Swan Estuary, cobbler movement follows a seasonal pattern that corresponds to variations in salinity. Fish are concentrated in the middle estuary in winter, spread upstream to the upper estuary during spring/early summer (following the upstream intrusion of the salt wedge) and are most dispersed throughout the estuary in late summer (Kowarsky 1975). Abundance tends to be highest in the middle estuary throughout the year and larger fish are most often found in the middle estuary (Nel *et al*. 1985).

In winter/spring, cobbler form tight aggregations in the middle estuary. For example, Point Walter is well known to recreational and commercial fishers as a site where aggregations occur. Winter aggregations at this location have historically been a major component of the commercial cobbler catch. It is not clear whether the purpose of these aggregations is feeding or reproduction.

Cobbler attain a maximum size of 760 mm and age of 13 y. In the Swan Estuary, 50% maturity is reached at an age of 2-3 y and a total length of 385/405 mm (male/female) (Nel *et al*. 1985). In the Swan Estuary, spawning occurs from October to December. Eggs are laid in burrows constructed and guarded by males. Cobbler produce relatively few eggs (500-3500 eggs per batch), but this low level of fecundity is offset by high parental investment in offspring (i.e. large egg size and relatively late developmental stage at which larvae emerge from burrows). This reproductive strategy promotes low dispersal of larvae.

Fish kills and environmental impacts on stock: Observations of cobbler in several south-west estuaries, including the Swan, indicate that burrows are located under structures such as rocks or seagrass root mats, which form the roof of the burrow. Hence, reproduction is dependent on the availability of suitable habitat. Burrow entrances are typically 15-20 cm wide and burrows may be up to 1.5 m deep, with an expanded brood chamber at the far end (Cliff and Lenanton 1993). In the Swan Estuary, nesting is known to occur in Alfred Cove in the middle estuary. In previous years, rock retaining walls adjacent to Riverside Drive (middle estuary) were used as nesting sites, but reconstruction of these walls to create smoother surfaces with less large crevices has apparently reduced nesting opportunities in this area (R. Lenanton, DoF, pers. comm.).

In the surf zones of coastal beaches, juvenile cobbler undergo diurnal movement from detached macrophytes (day) to open sand (night). This movement presumably allows juveniles to avoid visual predators during the day. Also, there is a positive relationship between the abundance of juveniles and the amount of drift weed in such habitats. Although these observations are from marine rather than estuarine habitats, they suggest that the availability of suitable habitat is generally very important to juveniles in predator avoidance and feeding success (Lenanton and Caputi 1989, Robertson and Lenanton 1984).

Harmful algal blooms and other factors causing fish kills are a moderate risk to this stock. In the Swan Estuary, fish kills tend to occur in summer/autumn in the upper estuary. At this time, cobbler are dispersed throughout the middle and upper estuary and so it is likely that some individuals will be affected by an event at this time/location. However, the affected proportion of the population is likely to be small because the majority of the population appears to reside in the middle estuary at all times of year.

Overall, the likelihood of a major fish kill directly affecting a large proportion of the cobbler stock in the Swan Estuary is low. However, any additional threat to this population must be considered serious, given the very depleted size of the stock. Future fish kills are likely to include small numbers of cobbler and may have indirect effects on this species, such as reducing the abundance of prey.

Trophic links: The diet of cobbler consists of benthic invertebrates (polychaetes, molluscs, crustaceans).

Fishery: Cobbler was previously an abundant and valuable component of commercial and recreational fishery landings in the Swan Estuary. However, it now represents only a small proportion of landings by both sectors (Tables 2-6). Cobbler is still an important component of landings in some other south-western estuaries

There is strong seasonality in the commercial catch of cobbler within the Swan Estuary. Catches peak in winter, which reflects a concentration of individuals in the fishery area at this time (Fig. 5). Catches are very low from Nov-March, which may reflect the combined effects of dispersal throughout the estuary, including movement to areas upstream of the fishery area, and the low catchability of burrowing males during spring (Nel *et al*. 1985, Laurenson 1992). The seasonal pattern of landings has become more pronounced since the 1970s which may be due to a decline in abundance in the estuary, making catch rates difficult to sustain at times when breeding fish are unavailable and the remaining fish are widely dispersed.

The legal minimum length of cobbler is 430 mm (whole body weight ~420 g) (Nel *et al*. 1985), which is greater than the length at maturity in the Swan Estuary. Hence, individuals may have an opportunity to breed at least once before caught and retained. The legal minimum length increased from 230 to 430 mm in 1995. Cobbler retained by the MAAC from 1986 to 1993 included fish of weights 200-400 g, which probably included some older juveniles. Therefore, immature fish are vulnerable to capture by recreational fishers. Rates of post-release mortality for cobbler are unknown.

A daily bag limit of 4 cobbler currently applies to recreational fishers in the Swan Estuary.

Stock assessment: Historically, this species was an important target species for commercial and recreational fishers and was known to be moderately abundant in the Swan Estuary until the 1980s (Loneragan *et al*. 1989). However, the abundance of cobbler in the estuary has since been declining. There is a body of evidence to suggest that the current abundance of this stock is very low relative to historic levels, including declines in commercial and recreational catches, declines in catches from fishery-independent sampling (I. Potter, Murdoch University, unpubl. data) and anecdotal reports from commercial and recreational fishers.

No data about the age or size structure of the cobbler stock in the Swan Estuary has been collected since the 1980s.

A decrease in recreational CPUE, coinciding with an increase in the average size of fish retained by recreational fishers, suggests recruitment failure during the mid-1990s. The commercial CPUE was maintained (i.e. exhibited 'hyperstability') until the stock collapsed in the mid-1990s, after which time recreational and commercial catches largely ceased.

The decline in abundance of cobbler in the Swan Estuary is likely to be due to the combined effects of fishing pressure and loss of key habitats. The impacts of fishing pressure on the population structure and abundance of cobbler have been demonstrated in other south-west estuaries. In Wilson Inlet, adult cobbler were found to be more abundant in an area near the estuary entrance that was closed to commercial fishing, than in open areas (Laurenson 1992). Although this distribution is likely to partly reflect a preference by adults for higher salinities, it is also likely that fishing contributes to localised depletions, given the moderately sedentary nature of this species. Large fish, especially females, appear to be most vulnerable to capture. In Wilson Inlet, catches in closed areas contained higher proportions of older fish and females than open areas. The sex ratio was balanced in catches from open areas. Males are probably less vulnerable to capture because they spend part of the year in burrows and also attain a smaller size-at-age than females.

This population inherently has limited capacity to recover because it is a discrete, self-replenishing stock. Low breeding stock size, low individual fecundity, a limited availability of key breeding habitats and fishing pressure would also limited recovery.

6.1.5 Yellowtail trumpeter

Biology: Yellowtail trumpeter (*Amniataba caudavittatus*) occurs in western and northern estuaries of Australia, from Cape Leeuwin (WA) to Bowen (Qld) including the Northern Territory (Hutchins and Swainston 1986). It also occurs in New Guinea. Individuals commonly form schools over sand and weed bottoms. Yellowtail trumpeter is primarily a marine species throughout its range, although it is largely confined to estuaries in south-western Western Australia (Potter *et al*. 1990).

Individuals can tolerate a very wide range of salinities, from fresh to hypersaline (e.g. Lenanton 1977). The distribution of these fish in the Swan Estuary tends to correspond to salinities of >30‰, suggesting a preference for oceanic salinities (Wise *et al*. 1994). In winter, yellowtail trumpeter is absent from the upper estuary, which experiences low salinity at this time. In winter, fish also tend to move into deeper waters of the middle estuary and reside below the halocline, again avoiding low salinities (Wise *et al*. 1994).

In spring, mature fish migrate to the upper estuary to spawn and only juvenile fish (age class 0+ y) remain in the middle estuary (Wise *et al*. 1994). Spawning occurs in the lower section of the upper estuary (between Heirisson Island and the Helena River) from mid-November to early February, but predominantly in January (Potter *et al*. 1994). Spawning is presumed to occur in shallow water (Potter *et al*. 1994). Fecundity increases with female body size, and ranges from 50,000 to 705,000 eggs at lengths of 150 to 254 mm (Potter *et al*. 1994). Eggs and larvae are pelagic and are potentially dispersed downstream throughout the upper and middle estuary, although currents are low at the time of spawning. The recruitment of small juveniles to shallow habitats in the upper estuary commences in January (Wise *et al*. 1994).

Adults and juveniles, including age 0+ fish, are relatively abundant in the upper estuary during summer and autumn, and then move downstream to the middle or lower estuary at the onset of winter rains.

Maturity is generally attained at the end of the 2nd year, although some individuals mature at the end of their 1st year. The minimum length at maturity is 130/150 mm (male/female), corresponding to an age of ~2 y and a body weight of ~55 g (Potter *et al*. 1994). Yellowtail trumpeter reach an age of at least 3 years and length of at least 260 mm in the Swan Estuary (Wise *et al*. 1994). Females attain a larger maximum size than males. The maximum recorded length of yellowtail trumpeter is 28 cm (Hutchins and Swainston 1986).

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills are a moderate risk to this stock. In the Swan Estuary, major fish kills typically occur in summer/autumn in the upper estuary. Adult yellowtail trumpeter aggregate to spawn in the upper estuary from November to February, with a peak in activity in January. Therefore, a fish kill in the upper estuary during summer could affect a high proportion of the breeding stock, many larvae and some juveniles. A significant proportion of juveniles occur in the middle estuary in summer and so would not be directly impacted by a fish kill in the upper estuary. Surviving juveniles would mature and spawn the following summer, along with surviving adults. Hence, following a severe fish kill in the upper estuary, some spawning would still occur in the following year. Major fish kills in the upper estuary during summer in 2 or more consecutive years would have a more serious impact on this stock.

During fish kills in the upper estuary in April-June 2003, no yellowtail trumpeter were reported dead. However, because a comprehensive survey of affected fish was not undertaken during this event, it is possible that some yellowtail trumpeter were killed, including small juveniles. Relatively low mortality of adults may have been due to a higher tolerance by yellowtail trumpeter of conditions created by the algal bloom (toxins, gill clogging, low oxygen), or greater ability to escape, than other fish species. Alternatively, only a small proportion of the yellowtail trumpeter stock may have been present in the affected area. From March onwards, adults and juveniles are dispersed throughout the middle and upper estuary. A fish kill in November-February, when adults and small juveniles are aggregated in the upper estuary during/after spawning, may have had a greater impact on this stock.

Fish kills may also have indirect effects on yellowtail trumpeter, such as reducing the abundance of prey. Similarly, mortality of yellowtail trumpeter during a fish kill could indirectly impact on stocks of larger predatory species.

Trophic links: Yellowtail trumpeter are omnivorous. Their diet includes benthic crustaceans, polychaetes, molluscs, algae and small fish such as gobies and small clupeids (Wise *et al*. 1994). Yellowtail trumpeter are probably consumed by numerous larger predatory fish.

Fishery: Yellowtail trumpeter is of low commercial value in the Swan Estuary, representing approximately <1% of the weight and <1% of the value of recent annual commercial landings in the estuary (Table 2, 3). Since 1989, commercial landings of yellowtail trumpeter have been negligible (<1 t), although in earlier years annual catches of up to 7 t were taken. The low recent commercial catch levels probably reflect low targeting because markets for this species are limited.

In contrast, yellowtail trumpeter is one of the main fish species retained by recreational fishers in the estuary. Yellowtail trumpeter is among the 5 most commonly caught species and among the 10 most commonly retained species in the recreational fishery (Tables 4-6). It is mainly caught by shore-based recreational fishers (Table 4).

There is currently no legal minimum length for yellowtail trumpeter in the Swan Estuary, but fish <200 mm tend to be released by recreational fishers (K. Smith, DoF, pers. obs.). Since

1986, the average size of yellowtail trumpeter retained by the MAAC has typically been >100 g. These sizes are above the size at maturity, suggesting that individuals have a chance to breed at least once before they are retained (assuming they survive release). A daily bag limit of 16 fish applies to recreational fishers.

Stock assessment: The magnitude of recreational catches and data from various fishery-independent surveys in the Swan Estuary indicate that this species was, and still is, one of the most abundant fish in the estuary (e.g. Loneragan *et al*. 1989, I. Potter, Murdoch University unpubl. data). However, recreational catch trends suggest that the abundance and average size of fish has been declining since 1993. Environmental degradation in the upper estuary and fishing-related mortality represent risks to this species. A steadily decline in average fish size between 1987 and 2003 is consistent with high rates of total mortality.

The Swan Estuary stock inherently has limited capacity to recover from depletion because it is an isolated breeding unit, with moderate fecundity and reliant on self-replenishment. A relatively early age at maturity (1-2 y) would assist the stock to reproduce relatively quickly and recover from depletion within a few years. However, persistently high annual mortality (e.g. due to fish kills in consecutive years) could limit recovery. In particular, mortality of eggs, larvae and small juveniles of yellowtail trumpeter during algal blooms or other harmful events in the upper estuary is unknown but could be significant.

A considerable number of yellowtail trumpeter are caught and released by recreational fishers. As an abundant species, it may also be caught and discarded by commercial fishers. However, the quantities of discards are unknown because no surveys of bycatch have been undertaken in the commercial fishery. The mortality rate of fish that have been discarded is unknown but, since discard rates are probably relatively high, post-release mortality could be significant.

6.1.6 Sea mullet

Biology: Sea mullet (*Mugil cephalus*) have a world-wide distribution, in temperate and tropical waters, from approximately 42°N to 42°S (Thomson 1963). Juveniles and adults of sea mullet are tolerant of a wide range of temperatures and salinities, including hypersaline and fresh waters (Smith and Deguara 2002). Sea mullet occur at all latitudes along the Western Australian coast. Swan Estuary sea mullet are probably part of a widespread south-western regional stock. Mixing between estuaries occurs via the migration of adults and the dispersal of marine eggs and larvae.

Small juvenile sea mullet recruit to the Swan Estuary in autumn/winter (May-Nov) at approximately 2-3 months of age and 20-30 mm length. They move rapidly through the lower estuary to settle in the middle and upper estuary and also eventually disperse to the tributaries of the upper estuary (Chubb *et al*. 1981). Juveniles occur in the middle and upper reaches of the Swan Estuary, including freshwater tributaries, at most times of year but tend to occur in the lower estuary during spring only (Chubb *et al*. 1981).

Sea mullet reach maturity at an age of 2-4 y. Adults typically reside in estuaries, except during spawning. In spring/summer, a large proportion of adults, and some 1+ and 2+ juveniles, migrate downstream and aggregate in the middle or lower estuary (Chubb *et al*. 1981). In late summer/autumn, adults migrate to ocean waters where they spawn in autumn/winter. They may be accompanied by some non-spawning juveniles although most fish probably remain in the estuary for the duration of their juvenile phase (Smith and Deguara 2002). Adults may not spawn every year, and some mature individuals may remain in upper, middle or lower reaches of the estuary during the spawning season.

Whilst in ocean waters, adults appear to migrate northwards along the coast prior to spawning. There is no evidence of a significant return (southward) migration along the Western Australian coast and so adults probably do not return to the same estuary after spawning.

Eggs and larvae may be dispersed north or south of the spawning site, depending on the direction of coastal currents, before recruiting as juveniles to estuaries. Eggs and larvae are potentially dispersed large distances during a larval phase lasting 2-3 months. Hence, juveniles recruiting to the Swan Estuary may have been spawned some distance away from the estuary. Adults entering the estuary probably originated from another estuary to the south.

Fish kills and environmental impacts on stock: Although sea mullet are known to reside permanently in sheltered marine waters elsewhere, in south-western Australia the majority of sea mullet spend their juvenile phase and most of their adult phase in estuaries or rivers and so can be considered 'estuarine-dependent'. A general decline in estuarine and riverine habitat quality throughout south-western Australia may have impacted on growth and mortality of this stock.

Harmful algal blooms and other factors causing fish kills appear to be a low risk to sea mullet in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would probably be elsewhere in the estuary at this time. In summer/autumn, sea mullet affected by a fish kill in the upper estuary could include some 0+ and 1+ juveniles, although fish in these age classes would also be widely dispersed in other parts of the estuary/river. Most adults would be in the lower estuary or ocean at this time.

Sea mullet consume algae and detritus and so mortality of other fauna during a fish kill would probably have a low impact on the feeding of this species.

Trophic links: Sea mullet consume algae and detritus and are consumed by numerous larger predatory fish such as sharks, mulloway, flathead, and tailor (Thomson 1957, Kailola *et al*. 1993).

Fishery: Sea mullet contributed approximately 22% by weight and 18% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). The commercial catch is seasonal, peaking in October/November when adults tend to aggregate in the fishery area (Fig. 5). Commercial catches are lowest in winter, when adults migrate to ocean waters to spawn. Compared to historic levels, recent annual landings of sea mullet in the Swan Estuary and elsewhere in south-western Australia have been low.

Since 2000, total annual landings of sea mullet in the south-western region of Western Australia have been declining. Most landings are made by gill nets and beach seine nets in estuaries. In 2004, total commercial landings in the south-western region were approximately 130 t.

There is currently no legal minimum length for sea mullet in the Swan Estuary, but a daily bag limit of 40 fish applies to recreational fishers. However, recreational catches of this species in the Swan Estuary are rare because netting is banned in this estuary. Nets are used by recreational fishers elsewhere in south-western Western Australia to target sea mullet belonging to the same stock as occurs in the Swan Estuary.

Stock assessment: Commercial catches of sea mullet in the Swan Estuary and other south-west estuaries (where the same stock occurs) have steadily declined since the 1950s (DoF, unpubl. data). The commercial CPUE has been declining since the early 1990s in the Swan Estuary and has been declining since 1980 in the adjacent Peel-Harvey Estuary. These declines at least partly reflect a decrease in market demand since the 1980s but probably also reflect a decline in stock abundance over recent decades. Historically, this species was a major target species in the Swan Estuary fishery and was known to be relatively abundant in the estuary until the 1980s (Loneragan *et al*. 1989). Catches taken during fishery independent surveys in the Swan Estuary have been declining since the 1980s (I. Potter Murdoch University unpubl. data).

Some fluctuations in CPUE may be due to recruitment variability, which is characteristic of sea mullet populations (e.g. Smith and Deguara 2002). For example, the average annual commercial catch and CPUE of sea mullet in the Swan Estuary increased from 1990 to 1997 but decreased from 1997 to 2003. However, it is unclear whether this was due to recruitment variability because the same fluctuation was not observed in the Peel-Harvey Estuary (DoF unpubl. data), which presumably experiences similar trends in recruitment by marine larvae of this species.

Sea mullet within the Swan Estuary are part of a larger stock that is distributed among the estuaries of south-western Australia. Adults spawn in ocean waters and the annual rate of juvenile recruitment to the Swan Estuary is not likely to be dependent on adult population size within the estuary. Therefore, an isolated fish kill in the Swan Estuary is likely to have a low impact on the stock and a low impact on commercial catches of sea mullet in the estuary. However, most of the south-western estuaries and rivers where this species occurs are degraded and experience occasional or annual fish kills. It is likely that the cumulative effects of various anthropogenic impacts throughout its range are impacting on this stock.

The extent to which the abundance of the south-west sea mullet stock has declined over recent years is difficult to assess from commercial fishery data due to the confounding effect of significant variations in effort and market-driven targeting. Unfortunately, fishery-independent surveys have been infrequent and so provide limited additional information.

6.1.7 Yellow-eye mullet

Biology: Yellow-eye mullet (*Aldrichetta forsteri*) occur in temperate waters of southern Australia, including Tasmania, from Shark Bay, WA, to the Hunter River, NSW (Kailola *et al*. 1993). Yellow-eye mullet within the Swan Estuary are part of a larger stock that is distributed throughout estuaries and marine waters of south-western Australia. Mixing of the stock between estuaries occurs via the dispersal of marine eggs and larvae and the movement of adults.

Yellow-eye mullet is essentially a marine species that utilises coastal waters and the lower, more saline reaches of estuaries. Older adults mainly occur in coastal waters. Mature fish migrate from the Swan Estuary to spawn in coastal waters near to the mouth of the estuary (Chubb *et al*. 1981). Spawning occurs from April to August. Post-larvae recruit to the Swan Estuary from marine waters between May and September.

Age 0+ fish occur in shallow waters in the lower, middle and downstream section of the upper estuary (i.e. mainly below Heirisson Island) throughout the year, and also occur in adjacent coastal waters (Chubb et *al*. 1981). Age 1+ and 2+ fish also occur in the same areas but are less abundant in warmer months, suggesting that many older juveniles migrate to sea in summer. This probably reflects a preference for cooler water.

Maturity of yellow-eye mullet is reached at 2-3 y, corresponding to a total length of 300 mm and a body weight of 297 g (Chubb *et al*. 1981).

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills appear to be a low risk to yellow-eye mullet in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on yellow-eye mullet, such as reducing the abundance of prey.

Yellow-eye mullet within the Swan Estuary are part of a larger stock that is distributed among the estuaries and coastal waters of south-western Australia. Adults spawn in ocean waters and the annual rate of juvenile recruitment to the Swan Estuary is not likely to be dependent on adult population size within the estuary. Therefore, high mortality in the Swan Estuary during one year is likely to have a low impact on the total stock and a low impact on subsequent fishery catches of yellow-eye mullet in the estuary.

On the other hand, most of the south-western estuaries where this species occurs are degraded and experience occasional or annual fish kills. While juveniles and adults of this species are not totally dependent on estuaries (i.e. they also utilise marine habitats), nevertheless many individuals of this species do occur in estuaries. It is possible that the cumulative effects of various anthropogenic impacts throughout its range are impacting on the stock.

Trophic links: Yellow-eye mullet is omnivorous, consuming small invertebrates and algae (Thomson 1957). The population of yellow-eye mullet within the Swan Estuary consists mainly of small fish (length <30 cm) that probably contribute to the diet of numerous larger predators such as sharks, mulloway, flathead and tailor (Thomson 1957, Kailola *et al*. 1993).

Fishery: Yellow-eye mullet contributed approximately 5% by weight and 2% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). It was caught in minor quantities by recreational fishers (Tables 4-6). Compared to historic levels, recent annual commercial landings of yellow-eye mullet in the Swan Estuary and elsewhere in south-western Western Australia have been low.

Since 2000, total commercial landings of yellow-eye mullet in the south-west region of Western Australia have varied between 40 and 75 t per year. Most landings are made by gill nets and haul nets in estuaries.

Fishery landings in the Swan Estuary are dominated by older juveniles and young adults, and these fish tend to migrate to ocean waters during warmer months (Chubb *et al*. 1981). Hence commercial catches of yellow-eye mullet Swan Estuary are seasonal, reaching a maximum in May-July and a minimum in December-January (Fig. 5).

There is currently no legal minimum length for yellow-eye mullet in the Swan Estuary. A daily bag limit of 40 fish applies to recreational fishers. Since 1986, the body weight of most yellow-eye mullet retained by the MAAC was between 100 and 200 g, suggesting that most fish retained by the Club were immature (Fig. 11). The mortality rate of fish that have been discarded by recreational or commercial fishers is unknown.

Stock assessment: Commercial catches of yellow-eye mullet in south-western estuaries have steadily declined over recent decades (DoF, unpubl. data). The commercial CPUE has been declining since the early 1990s in the Swan Estuary and has been declining since 1980 in the adjacent Peel-Harvey Estuary. These declines at least partly reflect a decrease in market demand since the 1980s but could also reflect a decline in stock abundance. This species was known to be relatively abundant in the Swan Estuary at least until the 1980s (Loneragan *et al*. 1989). A decline in catches taken during fishery-independent sampling since the 1980s (I. Potter, Murdoch University, unpubl. data) and an apparent decline in recreational CPUE since the mid-1990s suggest a decline in abundance in the Swan Estuary.

The extent to which yellow-eye mullet has declined (if at all) over recent years is difficult to assess from commercial fishery data due to the confounding effects of significant variations in effort and market-driven targeting. Unfortunately, fishery-independent surveys have been infrequent and so provide limited additional information.

6.1.8 Tailor

Biology: Tailor (*Pomatomus saltatrix*) have a world-wide distribution and occur in temperate waters of North and South America, east and west coasts of Africa, the Mediterranean Sea and the Black Sea (Juanes *et al*. 1996). In Australia, they occur in southern waters from Onslow (WA) to Fraser Island (Qld). Tailor typically form schools, which occur in continental shelf waters, coastal waters and estuaries. Stocks on the east and west Australian coasts are separate (Kailola *et al*. 1993). Tailor in the Swan Estuary belong to a stock that ranges throughout southern Western Australia (Edmonds *et al*. 1999, Young *et al*. 1999). Genetic mixing over this region occurs via adult migration and the dispersal of eggs and larvae. Tailor on the lower west coast are probably a separate stock to those occurring in Shark Bay.

In eastern Australia, adult tailor typically migrate northwards along the coast prior to spawning. They return southwards after spawning, although it is not clear whether they return to precisely the same pre-spawning location. Spawning behaviour on the west coast is less well known than on the east coast because western fish do not form large, conspicuous spawning aggregations. Water temperature and salinity that is conducive to tailor spawning occurs along much of the west coast, and so tailor may not need to migrate alongshore to find favourable spawning areas (unlike on the east coast) (Lenanton *et al*. 1996). On the west coast, northward movement of adults does occur and some spawning may occur around Geraldton in spring (Lenanton et al. 1996). However, limited evidence suggests that some spawning also occurs during summer at offshore reefs in the Perth area and during autumn along the lower west coast, south of Perth.

After a marine larval phase, tailor recruit as small (~40 mm) juveniles to sheltered coastal areas and estuaries, where they tend to remain until maturity. Juveniles that recruit to the Swan Estuary are probably spawned either locally or south of the estuary. Ocean circulation modelling suggests larvae in Perth coastal waters are probably derived from local spawning sites (Chisholm 2004). However, larvae spawned on the lower west coast in summer/autumn could potentially be transported northwards to the Swan Estuary by the Capes Current. In contrast, during the northern spawning season (spring/summer), coastal surface currents are predominantly northward and so larvae spawned in marine waters off Geraldton are unlikely to be transported southwards to the Swan Estuary.

Lenanton *et al*. (1996) estimated that 69% of the lower west coast stock resides in inshore marine and estuarine habitats and that this component of the stock largely consists of sub-adult fish <350 mm in length. In the west coast region, tailor reach maturity at 300-350 mm TL, which corresponds to a body weight of 270-415 g and age 2-3 y (Kailola *et al*. 1993, Juanes *et al*. 1996, DoF unpubl. data).

Tailor caught in fishery-independent surveys in the Swan Estuary range from 47 to 415 mm in length, but the majority are juveniles, i.e. <350 mm (Loneragan *et al*. 1989). Small juveniles occur in the lower, middle and upper estuary, whereas larger juveniles mostly occur in the lower and middle estuary (Loneragan *et al*. 1989).

Tailor reach approximately 150 mm by the end of their first year, and exceed 600 mm TL by age 5 y (Kailola *et al*. 1993). Maximum reported size is 1200 mm TL and 14 kg. Maximum reported age is 9 years (www.fishbase.com). However, age structure is unclear in most stocks, including south-western Australia, due to difficulties in determining age in tailor.

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills appear to be a low risk to tailor in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would probably be downstream (lower or middle estuary) or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on tailor, such as reducing the abundance of prey.

Tailor within the Swan Estuary are mainly immature fish that comprise a small fraction of a widespread stock that is distributed among the estuaries and coastal waters of the west coast. Adults spawn in ocean waters and annual recruitment to the estuary occurs via the influx of marine post-larvae in summer. The rate of recruitment is independent of the population size within the estuary. Therefore, high mortality in the Swan Estuary during one year is likely to have a low impact on the total stock and a low impact on subsequent fishery catches of tailor in the estuary.

While juveniles and adults of this species are not totally dependent on estuaries (i.e. they also utilise marine habitats), nevertheless many individuals of this species do occur in estuaries. Most of the south-western estuaries where juveniles of this species occur are degraded and experience occasional or annual fish kills. Some coastal waters are also degraded and have experienced recent fish kills (e.g. pilchard deaths in 1998/99). It is possible that the cumulative effects of various anthropogenic impacts throughout its range are impacting on the tailor stock, either directly or through a reduction in prey.

Trophic links: Juvenile tailor consume small fish and invertebrates, while adults mainly consume fish (Kailola *et al*. 1993).

Fishery: Tailor in the Swan Estuary are part of a widespread south-western regional stock. In this region, the majority (94%) of tailor landings are taken on the lower west coast by recreational fishers in coastal and estuarine waters (Penn 2005). In 2000/01, annual recreational landings along the lower west coast were estimated to be 187 t (Henry and Lyle 2003). Minor catches of tailor are taken by commercial fishers in south-west coastal waters, and in the Swan and Peel-Harvey Estuaries, Hardy Inlet and (to a lesser degree) in south coast estuaries.

Tailor contributed approximately 2% by weight and 2% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Commercial landings of tailor in the estuary are seasonal. Highest catches occur from August to December, moderate catches occur from January to April, and low catches occur from May to July (Fig. 5). Tailor is highly prized by recreational anglers and was one of the most commonly retained species in the Swan Estuary recreational fishery in recent years (Tables 4-6). Future recreational catches of tailor in the estuary may be lower as a result of an increase in the legal minimum length in 2003 (see below).

Tailor are vulnerable to capture by recreational fishers from their first year onwards. Prior to 1999, the average size of tailor retained in the Swan Estuary by the MAAC was <250 g, indicating that catches were mainly comprised of juveniles. Subsequent catches, from 1999 to 2003, had a slightly larger average size of 250-370 g, but these were still mainly juveniles.

Stock assessment: The total commercial catch and CPUE of tailor in the south-west region has been stable over an extended period. However, commercial landings may not be a reliable index of abundance because they represent only 6% of the total west coast catch (Penn 2005). In contrast, recreational CPUE trends in the Swan Estuary suggest a gradual decline in tailor abundance in the estuary since 1986/87. Both recreational and commercial CPUE trends suggest a slight increase in tailor abundance during the late 1990s followed by a marked decline in abundance, due to poor recruitment, after 2000. The average body size of fish retained by the MAAC suggest poor recruitment to the estuary from 1998 to 2003, and particularly in 2000/01. Annual surveys of juvenile recruitment, undertaken since 1995, also indicate that west coast tailor recruitment was relatively low from 1998 to 2004 (Penn 2005).

Concerns over the status of this stock have led to the daily bag limit for recreational fishers in the west coast region (including the Swan Estuary) being changed twice since the early 1990s – from unlimited to 20, then from 20 to 8 per person. In 2003, a provision was added to the daily bag limit such that only 2 fish >600 mm TL could be retained. However, recent anecdotal reports from recreational fishers suggest that fish >600 mm TL are very rare, even in offshore waters where larger tailor are typically found (C. Bibra, pers. comm.). A new upper limit of 500 mm TL has recently been proposed.

At the end of 2003, the legal minimum length (LML) was increased from 250 to 300 mm TL (i.e. from approximately 165 g to 270 g body weight). The new LML is likely to reduced recreational tailor landings in the Swan Estuary because the majority of tailor caught in estuaries are <300 mm. To comply with the LML, most fish caught in estuaries and some caught in ocean waters must now be released. Post-release mortality of locally caught fish appears to be relatively low (~3%) within the first few hours of release (Ayvazian *et al*. 2002) but longer-term mortality is unknown. A LML of 300 mm TL is still less than the length at 100% maturity, and so some juveniles and young adults are still likely to be caught and retained in estuaries and ocean waters prior to their first spawning.

Anecdotal reports suggest a recent increase by recreational fishers in targeting larger tailor around offshore reefs on lower west coast. Targeting of these fish, which appear to be spawning aggregations, is of concern. Despite bag and size limits, the recreational catch of tailor in ocean waters is essentially unconstrained.

6.1.9 Black bream

Biology: Black bream (*Acanthopagrus butcheri*) are endemic to Australia. They inhabit estuarine waters from Myall Lakes (NSW) to the Murchison River (WA), including Tasmania but excluding the Great Australian Bight (Kailola *et al*. 1993). Populations within each estuary are essentially discrete stocks with very limited movement of adults or eggs/larvae between estuaries (Norriss *et al*. 2002, Burridge *et al*. 2004).

In the Swan Estuary, adults are typically associated with salinities of 10-20 ppt (Sarre 1999). During winter, when freshwater discharge is high and salinities are very low in the upper estuary, many adults occur in the middle and lower estuary. In spring/early summer (Oct-Dec), a large proportion of adults appear to migrate upstream, following the upstream migration of the salt wedge. Adults remain in the upper estuary until the onset of autumn rains, when they are either flushed or migrate from the upper estuary.

The movements of tagged and recaptured fish and monthly fishery catch trends are consistent with these seasonal movement patterns. In March 1995, 767 artificially reared and tagged juvenile fish were released at Ron Courtney Island (middle estuary) (Dibden *et al*. 2000). Recaptures (n = 97) of tagged fish occurred at or upstream of this site, except in winter/early spring when some fish were recaptured downstream in the middle estuary. The autumn migration of fish from the upper estuary is followed by a winter peak in commercial catches in the middle estuary.

Contrary to the general pattern of movement, there is evidence that some adults do not migrate with the salt wedge and are perhaps resident in each section of the estuary throughout the year. Firstly, adults are caught in summer/autumn by commercial fishers in the middle estuary and by recreational fishers in the lower estuary, indicating that not all fish migrate upstream following the salt wedge. Secondly, large fish are caught by recreational fishers in the upper estuary in winter (Jun-Sep), even during periods of heavy freshwater discharge. Black bream are believed to prefer saline or brackish water, but some individuals may persist throughout the year in the upper estuary by inhabiting deep pockets of brackish water during freshwater flows (Sarre 1999).

In WA, spawning by black bream may occur in winter, spring or summer depending on the estuary. In all estuaries, spawning typically occurs at the interface between fresh and brackish waters (i.e. the boundary of the salt wedge). In the Swan Estuary, spawning mainly occurs from October to January, with a peak in activity in November (Sarre 1999). At this time, the boundary of the salt wedge is located in the upper estuary. Spawning is believed to occur in the upper estuary, from approximately Heirrison Island to Ron Courtney Island (R. Lenanton, pers. comm). In this area, aggregations of sexually mature fish occur in salinities of 6-25 ppt but are mainly associated with salinities of 10-19 ppt (Sarre 1999).

During the spawning season, several batches of eggs are released by individual females. Fecundity increases with female body size. Total fecundity ranges from approximately 350,000 (at 250 mm TL) to 6,600,000 eggs (at 500 mm TL) (Sarre 1999). Egg buoyancy depends on water density. At salinities and temperatures that are typical of the upper Swan Estuary during the spawning season, eggs are probably neutrally buoyant (Butcher 1945, Newton 1996, Partridge *et al*. 2003). Therefore, eggs could be dispersed downstream by currents although flow rates at this time are low. Aquarium studies and limited field observations suggest that larvae are demersal and so are unlikely to disperse far from the spawning site. Small juvenile black bream are initially distributed in the upper or middle estuary.

Juveniles are typically associated with salinities of 20-30 ppt (Sarre 1999). A low tolerance to freshwater may partly explain why juveniles never occur in the upstream section of the upper estuary and are rare throughout the upper estuary in winter/early spring, corresponding to situations of low salinity (Sarre 1999). After a residence of almost 12 months in the upper estuary, juveniles may either actively migrate or be flushed downstream at the onset of autumn rains (Sarre 1999).

Black bream move into deeper water with increasing age. In the Swan Estuary, small juveniles (16-60 mm) are common during the warmer months in shallow (< 1.5 m depth) beds of macroalgae (*Gracilaria verrucosa*). Larger juveniles (> 60 mm) tend to occur over shallow sand and large adults tend to occur in deeper areas (Sarre 1999).

Juveniles grow rapidly in their first summer, reaching 100 mm TL after approximately 6 months (Sarre 1999). Length is approximately 125 mm at 1 year and approximately 200 mm at 2 years. Males and females both attain 50% maturity at approximately 2.2 y and 220 mm TL. Sarre and Potter (2000) observed a maximum age of 21 y among black bream collected from 1993 to 1995 but found that the proportion of fish aged $\geq$ 5 y in the Swan Estuary population was small, relative to populations in other estuaries. Black bream exceeding 30 y of age have been captured in the Blackwood River (S. de Lestang, pers. comm.).

The growth rate of black bream appears to be highly plastic, varying in response to diet, water temperature and other environmental conditions. For example, in the mid-1990s, average growth rates in the Swan Estuary were higher than in some other south-western estuaries (Sarre and Potter 2000). At this time, black bream in the Swan Estuary mainly consumed benthic invertebrates (mussels, polychaetes, amphipods) and larger fish (>350 mm) also consumed crabs and fish. In other estuaries, where growth rates were slower, black bream consumed a higher proportion of algae.

Fish kills and environmental impacts on stock: Harmful algal blooms or other factors resulting in fish kills in the upper estuary during summer/autumn represent a high risk to this stock. Black bream occur in this area throughout the year and are likely to be a component of a fish kill at any time in this location. During summer or autumn, a large proportion of the population (including eggs, larvae, juveniles and adults) is expected to occur in the upper estuary. Indeed, black bream were a dominant component of autumn fish kills in the upper estuary in 2003 and 2004.

In spring/summer (October-January), adults are aggregated to spawn in the upper estuary. In late summer/autumn, a smaller proportion of spawning adults may be aggregated in the upper estuary but a large proportion of 0+ juveniles would be present. Harmful algal blooms are less likely during spring/early summer than in late summer/autumn, although other events such as chemical spills (e.g. November 1997) have occurred in spring and have resulted in mass mortality of fish.

During summer/autumn, some juveniles and adults occur upstream and downstream of the upper estuary and would not be directly affected by a fish kill at this time. This is supported by the fact that black bream were caught upstream and downstream of the affected area during and after the 2003 fish kills.

Trophic links: Black bream are omnivorous, consuming a wide range of benthic invertebrates, algae and small fish. The diet varies between estuaries depending on the availability of food items. In the Swan River, the dominant dietary component of all black bream of lengths >100 mm are Swan River mussels (Sarre and Potter 2000).

Fishery: The majority (>80% by weight) of recent black bream landings in the Swan Estuary have been taken by recreational fishers. It is highly prized by anglers and is the most commonly retained finfish species in the recreational fishery (Tables 4-6). The most recent survey of the recreational fishery in 2000/01 estimated a retained bream catch of approximately 16 t, and a similar weight of discarded fish (Henry and Lyle 2003). Black bream contributed approximately 7% by weight and 12% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Commercial landings of black bream in the Swan Estuary are highly seasonal (Fig. 5). Most commercial catches occur from July to October, when the maximum number of adult fish occur in the fishery area (i.e. the middle estuary).

In the Swan Estuary, recreational fishers are subject to a bag limit of 4 black bream, with only 2 fish >400 mm TL allowed to be retained. The legal minimum length is 250 mm (corresponding to age ~2.7 y and whole body weight ~288 g), which is greater than the size at 50% maturity (~220 mm, ~193 g). Therefore, most fish have an opportunity to breed before being retained, if they survive release.

From 1986 to 2003, the vast majority of black bream retained by the MAAC were mature (body weights 200-800 g). However, black bream are vulnerable to capture by recreational fishers at approximately 200 mm TL, and many are probably caught and released before reaching maturity (K. Smith, DoF unpubl. data).

Stock assessment: Fishery catch trends indicate a stable or increasing abundance of black bream in the Swan Estuary since about 1990. Recent catch levels suggest that this species is currently one of the more abundant target species in the estuary. However, the abundance of larger/older fish in 1993-95 (Sarre and Potter 2000) and in 2003/04 (K. Smith, unpubl. data) was low. In 2003/04, the average size (260-300 mm TL) and age (~3 y) of retained bream in recreational catches was relatively small (K. Smith, DoF, unpubl. data), compared with the maximum size (>400 mm) and age (>20 y) for this species.

Relatively high catch rates of small black bream since 1990 suggest that recruitment levels have been adequate to maintain the stock despite high fishing pressure and the impacts of various environmental factors in the estuary. However, the relatively small size and age of retained fish indicates that the stock is growth overfished, which increases the risk of recruitment overfishing. The relationship between spawning stock size and recruitment of black bream is not known.

The apparent increase in abundance of black bream suggested by recent catch rates may be an artefact of two factors. Firstly, an increased proportion of younger fish could influence catch rates since the catchability of smaller fish is probably higher than that of larger fish. Secondly, it is possible that changes in the commercial fishery that have occurred since 1990 (reduced effort, changes in catch reporting, entry/exit of fishers from the fishery, etc.) may have increased the targeting of bream. However, bream has always fetched a good price and so targeting has probably remained fairly constant.

Black bream population size in the Swan Estuary is likely to vary among years due to variations in recruitment. Strong year classes suggest high spawning success in 1990/91, 1991/92, 1995/96, 1998/99 and 2003/4, and low spawning success in 1999/00 (Sarre and Potter 2000, K. Smith, DoF, unpubl. data). In Victoria, populations of black bream also show extremely variable recruitment (e.g. Morison *et al*. 1998). Salinity levels are known to affect egg production and growth, and so variations in rainfall patterns among years could be partly responsible for recruitment variation by influencing annual spawning output and juvenile survival.

Intense fishing pressure probably results in many black bream being caught and released before reaching maturity. The mortality of released fish in the Swan estuary is unknown but a study in the Gippsland Lakes, Victoria, found that post-release mortality of black bream is relatively high (~23%) when fish were deep-hooked (i.e. throat, gill or gut) and relatively low (~3%) when shallow-hooked (lip or mouth) (Conron et al. 2004). Generally, larger fish (with larger mouth gape) are more likely to be deep-hooked.

If fishing techniques can be adjusted to ensure minimal mortality of released fish, then consideration could be given to alternative management strategies that improve the quality of recreational fishing by increasing average fish size, and at the same time decrease the risk of recruitment overfishing.

Harmful algal blooms and fish kills during summer/autumn in the upper estuary represent a serious risk to this stock. To fully assess this risk, there is a need for more information about the movement patterns of adult black bream in the Swan Estuary, including the proportion of fish that do not migrate and are resident either upstream or downstream of the upper estuary. These fish are least likely to be directly impacted by a fish kill. The extent to which these fish contribute to spawning and recruitment is unknown, but may be an important factor determining the rate of population recovery after a fish kill.

Black bream are inherently vulnerable to depletion because they spend their entire life cycle in estuaries and there are discrete, self-replenishing stocks in the each estuary. In the Swan Estuary, high fishing pressure could further limit recovery.

6.1.10 Australian herring

Biology: Australian herring (*Arripis georgianus*) occur from Shark Bay (WA) southward along the south coast to the Gippsland Lakes (Vic) (Kailola *et al*.1993). They constitute a single stock across this range (Tregonning *et al*. 1994, How 1997). Adults and juveniles form pelagic schools in coastal and estuarine waters.

Juveniles occur in Victoria, South Australia and along the south-west coast of WA. Adults occur only in WA. Maturing juveniles and adults migrate to spawning grounds by travelling westwards along the southern coast and potentially also northward along the west coast. Spawning occurs between April and late June in coastal waters of WA, mostly between Cervantes and Bremer Bay (Fairclough 1998). Pelagic eggs and larvae are transported southward/eastward by the Leeuwin Current to nursery areas. The westward/northward distribution of spawning, and the southwards/eastward transport of larvae, depends largely on the strength of the Leeuwin Current each year.

After spawning, adults disperse and become resident in coastal and estuarine waters of the south-west region, forming the basis for fishery landings that are taken there throughout the year. Post-spawning adults enter the Swan Estuary during spring and may remain until summer/autumn when they return to coastal waters to spawn during winter. Australian herring is essentially a marine species, and mainly occurs in the lower Swan Estuary.

Juveniles of Australian herring recruit to sheltered coastal waters and estuaries at ~30 mm TL on the lower west coast, 40-50 mm on the south coast of Western Australia and ~60 mm in South Australia (Fairclough 1998). In the south-west region, juveniles attain lengths of 140-160 mm TL by the end of their first year (Fairclough 1998). One year old juveniles are smaller on the south coast and in South Australia, possibly due to slower growth at lower temperatures.

Maturity by both sexes is attained at age 2-3 y. The size at 50% maturity is 196/215 mm TL (male/female), equivalent to a whole body weight of 83/110 g (Fairclough 1998).

The maximum recorded size for Australian herring is 411 mm TL and 843 g. Most fish in commercial and recreational landings in Western Australia are 200-269 mm and fish >300 mm are rare (Fairclough 1998). Maximum age is approximately 14 y, but fish aged >8 y are rare.

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills are a low risk to Australian herring in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on Australian herring, such as reducing the abundance of prey.

Any environmental factor causing high mortality of Australian herring in the Swan Estuary during one year is likely to have a negligible impact on the total stock and a low impact on subsequent fishery catches of Australian herring in the estuary. Australian herring within the estuary are mainly adults and are part of a larger stock that is distributed widely throughout the coastal waters and estuaries of southern Australia. Spawning occurs in ocean waters and the annual rate of recruitment by post-spawning adults to the Swan Estuary is not dependent on the previous population size within the estuary.

The juveniles and adults of this species utilise coastal and estuarine habitats, many of which are degraded and experience occasional fish kills. While an isolated fish kill in the Swan Estuary would have a low impact on the stock, it is possible that the cumulative effects of various anthropogenic impacts throughout its range are impacting on the stock. For example, juvenile herring grow slightly faster in estuaries than in marine waters and so degradation of estuarine habitats could impact on stock productivity.

Trophic links: Adult Australian herring consume small fish (e.g. whitebait, anchovies, garfish, pilchards) and invertebrates. Juveniles feed mainly on small invertebrates, especially crustaceans (Lenanton *et al*. 1982). Juvenile and adult Australian herring are consumed by various large predators such as dolphins, seabirds, sharks, Australian salmon, tailor, Australian salmon, yellowtail kingfish and mulloway (Kailola *et al*. 1993).

Fishery: Australian herring in the Swan Estuary are part of a widespread southern Australian stock. This stock is targeted by recreational fishers and commercial fishers in coastal waters and estuaries of Western Australia and South Australia. Juveniles of this stock are targeted by commercial and recreational fishers in South Australia and to a lesser extent in Victoria (Kailola *et al*. 1993). Adults are caught in WA, where they are the most common finfish species in the south-west coastal recreational catch (Penn 2005).

Since 2000, total annual landings of Australian herring in Western Australia have been declining as a result of declines in commercial catches on the southern coast of WA. In 2004, total landings in Western Australia were approximately 600-700 t per year, including recreational and commercial catches (Penn 2005).

Australian herring was among the top 3 finfish species in recent recreational landings in the Swan Estuary (Tables 4-6). In 2000/01, the retained recreational catch of herring was estimated to be approximately 2 t (Henry and Lyle 2003). Annual commercial landings of Australian herring in the Swan Estuary are highly variable but are typically low relative to landings of other target species. Australian herring contributed approximately 1% by weight and <1% by value to recent annual commercial finfish catches in the estuary (Tables 2, 3).

Herring migration patterns are reflected in monthly fishery landings in the Swan Estuary. Commercial catches of herring peak during spring (Sept-Dec), coinciding with an influx of post-spawning adults to the estuary. Negligible catches occur in winter when adults are spawning in marine waters (Fig. 5).

From 1986 to 2003, herring catch rates by the MAAC in the Swan Estuary were also seasonal, typically peaking in summer. The average weight of retained herring was greatest in summer (peaking at ~200 g in March) and lowest in winter (~130 g in June-July) (K. Smith, DoF, unpubl. data), reflecting the migration from the estuary by spawning adults in winter.

A daily bag limit of 40 Australian herring applies to recreational fishers. There is currently no legal minimum length for this species in the Swan Estuary. From 1987 to 2003, herring retained by the MAAC in the Swan Estuary were generally adults, with individual fish typically weighing 100-250 g (Fig. 11a). However, throughout the south-west region, recreational landings of Australian herring are known to include a small but significant proportion of immature fish (Fairclough 1998). Approximately 75% of fish in the total recreational catch are females (Fairclough 1998).

Stock assessment: Trends in Australian herring landings in the Swan Estuary appear to be driven by highly variable recruitment of adults to the estuary. Peaks in recreational catches in 1993-94, and peaks in both recreational and commercial catches during 1998-2000, suggest pulses of recruitment to the estuary at these times. There appears to be an inverse relationship between recreational CPUE and average fish size, consistent with recruitment-driven variations in the catch of this species (Figs. 11, 12).

The abundance of Australian herring in the estuary, and elsewhere on the west coast, is determined largely by the strength of the Leeuwin Current each year. A weak current is likely to result in more fish migrating northwards along the west coast to spawn. Post-spawning fish then disperse into coastal waters and estuaries, including the Swan Estuary. This annual influx of post-spawners during spring constitutes the majority of estuary fishery landings. The rate of recruitment to the Swan Estuary by post-spawners is not dependent on previous population size within the estuary.

Australian herring within the Swan Estuary are part of a widespread stock that is distributed around southern Australia. Although degradation of coastal and estuarine habitats could have a negative impact on Australian herring, the major threat to the stock is fishing pressure. This stock is subject to strong recreational and commercial fishing pressure across it's entire range. Recreational and commercial landings in South Australia and Victoria are comprised entirely of juveniles and, while most of the fish caught in Western Australia are adults, not all have an opportunity to spawn before capture. Fishing pressure in all states has the potential to affect recruitment and stock abundance. Apart from a bag limit, which is probably only occasionally attained (Roennfeldt 1997), the recreational catch of this species in Western Australia is unconstrained.

6.1.11 Bar-tailed flathead

Biology: Bar-tail flathead (*Platycephalus endrachtensis*) is distributed across northern Australia from Fremantle, WA, to Port Hacking, NSW (Prokop 2002). They also occur in New Guinea (Allen 1997). They occur on sand, silt and mud habitats in estuaries and are relatively common in the Swan Estuary compared to their abundance elsewhere.

Stock structure of bar-tail flathead in Western Australia is unknown but, given that spawning occurs in estuaries, there may be limited mixing between estuarine populations. Therefore, bar-tailed flathead in the Swan Estuary are probably a discrete breeding stock, reliant on self-replenishment.

Spawning occurs in the estuary, mainly from December to February (P. Coulson, Murdoch University, pers. comm.). Larvae have been recorded from the lower, middle and upper estuary (Neira *et al*. 1992), suggesting that spawning activity could be widespread in the system. Low river flows during summer would limit downstream dispersal of pelagic eggs and larvae and assist in retaining them within the estuary.

Juveniles and adults occur in the lower, middle and upper estuary throughout the year (Loneragan *et al*. 1989, Kanandjembo *et al*. 2001). However, they mainly occur in the lower estuary during winter and then disperse as far as the upper estuary during summer/autumn, following the intrusion of saline water.

In the Swan Estuary, the size at maturity of bar-tail flathead is unclear, but probably occurs below lengths of 293 mm TL (female) and 222 mm TL (male) (P. Coulson, Murdoch University, pers comm.). These lengths are equivalent to whole body weights of ~155 g and ~63 g, respectively. Maximum reported size of bar-tail flathead is 100 cm, but in the Swan Estuary they rare above 55 cm and most fish caught by anglers are 30-45 cm (Prokop 2002). Maximum age is unknown.

Fish kills and environmental impacts on stock: The abundance of bar-tailed flathead in the estuary appears to be is highly variable, reflecting trends in annual recruitment. Since 1940, when fishery catch records became available, three periods of high catch rates are evident (presumably reflecting pulses of recruitment in the estuary). The factors determining recruitment success are unknown. Interestingly, peaks in flathead catches have been preceded by peaks in flounder catches a few years earlier, suggesting that recruitment success in these two species may be influenced by the same environmental factor(s).

Harmful algal blooms and other factors causing fish kills appear to be a moderate risk to bar-tailed flathead in the Swan Estuary. Major fish kills are most likely to occur in the upper estuary in summer/autumn. Flathead occur in this area throughout the year. During summer/autumn, a significant proportion of the population (including eggs, larvae, juveniles and adults) is expected to occur in the upper estuary. Indeed, flathead were a component of autumn fish kills in the upper estuary in 2003 and 2004.

However, flathead also occur upstream and downstream of the upper estuary in summer/autumn and so part of the stock would not be directly affected by a fish kill at this time. Fish kills may have indirect effects on fish bar-tailed flathead, such as reducing the abundance of prey.

Trophic links: Flathead consume small fish and invertebrates.

Fishery: The majority (~75% by weight) of recent bar-tailed flathead landings in the Swan Estuary have been taken by recreational fishers. It is among the most commonly retained finfish species in the recreational fishery (Tables 4-6). The most recent survey of the recreational fishery in 2000/01 estimated a retained flathead catch of approximately 1.6 t (Henry and Lyle 2003). Flathead contributed approximately 1% by weight and 1% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Commercial landings of flathead occurred in all months but were highest from August to November (Fig. 5).

In the Swan Estuary, recreational fishers are subject to a combined flathead/flounder bag limit of 8 fish. The minimum legal length is 300 mm TL (corresponding to whole body weight ~160 g), which is greater than the size at maturity. Therefore, most fish have an opportunity to breed before being retained, if they survive release. From 1986 to 2003, the majority of flathead retained by the MAAC in the Swan Estuary were mature, with individual fish typically weighing 200-400 g (Fig. 11a).

Stock assessment: Trends in commercial and recreational CPUEs suggest that the abundance of flathead in the Swan Estuary is highly variable, probably as a result of variable recruitment. Peaks in CPUE suggest 3 periods of strong recruitment to the estuary: i) in the mid-1940s, ii) over an extended period in the late 1950s to late 1960s, and iii) in the mid-1990s. A peak in 1999 in the average size of flathead retained by the MAAC was also consistent with the possibility of strong recruitment in the mid-1990s.

Trends in commercial and recreational CPUEs suggest that the abundance of flathead in the estuary has been declining since the mid-1990s. Harmful algal blooms and other impacts in the estuary may be contributing to this decline, either directly via mortality of larvae, juveniles and adults, or indirectly via mortality of prey.

6.1.12 Small-toothed flounder

Biology: Small-toothed flounder (*Pseudorhombus jenynsii*) are distributed widely across southern Australia from central Queensland to Exmouth Gulf in WA, but not Tasmania (Prokop 2002). Adults are most often found over sand, mud or gravel in estuaries and bays but can also occur in shelf waters to depths of ~50 m (Kuiter 1993). Juveniles inhabit coastal waters and the lower reaches of estuaries (Lenanton 1982). In the Swan Estuary, small-toothed flounder mainly occur in the lower estuary but may disperse as far as the middle and upper estuary during summer/autumn (Loneragan *et al.* 1989).

Stock structure is unknown but small-toothed flounder on the lower west coast, including the Swan Estuary, are probably a single stock as a result of mixing due to adult movement and dispersal of planktonic eggs and larvae in marine waters. Spawning occurs in marine waters. Larvae are transported during flood tides into the lower reaches of estuaries (Young and Potter 2003). Small juveniles <100 mm occur in estuaries in summer/autumn, suggesting spawning in spring/summer (Lenanton 1977).

Growth and reproduction of small-toothed flounder in south western Australia is poorly understood. Size and age at maturity is unknown. The maximum age is unknown. The maximum recorded size is 381 mm TL (Loneragan *et al.* 1989).

Fish kills and environmental impacts on stock: The abundance of small-tooth flounder in the estuary is highly variable, reflecting trends in annual recruitment. Since 1940, when fishery catch records became available, three periods of high CPUE are evident (presumably reflecting pulses of recruitment to the estuary). The factors determining recruitment success are unknown. Interestingly, peaks in flounder catches have been followed by peaks bar-tailed flathead in catches a few years later, suggesting that recruitment in these two species may be influenced by the same environmental factor(s).

Harmful algal blooms and other factors causing fish kills are a low risk to small-tooth flounder in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the stock would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on flounder, such as reducing the abundance of prey.

Trophic links: Small-toothed flounder consume fish and benthic invertebrates (Schafer *et al.* 2002).

Fishery: The majority (~70% by weight) of recent flounder landings in the Swan Estuary have been taken by recreational fishers. The most recent survey of the recreational fishery in 2000/01 estimated a retained flounder catch of approximately 0.4 t (Henry and Lyle 2003). Flounder contributed <1% by weight and 1% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Commercial landings of flounder peaked in spring (Nov-Dec) and were lowest in winter (May-Sep) (Fig. 5).

In the Swan Estuary, recreational fishers are subject to a combined flathead/flounder bag limit of 8 fish. The minimum legal length is 250 mm TL (~150 g). From 1986 to 2003, the majority of flounder retained by MAAC in the Swan Estuary weighed 150-400 g (Fig. 11a).

Stock assessment: Trends in commercial and recreational catch rates suggest that the abundance of flounder in the Swan Estuary is highly variable, probably as a result of infrequent pulses of strong recruitment. Peaks in catch rates suggest strong recruitment to the estuary in approximately 1958 and 1988, and possibly also a minor pulse in the late 1990s.

Trends in catch rates suggest that the abundance of flounder in the estuary has been declining since 1988 and has been particularly low since 2000. MAAC members agree that flounder has been relatively rare in the estuary in recent years (D. Cox, MAAC, pers. comm.). The fishery CPUE of flounder is likely to be a reasonable indicator of abundance because this species is of relatively high value to each sector and will probably be retained whenever available. Catch records of the MAAC indicate that flounder was among the more common finfish species in the club's catch in the late 1980s and early 1990s, confirming that is highly targeted by recreational fishers when available.

6.1.13 Yellowfin whiting

Biology: Yellowfin whiting (*Sillago schomburgkii*), also known as western sand whiting, occur from Albany to Dampier in Western Australia and in Gulf St Vincent and Spencer Gulf in South Australia (Kailola *et al*. 1993). Adults typically occur in open, sandy areas, while juveniles are typically associated with mangrove, mud or seagrass habitats (Kailola *et al*. 1993). It is essentially a marine species. Adults and juveniles are most abundant in shallow (<5 m depth) inshore marine areas but also occur in estuaries (Lenanton 1982, Hyndes *et al*. 1996). In the Swan Estuary, adults and juveniles occur as far upstream as the upper estuary but are most common in the lower estuary (Loneragan *et al*. 1989, Kanandjembo *et al*. 2001).

Stock structure is unknown but yellowfin whiting on the lower west coast, including the Swan Estuary, are probably a single stock as a result of mixing due to adult movement and dispersal of planktonic eggs and larvae in marine waters.

Spawning occurs in marine waters. Larvae recruit to inshore and estuarine nursery sites at 12-13 mm length (Bruce 1994). Larvae are transported into estuaries during flood tides (Young and Potter 2003). Spawning by yellowfin whiting occurs later and over a shorter period on the lower west coast and in South Australia (December to February) than in Shark Bay in (August to December) (Kailola *et al*. 1993, Hyndes *et al*. 1997).

Juveniles grow relatively rapidly and reach 120-130 mm TL (whole body weight of 15-19 g) by age 1 y and 190-200 mm TL (60-70 g) by age 2 y. On lower west coast, maturity occurs at the end of the 2^{nd} year in both sexes (Hyndes *et al*. 1997, Coulson et al. 2005). The maximum recorded age and length of yellowfin whiting is 14 y and 420 mm, respectively, but fish >6 y and >350 mm TL are rare on the lower west coast (Kailola *et al*. 1993, Hyndes *et al*. 1997).

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills are a low risk to yellowfin whiting in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the stock would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on whiting in the estuary, such as reducing the abundance of prey.

Trophic links: Yellowfin whiting consume a wide range of benthic invertebrates (Hyndes *et al*. 1997).

Fishery: The majority of recent yellowfin whiting landings in the Swan Estuary have probably been taken by recreational fishers. The most recent survey of the recreational fishery in 2000/01 estimated a retained whiting catch of approximately 2 t (Henry and Lyle 2003). This catch may have included several whiting species, but was probably mainly yellowfin whiting. Recent annual commercial landings have been <2 t. Whiting (all species) contributed 1% by weight and 1% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Commercial landings of whiting were highest in spring (Sep-Dec), moderate in summer/autumn (Jan-May) and low in winter (Jun-Aug) (Fig. 5).

During the 1990s, total annual commercial landings of yellowfin whiting in the south-west region (i.e. south of 26° S latitude) increased and peaked at ~65 t (DoF unpubl. data). From 2001 to 2004, total annual landings in this region declined, although they were still within the typical historical catch range. In 2004, total commercial landings in the south-west region were approximately 30 t. Most yellowfin whiting landings are made by beach seine, haul and gill nets in coastal and estuarine waters.

In the Swan Estuary, recreational fishers are subject to a daily bag limit of 16 yellowfin whiting. There is currently no legal minimum length for this species. From 1986 to 2003, yellowfin whiting retained by the MAAC typically weighed 100-300 g, suggesting that most whiting retained by recreational fishers in the Swan Estuary are mature.

Stock assessment: The commercial catch trend for yellowfin whiting suggests an increase in abundance of this species in the Swan Estuary since 2000. However, annual commercial catches are generally very low (~400 kg). Recreational catch trends are probably more indicative of abundance in the estuary. Recreational catch trends suggest that yellowfin whiting were slightly less abundant, and of smaller size, in the Swan Estuary from 2000 to 2004 than during the 1990s.

6.2 Minor species

6 2.1 Trevally (or Skipjack)

Sand trevally (*Pseudocaranx wrighti*) and silver trevally (*Pseudocaranx dentex*) both occur in the Swan Estuary. Silver trevally attains a larger size but, when small, is very similar in appearance to sand trevally. Catches of these two species are often grouped together by anglers and in the scientific literature. Sand trevally may be more common in fishery landings. In scientific surveys in the Swan Estuary, sand trevally are moderately abundant and have been caught in shallow water (<2 m) by seine nets, whereas silver trevally are rare and have only been caught in deeper water using otter trawls (Loneragan *et al*. 1989).

Biology: Sand trevally are endemic to south-western temperate waters of Australia from Exmouth Gulf, WA, to Bass Strait (Neira *et al*. 1998). They form schools that inhabit estuaries, bays and coastal waters to 35 m. In coastal waters off Perth, sand trevally mainly occur over sand substrate and are most abundant in deeper (20-35 m) waters (Carter 2005).

Silver trevally occur in temperate and sub-tropical waters of Australia from Rockhampton, Qld, to North West Cape, WA. They also occur in New Zealand and in subtropical and temperate waters of the Indian and Atlantic Oceans (Kailola *et al*. 1993). Silver trevally is mainly a marine species. Juveniles inhabit estuaries, bays and inner continental shelf waters. Adults often form demersal schools in deeper waters to 120 m but can also occur at the surface and in inner shelf waters, bays and large estuaries (Kailola *et al*. 1993). In the Swan Estuary, trevally (Pseudocaranx spp.) are found mainly in the lower estuary and occasionally in the middle estuary (Loneragan *et al*. 1989).

The stock structure of trevallys on the lower west coast, including the Swan Estuary, is unknown but both species are probably single stocks as a result of mixing due to adult movement and dispersal of planktonic eggs and larvae in marine waters. Trevally eggs and larvae are pelagic.

Sand trevally larvae have been found in Cockburn Sound and in the lower Swan Estuary. In the estuary, larval abundance declines rapidly with distance from the entrance, which suggests spawning in nearshore marine waters or at the estuary entrance (Neira *et al*. 1992). Sand trevally larvae have been caught in the lower estuary in all seasons except winter, with a peak in abundance in spring. Spawning by sand trevally occurs from September to March on the lower west coast, with females spawning more than once during this period (Carter 2005).

Silver trevally can spawn in ocean waters or larger estuaries (Kailola *et al*. 1993). However, the absence of larvae suggests that they do not spawn in the Swan Estuary. On the east Australian coast spawning extends from spring to autumn (Rowling and Raines 2000). The pelagic larvae can disperse widely across the continental shelf prior to coastal recruitment, depending on currents (Smith 2003).

The maximum size of sand trevally is probably about 220 mm TL (Hutchins and Swainston 1986). Maximum sizes up to 70 cm TL have been reported (e.g. Gommon *et al*. 1994), but it is likely that identification was confused with silver trevally in such cases. In a recent survey of trawl fishery bycatch on the lower west coast, the maximum size of sand trevally was 213 mm TL (or 120 g) for females and 220mm TL (or 135 g) for males (Carter 2005). Maximum ages during the survey were 12 y and 11 y, respectively.

The maximum recorded size and age of silver trevally is 94 cm (or 10 kg) and 47 y (Kailola *et al*. 1993, Gommon *et al*. 1994). A recent study over the NSW continental shelf observed a maximum age of only 24 y, but this population was considered to be growth overfished (Rowling and Raines 2000).

On the lower west coast, sand trevally attain maturity at approximately 118 mm TL (female) and 108 mm TL (male), which occurs at 3 y and 1 y of age, respectively (Carter 2005). In this region, silver trevally mature at approximately 257 mm TL (female) or 265 mm TL (male) (French 2003). On the east coast, maturity in silver trevally occurs over a size range of 20-28 cm LCF for both sexes (Rowling and Raines 2000). This corresponds to a weight range of approximately 187-477 g. Age at maturity is probably quite variable for silver trevally but may typically occur between ages 2-5 y.

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills are a low risk to trevally in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the stock would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on trevally in the estuary, such as reducing the abundance of prey.

Trophic links: Trevally are carnivores. Small fish feed mainly on copepods. Larger fish consume a variety of crustaceans, molluscs, polychaetes and echinoderms (Kailola *et al*. 1993, Platell et al. 1997).

Fishery: Trevally are rarely targeted by commercial fishers in the Swan Estuary (Tables 2, 3). Surveys in 1998/99 and 2000/01 estimated a minor recreational catch of trevally, which was taken in the lower estuary (Table 4). In the Swan Estuary, recreational fishers are subject to a bag limit of 8 trevally.

In 1997, the minimum legal length for trevally was increased from 200 mm to 250 mm TL. A length of 250 mm TL is equivalent to a whole body weight of approximately 187 g for silver trevally (Rowling and Raines 2000). At this size, some silver trevally are likely to be immature. The change in legal length effectively prevented the retention of any sand trevally by recreational fishers because the maximum length attained by this species is only 220 mm.

From 1986 to 1996, prior to the change in minimum legal length, most trevally retained by the MAAC weighed 100-160 g and were probably mostly sand trevally. From 1997 to 2003, most fish retained by the MAAC weighed 180-280 g and were probably silver trevally. These data indicate that small trevally are vulnerable to capture by recreational fishers and suggest that both adult sand trevally and juvenile silver trevally are currently caught and released by recreational fishers in the Swan Estuary.

From 1987 to 2003, trevally CPUE by the MAAC in the Swan Estuary were generally highest in summer and lowest in winter. The average weight of retained fish was similar between months (K. Smith, DoF unpubl. data).

The total commercial catch of sand trevally in Western Australia is unknown because commercial catches of this species are reported as ‘other trevally’, which includes numerous species. The total Western Australian commercial catch of ‘other trevally’ was 220 t in 2003/04 (Penn 2005), but sand trevally probably comprise a very small proportion of this total. Sand trevally is taken in relatively large quantities as bycatch by prawn and scallop fishers on the lower west coast (Platell *et al*. 1997, Hyndes *et al*. 1999).

The total Western Australian commercial catch of silver trevally was 6 t in 2003/04, although some silver trevally may also be reported as ‘other’.

Assessment: Commercial and recreational catches of trevally in the Swan Estuary are relatively low, and so annual catch rates by each sector may not be a reliable index of stock abundance. The minimum legal length for trevally increased in 1997, further confounding the interpretation of trends in recreational CPUE.

The legal minimum length for trevally prevents retention of all sand trevally by recreational fishers in Western Australia. Such a low level of targeting probably affords reasonable protection to this stock. The main source of fishing mortality on sand trevally in the south-west region is probably nearshore trawling, when sand trevally are taken as bycatch.

Silver trevally is relatively slow-growing and long-lived and so is inherently vulnerable to overfishing. This species has been growth overfished on the east coast. However, silver trevally are taken in low quantities by commercial and recreational fishers in Western Australia, compared with catch levels on the east coast (albeit the western stock size may also be smaller). Most silver trevally retained by recreational fishers on the west coast are probably mature, although some fish may be caught as young adults prior to their first spawning.

The majority of all trevally caught by recreational fishers in the Swan Estuary are probably below the legal minimum length and are released. Both adult sand trevally and juvenile silver trevally are probably caught and released. Rates of post-release mortality of small silver trevally appear to be low for fish that experience minimal handling and are released immediately after capture (Broadhurst *et al*. 2005).

6.2.3 Tarwhine

Biology: Tarwhine (*Rhabdosargus sarba*) reportedly occur in tropical and subtropical waters of the Indo-West Pacific, including the Red Sea, east Africa, Australia, China and Japan (Smith and Heemstra 1984). However, there is some evidence to suggest that these populations actually consist of several species (Hesp *et al*. 2004). In Australia, tarwhine are distributed from Queensland to the Gippsland Lakes, Victoria, and from Albany to Coral Bay, in Western Australia (Kailola *et al*. 1993). Adults commonly form schools in coastal waters around reefs and in estuaries.

Stock structure is unknown, but tarwhine in Western Australia probably comprise a single genetic stock due to some mixing via movement of adults in ocean waters and dispersal of eggs/ larvae. There may be sub-populations of adults in each region that largely remain separate after recruitment, e.g. in Shark Bay.

Throughout Australia, spawning by tarwhine typically occurs in coastal waters, often adjacent to reefs. Juveniles typically use estuarine or sheltered coastal areas as nursery grounds, and move to deeper waters with age. However, tarwhine exhibit atypical behaviour in the Swan Estuary. Spawning occurs in the lower estuary during ebb tides, which allows the pelagic eggs to be immediately transported from the estuary (Hesp *et al*. 2004). Larvae then settle out of the plankton at a length of ~10 mm into sheltered sandy habitats in coastal waters. Juveniles move into nearby seagrass beds at lengths of >40mm. At ~90 mm length, fish commence movement to more exposed coastal sites and finally move to offshore reefs, where fish >3 y are common. It has been suggested that tarwhine usually recruit back to the Swan Estuary at about 1 y of age and ~140 mm (Hesp *et al*. 2004). However, small (23-90 mm) juveniles have been caught in the lower, middle and upper estuary (Loneragan *et al*. 1989, Kanandjembo *et al*. 2001).

Spawning near the Swan Estuary occurs over an extended period from July to October, when individual females spawn multiple batches of eggs (Hesp 2003).

Tarwhine attain a total length of 142, 216 and 254 mm at age 1, 2 and 3 years, respectively (Hesp 2003). In the Swan Estuary, the size at 50% maturity of tarwhine is ~170 mm TL (body weight of ~85 g), which occurs an age of 2 y (Hesp and Potter 2003, A. Hesp, Murdoch University, unpubl. data). The maximum recorded size of tarwhine is 80 cm (Kailola *et al*. 1993). A maximum age of 13 y has been recorded in Shark Bay (Hesp 2003)

Fish kills and environmental impacts on stock: Harmful algal blooms and other factors causing fish kills appear to be a low risk to tarwhine in the Swan Estuary. Major fish kills are most likely to occur in summer/autumn in the upper estuary and the majority of the population would be downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on tarwhine, such as reducing the abundance of prey.

Tarwhine within the Swan Estuary are probably part of a larger stock that is distributed among the estuaries and coastal waters of south-western Australia. Adults spawn at the mouth of the estuary, but larvae are then transported to ocean waters where they presumably mix with larvae from other spawning aggregations. Juveniles recruiting to the estuary are probably derived from various spawning locations and so the annual rate of juvenile recruitment to the Swan Estuary is not likely to be strongly dependent on population size within the estuary. Therefore, high mortality in the Swan Estuary during one year is likely to have a low impact on the total stock and a low impact on subsequent fishery catches of tarwhine in the estuary.

On the other hand, most of the south-western estuaries and some of the coastal areas where this species occurs are degraded and experience occasional or annual fish kills. While juveniles and adults of this species are not totally dependent on estuaries (i.e. they also utilise marine habitats), nevertheless many individuals of this species do occur in estuaries especially as juveniles. It is possible that the cumulative effects of various anthropogenic impacts throughout its range could impact on the stock.

Trophic links: Tarwhine are omnivorous. They mainly consume various benthic invertebrates and algae (Blaber 1984).

Fishery: Tarwhine contributed approximately <1% by weight and <1% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). Recent annual commercial catches have been <500 kg. The most recent survey of the recreational fishery in 2000/01 estimated a retained catch of <1 t (Henry and Lyle 2003).

In the Swan Estuary, recreational fishers are subject to a daily bag limit of 16 tarwhine. The minimum legal length is 230 mm TL, which equivalent to a body weight of ~195 g. From 1986 to 2003, the majority of tarwhine retained by the MAAC weighed 180-280 g, suggesting that tarwhine retained by recreational fishers in the estuary are mature (Fig. 11b).

Stock assessment: Tarwhine have historically been a minor component of commercial and recreational landings in WA. However, commercial and recreational landings have increased in recent years throughout the south-west region, possibly reflecting an increase in abundance.

6.2.4 Yellowtail scad

Biology: Yellowtail scad (*Trachurus novaezelandiae*) are distributed around southern Australia, from southern Queensland to Exmouth Gulf, WA, and also occur in New Zealand (Kailola *et al*. 1993). They are most abundant on the south-east coast, where they are one of the most common small pelagic fish species. Adults and juveniles are pelagic and form schools in inshore marine and estuarine waters. Adults often occur over offshore reefs, whereas juveniles often occur over shallow, soft substrates. Fish tend to move offshore with increasing age (Horn 1991).

The distribution of yellowtail scad in ocean waters appears to be related to temperature. In the south-eastern Australia, commercial fishers report that fish disappear from coastal waters in winter when temperatures fall below 13 ^{0}C and most reappear in spring/summer when temperatures reach ~17 ^{0}C (Stewart and Ferrell 2001).

Spawning occurs in marine waters, probably over the inner shelf. Eggs and larvae are pelagic and can disperse widely across the continental shelf, depending on currents (Smith 2003). Hence, yellowtail scad along the Western Australian coast are probably a single stock due to adult movement and widespread dispersal of marine larvae. Larvae transform to juveniles at approximately 14-15 mm and then recruit to inshore and estuarine waters (Neira *et al*. 1998).

Yellowtail scad reach maturity at 220-250 mm TL, which corresponds to a body weight of 192-250 g and an age of ~3 years (Kailola *et al*. 1993, Stewart and Ferrell 2001). Growth rate is variable between regions (Stewart and Ferrell 2001).

In Australia, a maximum length of 33 cm fork length has been recorded, although 44 cm fork length has been recorded from New Zealand (Horn 1993, Stewart and Ferrell 2001). Maximum recorded age is 28 y (Horn 1991).

Fish kills and environmental impacts on stock: Any environmental factor (e.g. harmful algal bloom) causing high mortality of yellowtail scad in the Swan Estuary is likely to have a negligible impact on the total stock and a low impact on subsequent fishery catches of this species in the estuary. Yellowtail scad within the estuary are mainly juveniles and are part of a widespread stock that is distributed among the coastal waters and estuaries of south-western Australia. Spawning occurs in ocean waters and the annual rate of recruitment to the Swan Estuary is not dependent on the previous population size within the estuary.

Populations of yellowtail scad in eastern Australia are characterised by highly variable recruitment. The environmental factor(s) influencing recruitment success are unknown, but may include appropriate dispersal of eggs and larvae by ocean currents and adequate abundance of planktonic prey.

Trophic links: Yellowtail scad are small, pelagic schooling fish. They are likely to be consumed by numerous larger predators, including sea birds, dolphins, seals, sharks and finfish. Yellowtail scad are planktivorous.

Fishery: Yellowtail scad have historically been a minor component of commercial and recreational landings in WA, which reflects low market demand and their relatively low abundance compared to their abundance in eastern Australia. Commercial landings have increased in recent years, mainly in response to market demand (R.J. Bales, commercial fisher, pers. comm.).

Yellowtail scad contributed approximately 1% by weight and <1% by value to recent annual commercial finfish catches in the Swan Estuary (Tables 2, 3). The annual commercial catch was <2 t in all years. Commercial landings of yellowtail scad can occur in all months but are typically highest in February-March (Fig. 5). The most recent survey of the recreational fishery in 2000/01 estimated a retained catch of <1 t (Henry and Lyle 2003).

Most yellowtail scad caught in the estuary are probably juveniles. The average size of yellowtail scad retained by the MAAC was 80-120 g, indicating that virtually all retained fish were immature (Fig. 11b).

In the Swan Estuary, recreational fishers are subject to a daily bag limit of 40 yellowtail scad. There is currently no legal minimum length for yellowtail scad.

The vast majority of yellowtail scad landings in Western Australia are taken by the West Coast Purse Seine Managed Fishery. A total Western Australian commercial catch of 15.6 t of yellowtail scad was recorded in 2003/04 (Penn 2005).

Stock Assessment: Yellowtail scad is typically regarded as a ‘baitfish’, which implies a schooling species that is fast-growing and short-lived, with highly variable stock abundance. ‘Baitfish’ fisheries are characterised by high variable annual landings and the potential for sudden stock collapse, due to highly variable recruitment. While yellowtail scad meet some of these criteria – they are fast growing and have variable recruitment – they are in fact relatively long-lived (28 y) and require more conservative management than other, shorter-lived baitfish species.

Yellowtail scad move offshore with increasing age. Hence, fishery landings in estuaries and coastal waters comprise relatively young fish. The breeding adults tend to occur offshore where they are currently subject to moderate fishing pressure in WA. A future increase in offshore landings would need to be monitored carefully.

Despite a being historically targeted as a ‘baitfish’, yellowtail scad are actually good quality eating and there are potential domestic and export markets for human consumption. Yellowtail scad are caught by line and net methods, and so are vulnerable to capture by recreational and commercial fishers.

6.2.5 Mulloway

Mullloway (*Argyrosomus japonicus*) occur around southern Australia from North West Cape, WA, to Bundaberg, Qld. They also occur widely across the Indo-Pacfic (Kailola *et al*. 1993). They are demersal and mainly inhabit coastal areas (estuaries, coastal reefs, beaches, embayments) but also occur in continental shelf waters to 150 m. They can be solitary or form loose schools. Juveniles tend to occur in estuaries and adults in ocean waters, although adults also enter estuaries. West coast mulloway, including those in the Swan Estuary, are a distinct population to those in the Great Australian Bight or further east (Kailola *et al*. 1993).

Mulloway are capable of extensive (100s of kilometres) movement between estuaries. However, in South Australia, tagged fish have been found to leave the estuary in autumn and return to adjacent beaches next summer, suggesting a restricted home range (Kailola *et al*. 1993).

The distribution of mulloway in estuaries tends to coincide with oceanic salinities, although juveniles also tolerate brackish water. Older mulloway (age >2 y) mainly occur in the lower and middle sections of the Swan Estuary, but leave the estuary at the onset of winter rains and return during spring/summer. Younger fish appear to remain in the lower estuary in winter and disperse to all sections of the estuary at other times of the year (Holt 1978, Loneragan *et al*. 1989).

Spawning aggregations tend to occur in/around the entrance of estuaries, including in surf zones, although spawning fish have also been found away from estuaries (Hall 1986, Kailola *et al*. 1993). Spawning occurs in the Swan Estuary (B. Farmer, Murdoch University, unpubl. data). In WA, spawning and spent fish have been caught in the lower parts of estuaries, including in the Swan Estuary (Holt 1978, Lenanton 1977). In general, spawning occurs in spring/summer and larvae occur in ocean waters during summer/autumn, suggesting a larval phase of several months (Neira *et al*. 1998). Eggs and young larvae are pelagic but older larvae are demersal, thus restricting dispersal in marine waters (Smith 2003). Larvae metamorphose to juveniles at ~12 mm, but a low abundance of small juveniles suggests that they may not recruit to west coast estuaries until 100-150 mm ((Neira *et al*. 1998, Potter *et al*. 1983). However, smaller (<50 mm) fish have been caught in eastern Australian estuaries and so the lack of observations may be due to the difficulty of capturing small demersal fish (Kailola *et al*. 1993).

In South Australia, mulloway reach ~46 cm (1.5 kg) by 2-3 y of age, and reach ~80 cm (8 kg) by 5-6 y of age (Kailola *et al*. 1993). On the lower west coast, growth is relatively rapid and fish attain 920 cm TL (male) or 950 cm (female) at 6 y (B. Farmer, Murdoch University, unpubl. data). Maturity occurs at ~6 y of age. In Australia, the maximum reported size and weight of mulloway is >2 m and >43 kg, respectively, but 71 kg has been recorded in South Africa. Recent observations on the lower west coast include fish up to 31 years old and 1400 cm TL (B. Farmer, Murdoch University, unpubl. data).

Fish kills and environmental impacts on stock: In South Australia, mulloway abundance appears to have declined as a result of poor recruitment following consecutive years of low Murray River flow. Successive years of low freshwater outflow from west coast estuaries, due to low rainfall or diversion of river flows, may also have had a negative impact on the stock(s).

Harmful algal blooms and other factors causing fish kills appear to be a low risk to mulloway in the Swan Estuary. Major fish kills are most likely to occur in the upper estuary in summer/autumn. Some juvenile mulloway occur in this area at this time but adults would be mostly downstream or in ocean waters at this time and not be directly affected. However, fish kills may have indirect effects on mulloway, such as reducing the abundance of prey. For example, mulloway are known to feed on Perth herring, which is at high risk from fish kills.

Trophic links: Juveniles and adults feed throughout the water column on various fish species (e.g. mullet, garfish, Australian herring, pilchards, yellowtail scad, smaller mulloway) and larger benthic invertebrates (e.g. crabs, prawns, worms). Movement and foraging usually occurs at night, with individuals often returning to the same resting site each day (M. Taylor, University of NSW, pers. comm.).

Fishery: Mulloway contributed approximately <1% by weight and <1% by value to recent annual commercial finfish catches in the Swan Estuary (Table 2). Recent annual commercial landings have been <500 kg. The most recent survey of the recreational fishery in 2000/01 estimated a retained catch of ~1 t (Henry and Lyle 2003).

In the west coast bioregion, total commercial landings of mulloway were approximately 23 t in 2003 and 14 t in 2004. Most of these landings were taken by wetline and gill net fishers. The total recreational catch in the west coast region was estimated to be about 65 t in 2000/01, most of which was taken by boat-based fishers in inshore coastal waters (Henry and Lyle 2003).

In the Swan Estuary, recreational fishers are subject to a daily bag limit of 2 mulloway. The legal minimum length is currently 500 mm, which is significantly less than the size at maturity.

Stock assessment: The status of mulloway stock(s) on the lower west coast is unclear. The majority of landings on the lower west coast are taken by recreational sector. Apart from bag and size limits, recreational landings are essentially unconstrained. Mulloway is inherently vulnerable to overfishing because it is relatively slow-growing, long-lived and late-maturing.

6.2.7 Common blowfish

Biology: Blowfish (*Torquigener pleurogramma*) are common in estuaries and protected coastal waters of southern Australia from Coral Bay, WA, to Adelaide, SA, and from Harvey Bay, Qld, to Narooma, NSW. They do not occur in Bass Strait or Tasmania but do occur around Lord Howe Island (Hutchins and Swainston 1986, Kuiter 1993). They form small to large schools, usually over sand (Kuiter 1993).

In the Swan Estuary, blowfish are most abundant in the lower estuary, moderately abundant in the middle estuary and rare in the upper estuary (Potter *et al*. 1988). They are most abundant in shallow (<4 m) waters. Blowfish in the Swan Estuary probably belong to a single genetic stock along the lower west coast, due to the mixing of planktonic larvae in ocean waters. However, there is probably some degree of subdivision among populations within estuaries because movement by adults appears to be limited and eggs are demersal, which would limit dispersal and mixing.

Mature blowfish migrate from the Swan Estuary to spawn at shallow coastal sites immediately outside the estuary entrance. Spawning occurs from October to January, peaking in November and December (Potter *et al*. 1988). Many adults re-enter the estuary after spawning. Large adult schools have been observed in summer moving from estuary to ocean, and large numbers of dead blowfish have occasionally been observed along the coast in autumn, presumably dying after spawning (Hutchins and Thompson 1983).

Juveniles spawned outside the Swan Estuary probably recruit to adjacent coastal nurseries (e.g. Rockingham), as well as the Swan Estuary. No larvae have been caught in the estuary, indicating that blowfish recruit to the estuary as juveniles. They typically enter in July-August, at age 7-9 months, length 50-70 mm and weight 2-6 g (Potter *et al*. 1988). Growth is apparently faster in estuaries than adjacent coastal areas. At age 1 y, total length is 85-100 mm in the Swan Estuary but only 74 mm at Rockingham and 65 mm at Jurien Bay and Dongara (Potter et al. 1988).

Maturity is reached at the end of the 2nd year, at length ~125 mm TL and weight ~39 g. A maximum length and age of 230 mm TL and 6 y, respectively, has been recorded from the Swan Estuary (Potter *et al*. 1988).

Fish kills and environmental impacts on stock: Spawning and recruitment success by blowfish appear to be extremely variable. For example, Potter *et al*. (1988) observed very strong year classes in 1980 and 1985. Limited data from the recreational fishery indicated that blowfish were very abundant in the Swan Estuary from 1998/99 to 2004. The environmental factors influencing recruitment success are unknown. Anecdotal reports from recreational fishers suggest that abundances were low until the early 1970s, coinciding with a marked decrease in rainfall. Current trends in climate change (lower river flows, warmer temperatures, more saline estuarine water) may be favouring blowfish recruitment.

Trophic links: Blowfish are opportunistic and consumes a wide variety of benthic invertebrates, especially polychaetes, amphipods and bivalve molluscs (Potter e*t al*. 1988). Large predatory fish, including tuna, are reported to consume blowfish.

Fishery: There is no fishery for blowfish in WA. The flesh is poisonous.

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8.0 Tables and figures

Table 1. Recent fish kills in Swan-Canning Estuary (communicated by T. Rose, Waters and Rivers Commission).

Month	Date	Location	Probable cause	Species affected, number (n) of fish collected
Summer	Jan, 1999	Guildford, Swan River	Flush of organic matter & fresh water into river following heavy rains, resulted in low oxygen.	n=40, species unknown
	Feb 2000	Fremantle (Pier 21)	*Microcystis* bloom & low oxygen.	n= <10, blowfish
	Feb 2000	Mosman Bay	Possibly disease	n=<10, mullet
Autumn	Mar 2000	Claisebrook Cove up to Railway Bridge	Myxosporidiosis & low oxygen	n=100, mullet
	Mar 2000	Mill St drain, Canning River, at Wilson	Chemical spill over small area	n=1000, carp & other species
	Apr 2001	Guildford, Swan River	Unknown	n=<10 mullet
	Apr-Jun 2003	Perth Water to Ron Courtney Island & throughout Canning River	*Karlodinium micrum* blooms, toxins, low oxygen	Nearly all collected dead fish (approx 7.8 t) were black bream, but other species (including herring, gobies, flathead, flounder, mulloway, mullet) also killed.
	Apr 2005	East Perth to Bassendean	*Karlodinium micrum* blooms, low oxygen	N = >5000, including blowfish, black bream, flathead, Perth herring, sea mullet, 6-lined trumpeter & gobbleguts.
	May 2000	Black Creek, Welshpool	Chemical spill over small area	n=40, carp
	May 2001	Ascot	Chemical spill	n=12, bream & mullet
	Jun 2004	Como Beach, Matilda Bay	*Karlodinium micrum* blooms	24,000 blowfish, 8,000 gobbleguts
Winter	Jul 1998	Cockram St drain, Canning River	Chemical spill over small area	no fish collected but dead observed
Spring	Oct 2001	Mosman Bay	Possibly low oxygen	n=50, seahorses
	Nov 1997	Ascot	Chemical spill	n > 15,000, bream & herring

Table 2. Average annual landings by Swan Estuary commercial fishery, 1995-2004. (*catch value based on 2000/01 prices paid to fishers).

Species		Average annual catch, 1995-2004			
		Average annual weight (kg)	% of total catch weight	% of total catch value*	*2000/1 price $/kg
Blue swimmer crab	*Portunus pelagicus*	19329	34	57	4.25
Mud crab	*Scylla serrata*	1	< 1	< 1	
Perth herring	*Nematalosa vlaminghi*	13393	24	4	0.45
Sea mullet	*Mugil cephalus*	12258	22	18	2.09
Black bream	*Acanthopagrus butcheri*	3832	7	12	4.72
Yellow-eye mullet	*Aldrichetta forsteri*	2828	5	2	0.89
Tailor	*Pomatomus saltatrix*	936	2	2	2.73
Yellowtail scad	*Trachurus novazelandiae*	627	1	< 1	
Cobbler	*Cnidoglanis macrocephalus*	470	1	1	4.35
Flathead	*Platycephalus endrachtensis*	462	1	1	2.30
Whiting, various	Sillaginidae	403	1	1	3.55
Australian herring	*Arripis georgianus*	285	1	< 1	
Tarwhine	*Rhabdosargus sarba*	225	< 1	< 1	
Flounder	*Pseudorhombus jenynsii*	208	< 1	1	5.00
Other fish		177	< 1	< 1	
Mulloway	*Argyrosomus japonicus*	173	< 1	< 1	
Pilchard	*Sardinops sagax*	129	< 1	< 1	
Skates and rays	Elasmobranchi	113	< 1	< 1	
Yellowtail kingfish	*Seriola lalandi*	112	< 1	< 1	
Whitebait	*Hyperlophus vittatus*	104	< 1	< 1	
Roach	*Gerres subfasciatus*	91	< 1	< 1	
Yellowtail trumpeter	*Amniataba caudavittata*	50	< 1	< 1	
Pink snapper	*Pagrus auratus*	49	< 1	< 1	
Shark, various	(mainly Carcharhinidae)	30	< 1	< 1	
Samson fish	*Seriola hippos*	12	< 1	< 1	
Trevally, various	*Pseudocaranx* spp.	4	< 1	< 1	
Total finfish		36968	66	43	
Total crabs		19331	34	57	

Table 3. Total estimated catch retained by Swan Estuary recreational fishery in 1998/99[a] and 2000/01[b] ([a]Malseed and Sumner 2001: creel survey of lower and middle estuary only ; [b]Henry and Lyle 2003: national phone survey).

Species		1998/99 catch (no. of fish) Boat-based	Shore-based	TOTAL	2000/01 catch (no. of fish) Boat-based	Shore-based	TOTAL	2000/01 catch (weight) TOTAL* (kg)	*kg per fish (approx)**
Black bream	*Acanthopagrus butcheri*	900	699	1599	1632	33703	35334	16273	*0.46*
Blowfish	*Torquigener pleurogramma*	793	3544	4337	-	26159	26159	n/a	*n/a*
Australian herring	*Arripis georgianus*	843	831	1674	3532	12597	16128	2312	*0.14*
Tailor	*Pomatomus saltatrix*	2306	406	2712	1558	10511	12069	2420	*0.20*
Whiting, various	Sillaginidae	2153	182	2335	2030	7869	9899	2079	*0.21*
Flathead, various	*Platycephalus endrachtensis*	849	302	1151	-	7092	7092	1605	*0.23*
Yellow-finned whiting	*Sillago schomburgkii*	-	-	0	-	2707	2707	434	*0.16*
Flounder	*Pseudorhombus jenynsii*	775	minor	>775	-	2057	2057	407	*0.20*
Tarwhine	*Rhabdosargus sarba*	181	minor	>181	-	1999	1999	411	*0.21*
Small baitfish	various	-	-	0	-	1143	1143	91	*0.08*
Garfish	Hemiramphidae	-	-	0	-	1100	1100	202	*0.16*
Trumpeter	*Amniataba caudavittata?*	107	1049	1156	-	1005	1005	143	*0.14*
Catfish	*Cnidoglanis macrocephalus*	-	-	0	-	816	816	533	*0.65*
Yellowtail scad	*Trachurus novazelandiae*	-	minor	>1	-	696	696	56	*0.08*
Pink Snapper	*Pagrus auratus*	-	-	0	666	-	666	307	*0.46*
Mulloway	*Argyrosomus japonicus*	107	-	107	-	662	662	975	*1.47*
Trevally	*Pseudocaranx* spp.	160	minor	>160	-	-	-	0	-
Butterfish	*Pentapodus vita*	681	minor	>681	-	-	-	0	-
Yellow-eye mullet	*Aldrichetta forsteri*	minor	minor	>1	-	-	-	0	-
Blue swimmer crab	*Portunus pelagicus*	20176	699	20875	130985	17357	148341	33080	*0.22*
Prawns	Penaeidea	-	-	0	116366	6163	122528	2083	*0.02*
Blood worms	Annelida	-	-	0	-	55470	55470	n/a	*n/a*
Mussels	Mytilidae	-	-	0	7399	173882	181281	n/a	*n/a*

Table 4. Total number of captured (retained or discarded) fish reported by competitors at 'Swanfish', an annual public fishing competition on the Swan Estuary held in February each year. (*blowfish not fully reported in any year).

Species		Number of fish 2000	2001	2002	2003	2004
Blowfish*	*Torquigener pleurogramma*	22	107	369	67	1541
Black bream	*Acanthopagrus butcheri*	701	821	788	1610	889
Yellowtail trumpeter	*Amniataba caudavittata*	124	429	392	527	547
Flathead, various	*Platycephalus endrachtensis*	103	306	471	474	250
Tarwhine	*Rhabdosargus sarba*	28	135	289	392	192
Yellow-finned whiting	*Sillago schomburgkii*	39	205	260	220	267
Six-lined trumpeter	*Pelates sexlineatus*	25	109	48	142	132
Tailor	*Pomatomus saltatrix*	10	114	81	82	115
Flounder	*Pseudorhombus jenynsii*	22	70	93	64	29
Cobbler	*Cnidoglanis macrocephalus*	46	30	40	52	7
Australian herring	*Arripis georgianus*	7	36	17	29	18
Pink Snapper	*Pagrus auratus*	14	24	18	22	0
Mulloway	*Argyrosomus japonicus*	12	10	20	12	11
Trevally	*Pseudocaranx* spp.	1	5	8	28	1
Yellow-eye mullet	*Aldrichetta forsteri*	3	4	29	2	4
Gobbleguts	*Apogon rueppellii*	6	1	4	2	13
Butterfish	*Pentapodus vita*	0	0	6	8	11
Blue swimmer crab	*Portunus pelagicus*	3	9	1	2	10
Yellowtail scad	*Trachurus novazelandiae*	2	2	12	0	0
Snook	*Sphyraena novaehollandiae*	0	7	0	0	0
Whiting, various	Sillaginidae	3	0	0	0	1
Wrasse/groper	Labdridae	0	1	1	1	1
Sea garfish	*Hyporhamphus melanochir*	0	0	0	1	2
King George whiting	*Sillaginodes punctata*	1	0	0	1	0
Long-finned pike	*Dinolestes lewini*	0	1	0	0	0
Trumpeter whiting	*Sillago maculata*	0	0	0	1	0
Samson fish	*Seriola hippos*			1	0	0
Leatherjacket	Monocathidae	0	0	0	1	0
Ray	Elasmobranchi	0	0	1	0	0
Unidentified		27	130	181	327	108
Number of competitors surveyed		*439*	*695*	*824*	*1119*	*976*

Table 5. Number of fish reported at the monthly Estuary Field Day 'weigh-in' by the Melville Amateur Angling Club (MAAC), 1987 to 2003 (numbers do not include discards).

		Years				
Species		**1987-1991**	**1992-1995**	**1996-1999**	**2000-2003**	**TOTAL**
Australian herring	*Arripis georgianus*	123	230	105	406	864
Black bream	*Acanthopagrus butcheri*	131	295	159	259	844
Flathead, various	*Platycephalus endrachtensis*	128	214	122	193	657
Yellow-finned whiting	*Sillago schomburgkii*	103	730	185	185	1203
Tarwhine	*Rhabdosargus sarba*	113	11	45	175	344
Six-lined trumpeter	*Pelates sexlineatus*	168	92	93	119	472
Trevally	*Pseudocaranx* spp.	92	210	81	112	495
Yellowtail trumpeter	*Amniataba caudavittata*	176	278	117	105	676
Tailor	*Pomatomus saltatrix*	162	133	100	99	494
Wrasse/groper	Labdridae	15	24	14	85	138
Sea garfish	*Hyporhamphus melanochir*				59	59
King George whiting	*Sillaginodes punctata*	54	64	7	27	152
Yellowtail scad	*Trachurus novazelandiae*		39	30	21	90
Flounder	*Pseudorhombus jenynsii*	251	87	48	20	406
Mackerel, Blue	*Scomber australasicus*	17	37	7	12	73
Leatherjacket	Monocathidae	2	2		12	16
Butterfish	*Pentapodus vita*		2	1	11	14
Yellow-eye mullet	*Aldrichetta forsteri*	259	330	47	8	644
Scaly mackerel	*Sardinella lemura*				6	6
Long-finned pike	*Dinolestes lewini*			4	5	9
Trumpeter whiting	*Sillago maculata*		38	25	4	67
Mulloway	*Argyrosomus japonicus*	2	1	8	2	13
Longtom	Belonidae				2	2
Cobbler	*Cnidoglanis macrocephalus*	679	210	58	1	948
Blue weed whiting	*Haletta semifasciata*			3	1	4
Lizardfish/grinner	Synodontidae			2	1	3
Banded sweep	*Scorpis georgianus*	2			1	3
Common scalyfin	*Parma mccullochi*				1	1
Footballer/stripey	*Microcathus strigatus*				1	1
Snook	*Sphyraena novaehollandiae*				1	1
Pomfret	*Schuettea woodwardi*				1	1
Sweetlip	Haemulidae				1	1
Mackerel/bonito	Scombridae		89	4		93
Australian salmon	*Arripis truttaceus*	1	1	12		14
Roach	*Gerres subfasciatus*	2	2	3		7
Zebra fish	*Girella zebra*	1		4		5
Redfin perch	*Perca fluviatilis*			3		3
Bony herring	*Elops machnata*	1	2			3
Gurnard	*Chelidonichthys kumu*	1				1
Gummy shark	*Mustelus antarcticus*			1		1

Table 6. Abundance and status of key fishery stocks in Swan Estuary.

C = commercial fishery; **R** = recreational fishery; **1** = primary species; **2** = secondary species; **0** = minor/not caught; **O** = marine/estuarine opportunist (spawns at sea but common in estuaries, particularly as juveniles); **E** = estuarine (only found in estuaries); **EM** = estuarine and marine (can spawn in estuaries or ocean, often forms discrete populations in estuaries); **A** = semi-anadromous (spends part of life at sea but migrates to upper estuary to spawn); ↑ = catch trends suggest increase in estuary abundance; ↓ = catch trends suggest decrease in estuary abundance; **N/A** = insufficient data. 'Fish kill' risk (**High/Medium/Low**) = risk to stock from major fish kill in Swan Estuary.

Species	Recent Fishery Importance	Life History Category	'Fish kill' risk	Estuary catch trend since 1990
Black bream	C1, R1	E	H	↑
Yellowtail scad	C2, R2	O	L	↑
Tarwhine	C2, R2	O	L	↑
Blue swimmer crab	C1, R1	O	L	↑
Australian herring	C2, R1	O	L	↑ (longer-term trend is ↓)
Flathead	C2, R1	EM	M	↑ (longer-term trend is stable)
Flounder	C2, R2	O	L	↓ (longer-term trend is stable)
Six-lined trumpeter	C0, R2	O	L	Stable/fluctuating
Tailor	C1, R1	O	L	Stable/fluctuating
Yellowfin whiting	C1, R2	O	L	↓
Sea mullet	C1, R0	O	L	↓
Yellow-eye mullet	C1, R0	O	L	↓
Perth herring	C1, R0	A	H	↓
Cobbler	C2, R2	EM	M	↓
Yellowtail trumpeter	C2, R2	E	M	↓
School prawn	C0, R2	E	M	↓
Trevally	C0, R2	O	L	N/A
Mulloway	C2, R2	O	L	N/A
Garfish	C0, R2	O	L	N/A
Pink snapper	C0, R2	O	L	N/A

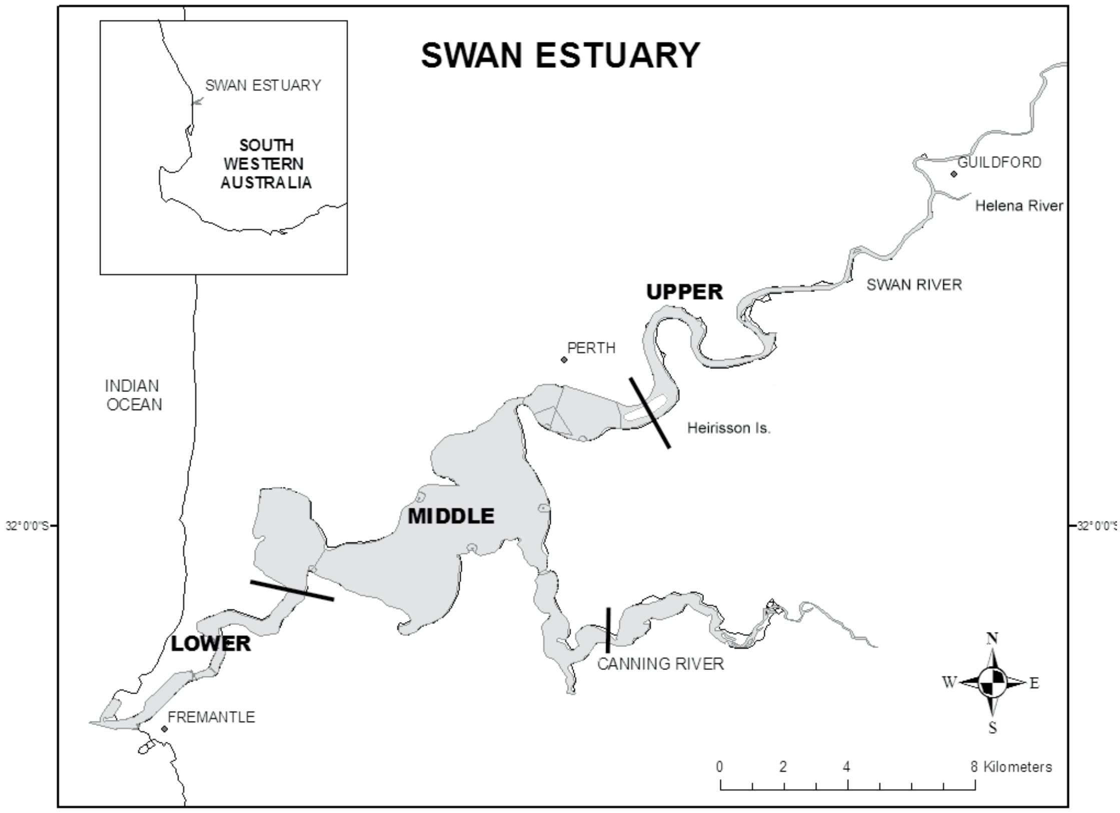


Figure 1. Map of Swan-Canning Estuary. 'Lower' estuary = entrance to Blackwall Reach; 'Middle' estuary = Blackwall Reach to Heirisson Island, and lower half of Canning River; 'Upper' estuary = upstream of Heirisson Island and upper half of Canning River. (Note: commercial fishery is located in middle estuary.

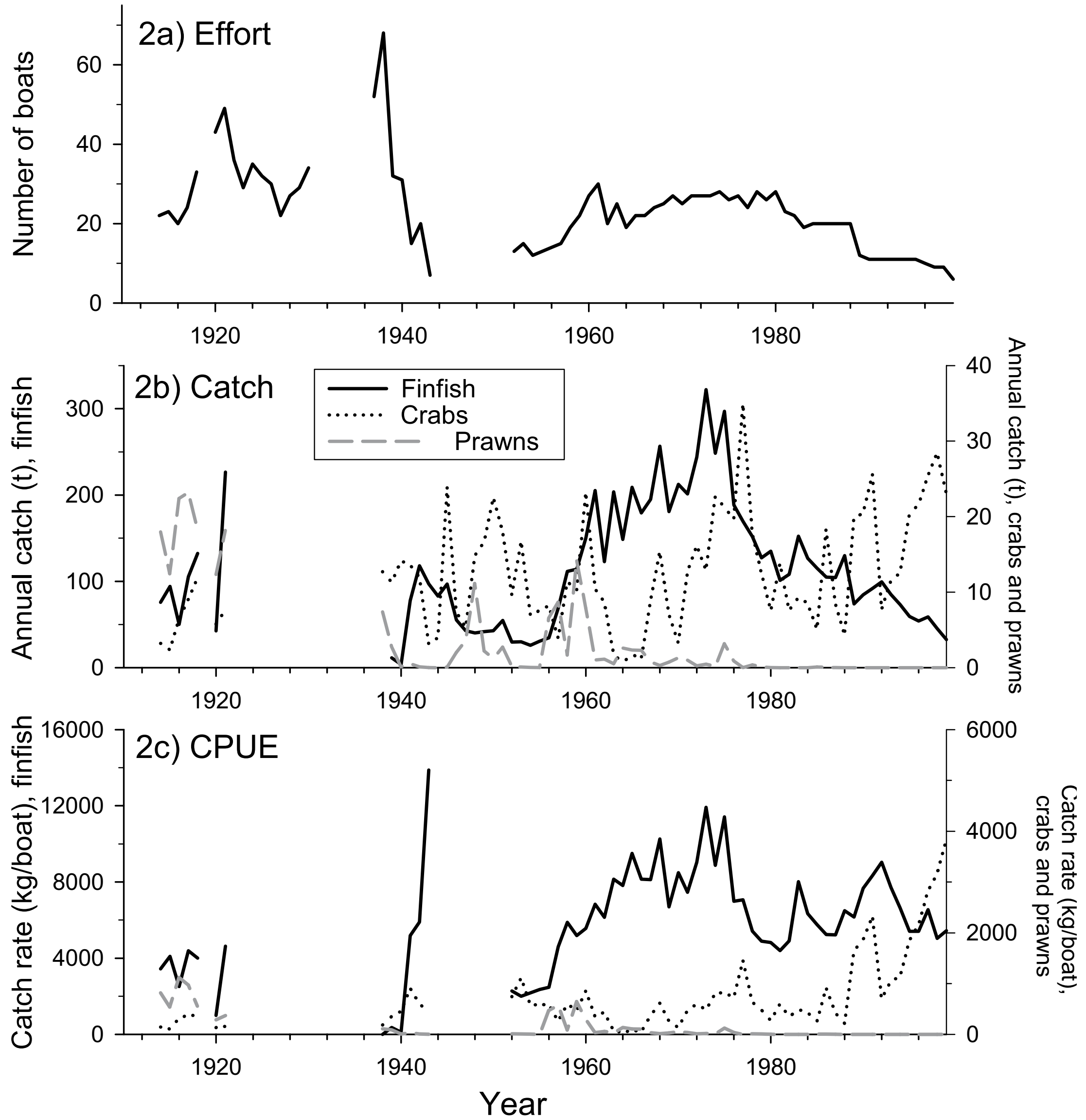


Figure 2. Annual a) total fishing effort (number of registered boats), b) catch and c) CPUE of total finfish, crabs and prawns in the Swan Estuary commercial fishery from 1912 to 1999. Some incomplete catch and effort data prior to 1939 and 1952, respectively. (Data from 2000 to 2004 not shown because catches were taken by <5 fishers in these years).

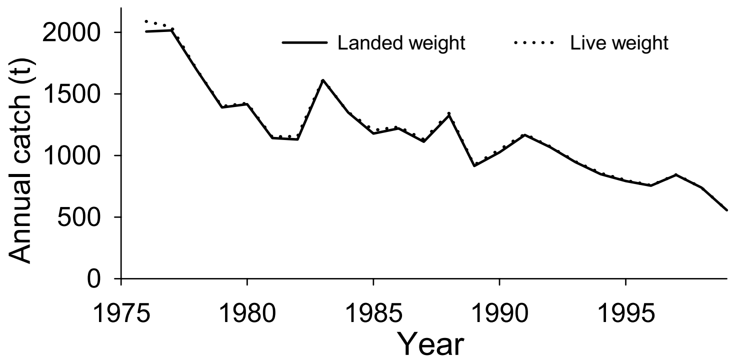


Figure 3. Comparison of annual landings by the Swan Estuary commercial fishery reported as 'live weight' and 'landed weight' in CAES database, 1975 to 1999. (Data from 2000 to 2004 not shown because catches were taken by <5 fishers in these years)

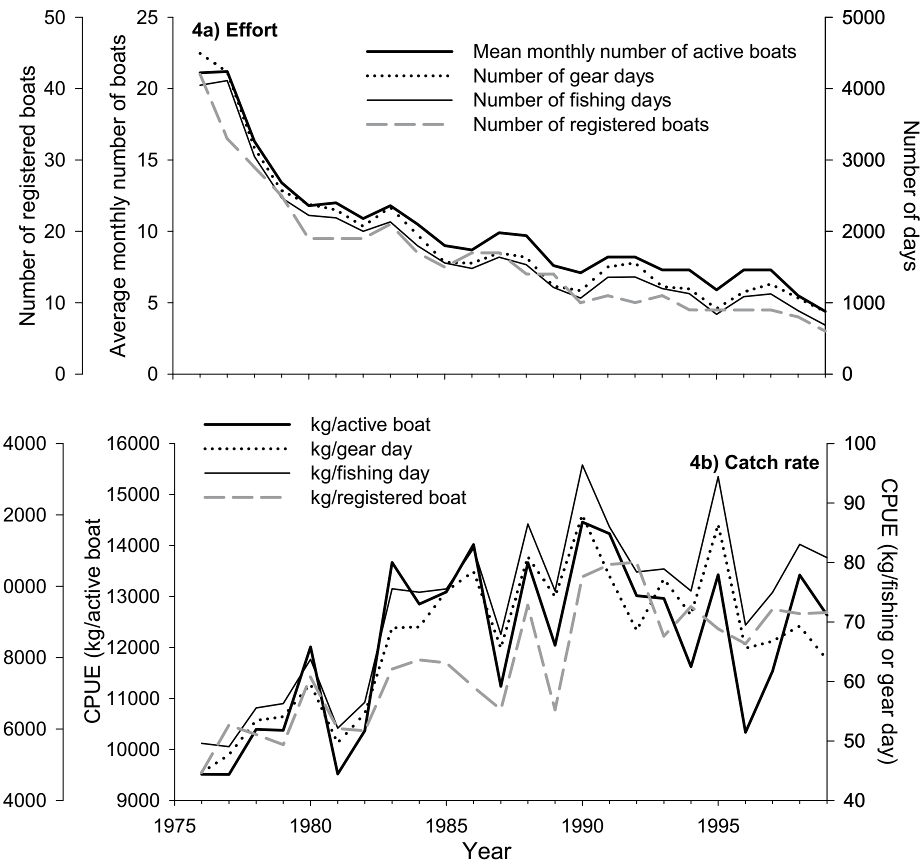


Figure 4. **a)** Comparison of the various available fishing effort units and **b)** their effect on the calculation of total annual CPUE in the Swan Estuary commercial fishery, 1976 to 1999. (Data from 2000 to 2004 not shown because catches were taken by <5 fishers in these years)

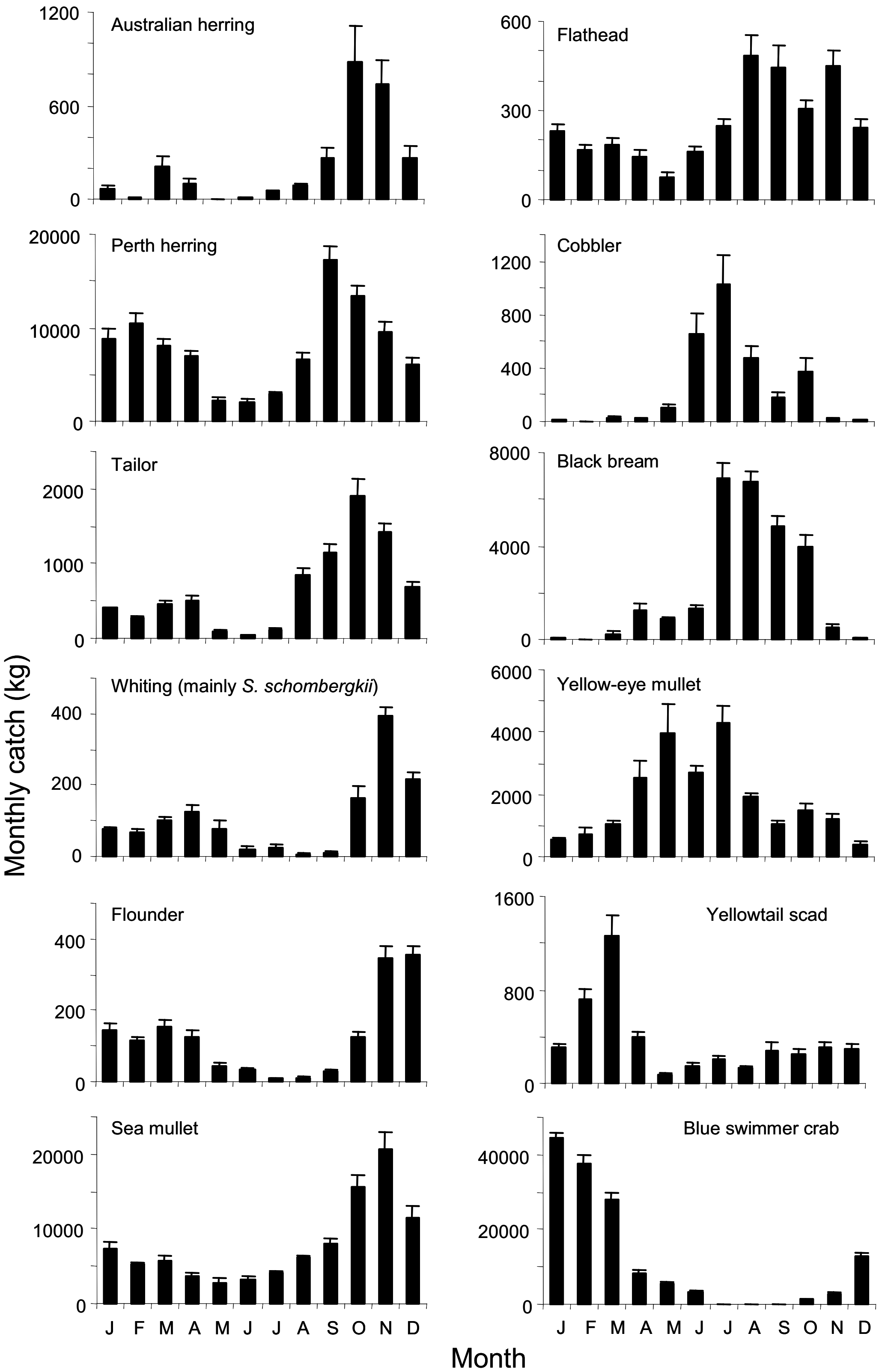


Figure 5. Mean (+ s.d.) monthly landings of key species in the Swan Estuary commercial fishery, 1996-2002.

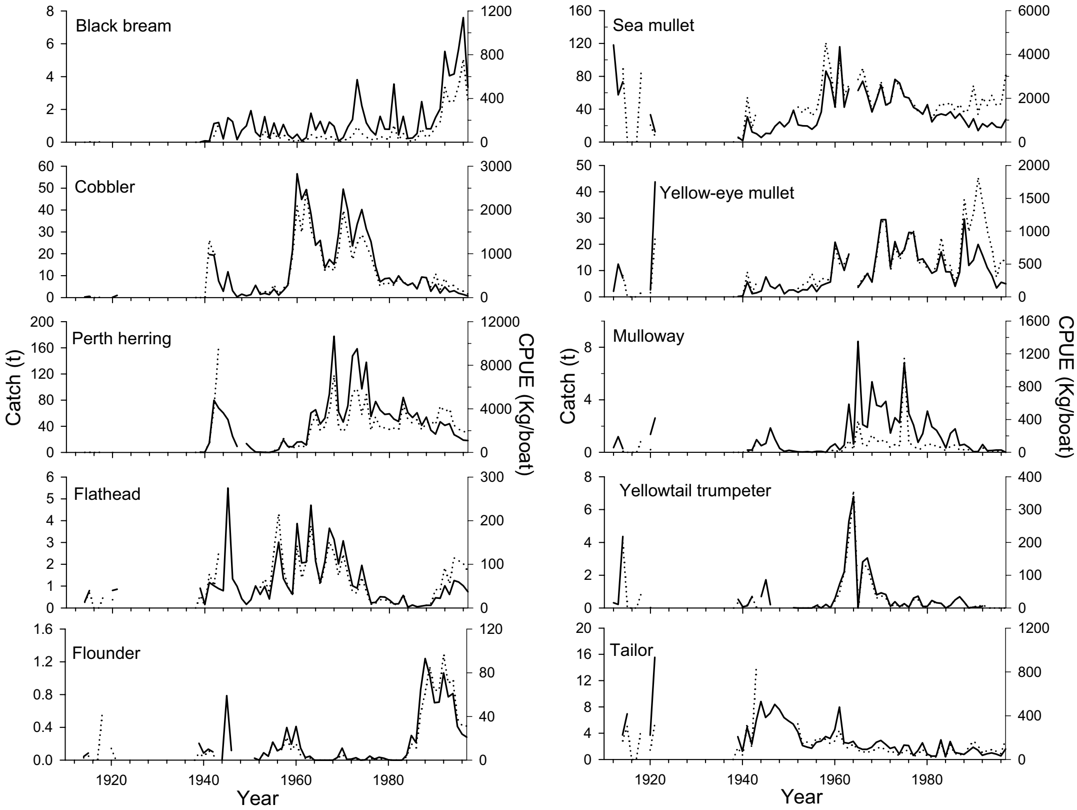


Figure 6. Annual catch (solid line) and CPUE* (dotted line) of key finfish species in Swan Estuary commercial fishery from 1912 to 1997 (*CPUE derived by using 'number of registered boats' as the unit of effort). (Data from 1998 to 2004 not shown because catches were taken by <5 fishers in these years).

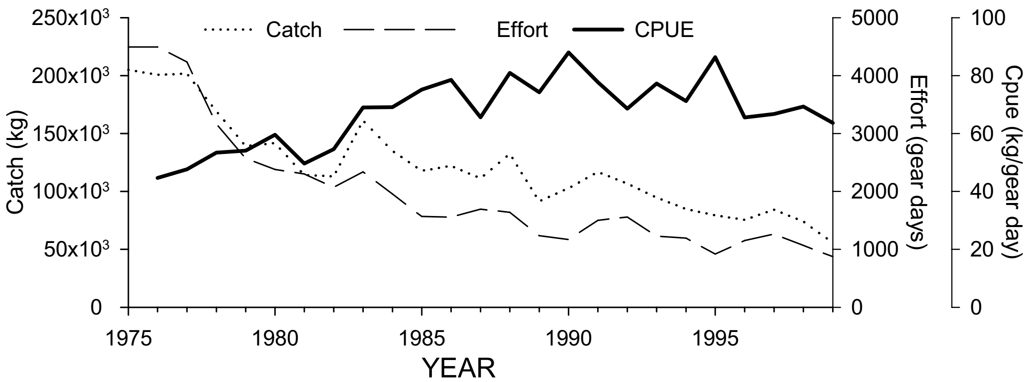


Figure 7. Recent total annual catch, effort and CPUE in Swan Estuary commercial fishery from 1975 to 1999. (Data from 2000 to 2004 not shown because catches were taken by <5 fishers in these years).

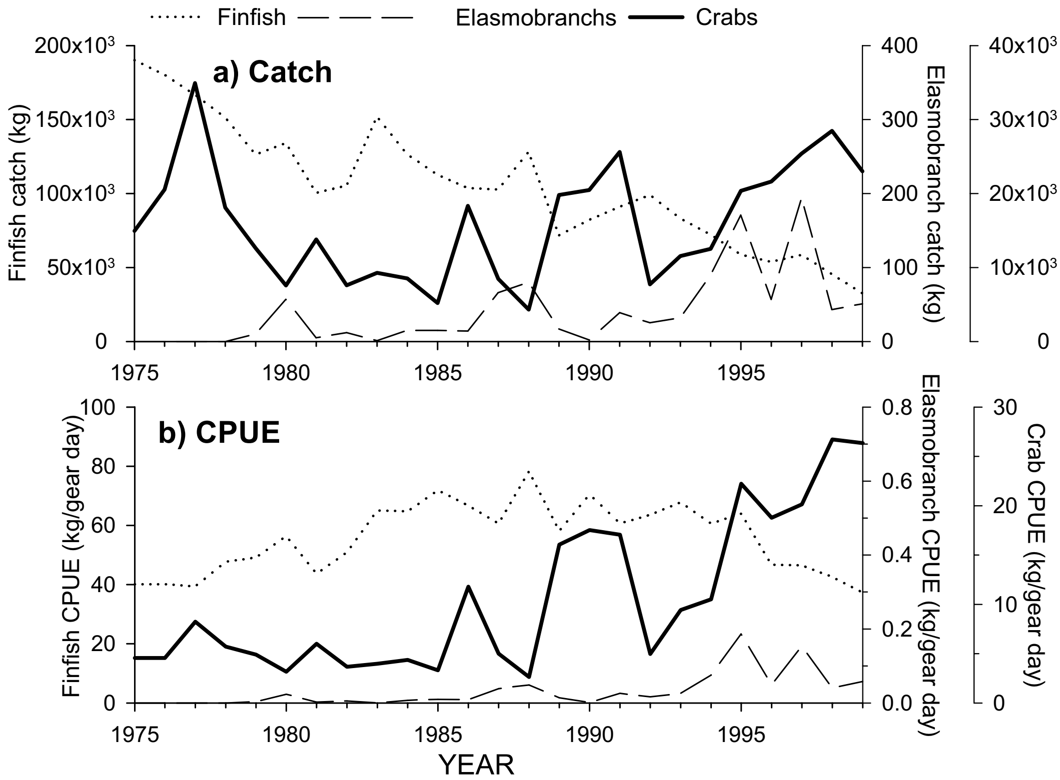


Figure 8. Recent annual **a)** catch and **b)** CPUE of major taxonomic groups in Swan Estuary commercial fishery from 1975 to 1999. (Data from 2000 to 2004 not shown because catches were taken by <5 fishers in these years).

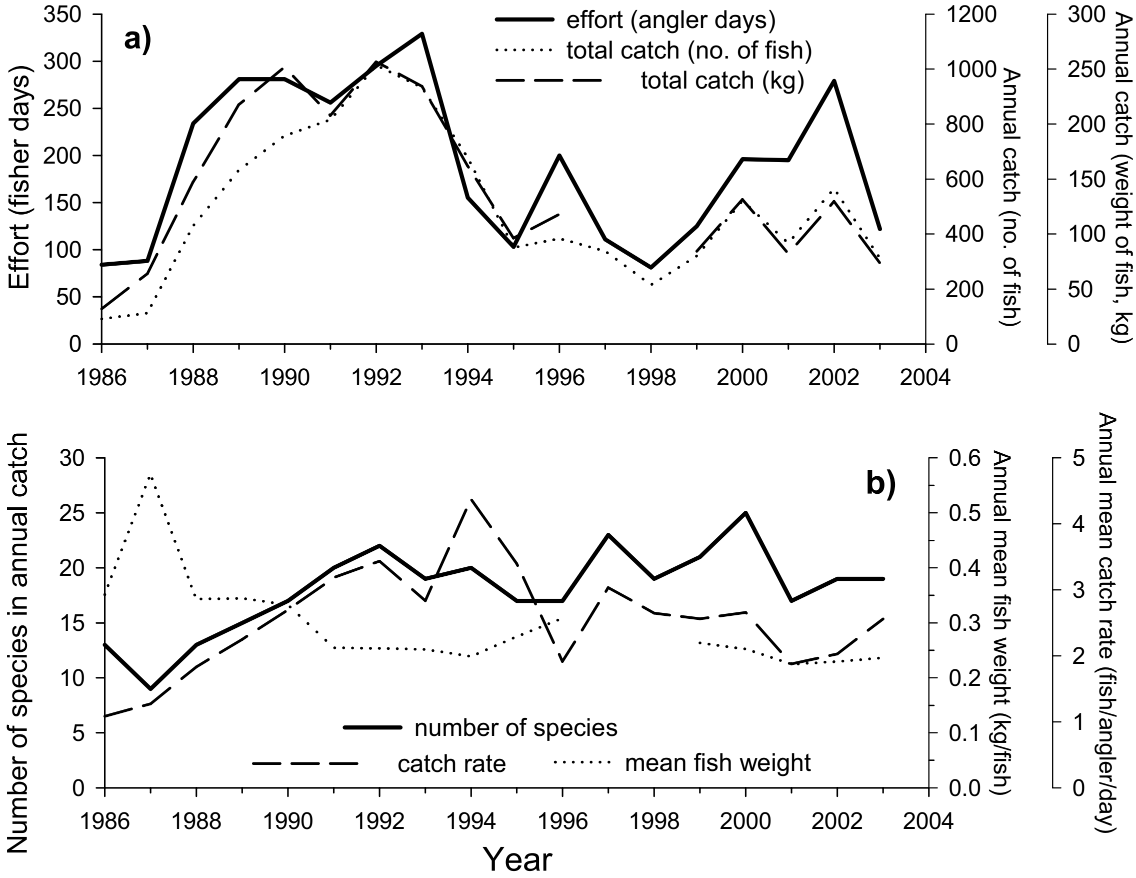


Figure 9. Melville Amateur Angling Club (MAAC) Swan Estuary fishing competition data. **a)** Annual catch and effort. **b)** Annual number of retained species, mean weight of retained fish and mean CPUE, 1986 to 2003. (Some fish weights not available in 1998 and 1999).

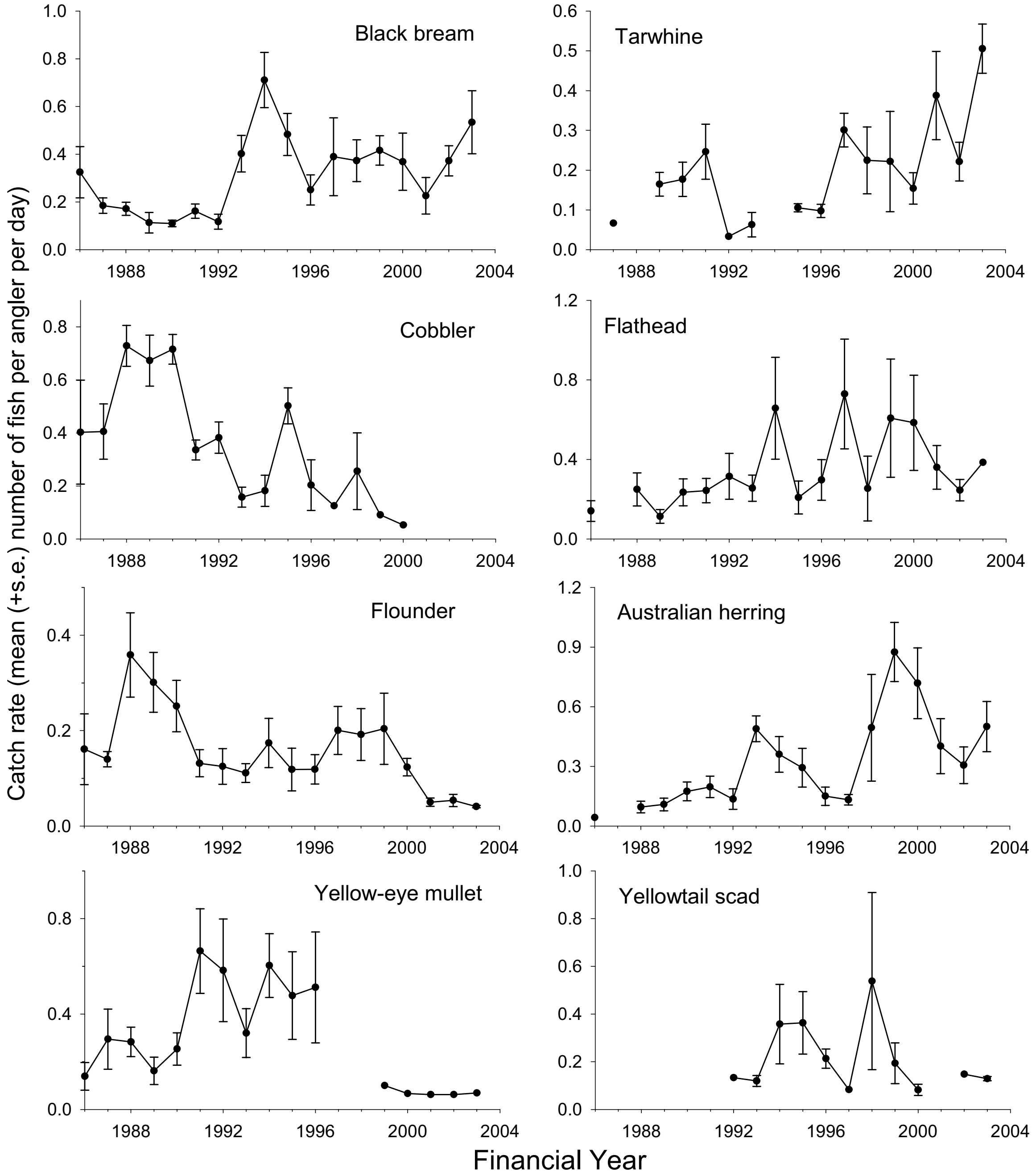


Figure 10a. Mean annual CPUE (+ s.e.) of key species retained by Melville Amateur Angling Club during their Swan Estuary fishing competition, 1986 to 2003.

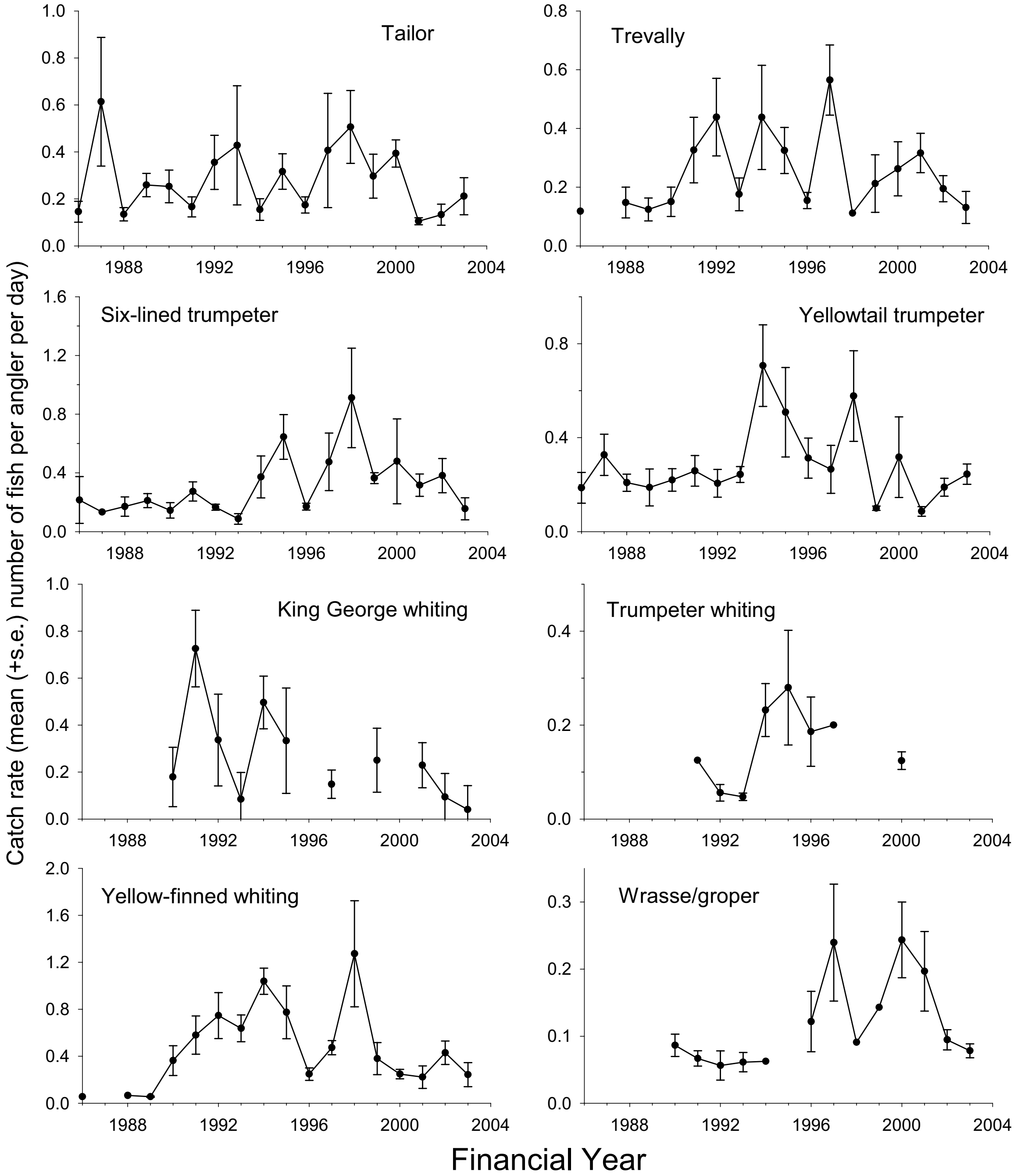


Figure 10b. Mean annual CPUE (+ s.e.) of key species retained by Melville Amateur Angling Club during their Swan Estuary fishing competition, 1986 to 2003.

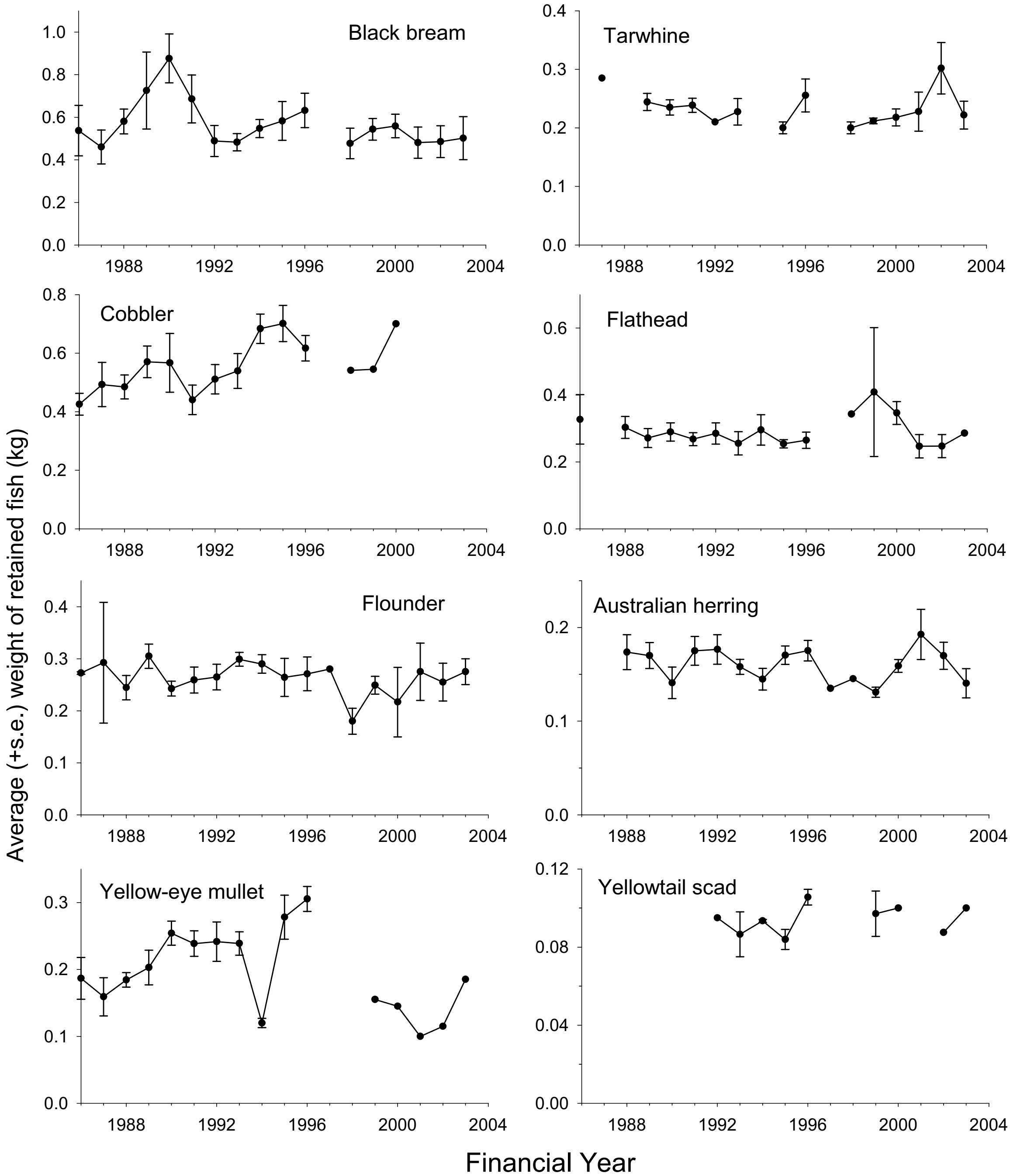


Figure 11a. Mean (+ s.e.) annual body weight of key species retained by Melville Amateur Angling Club during their Swan Estuary fishing competition, 1986 to 2003.

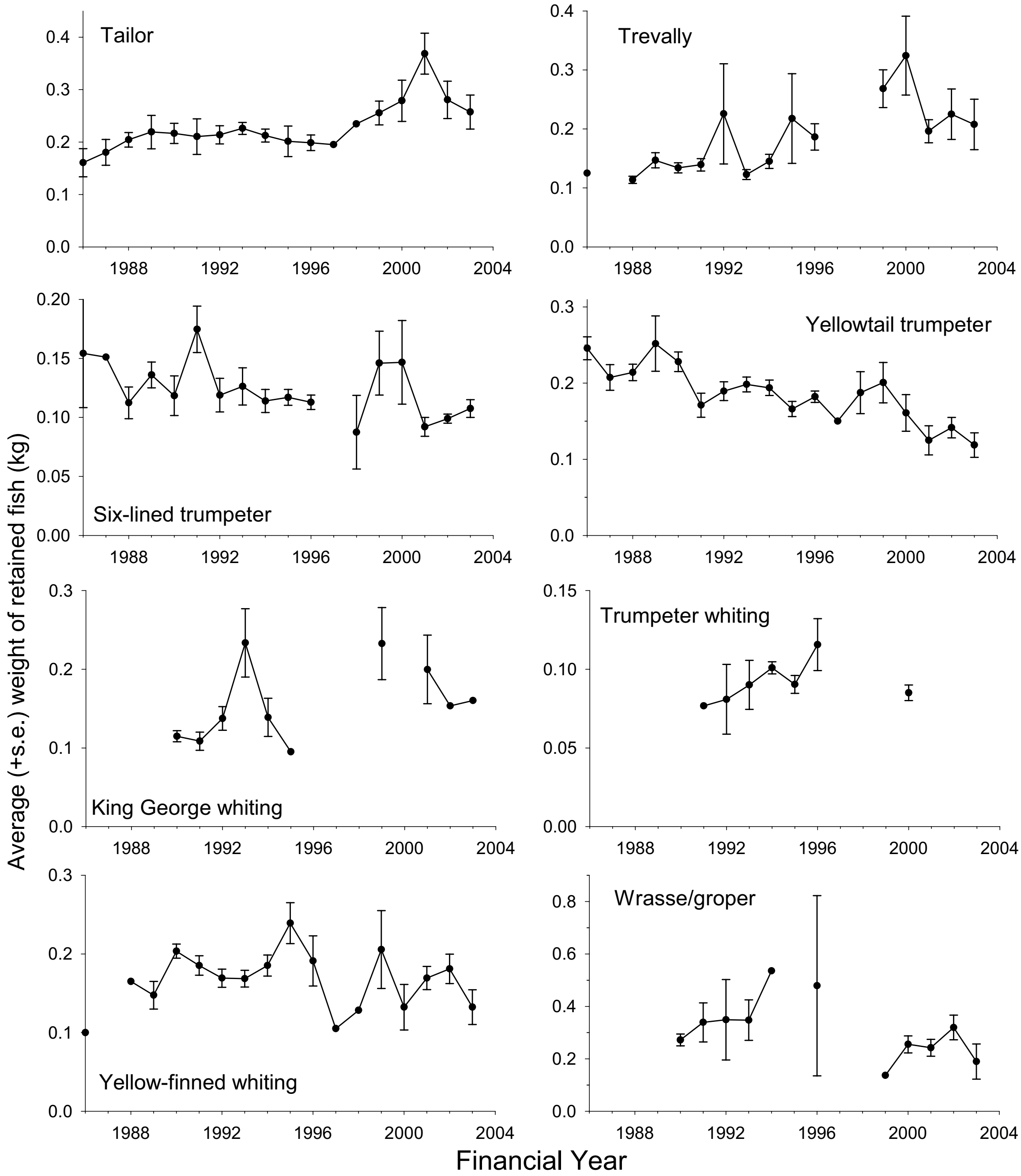
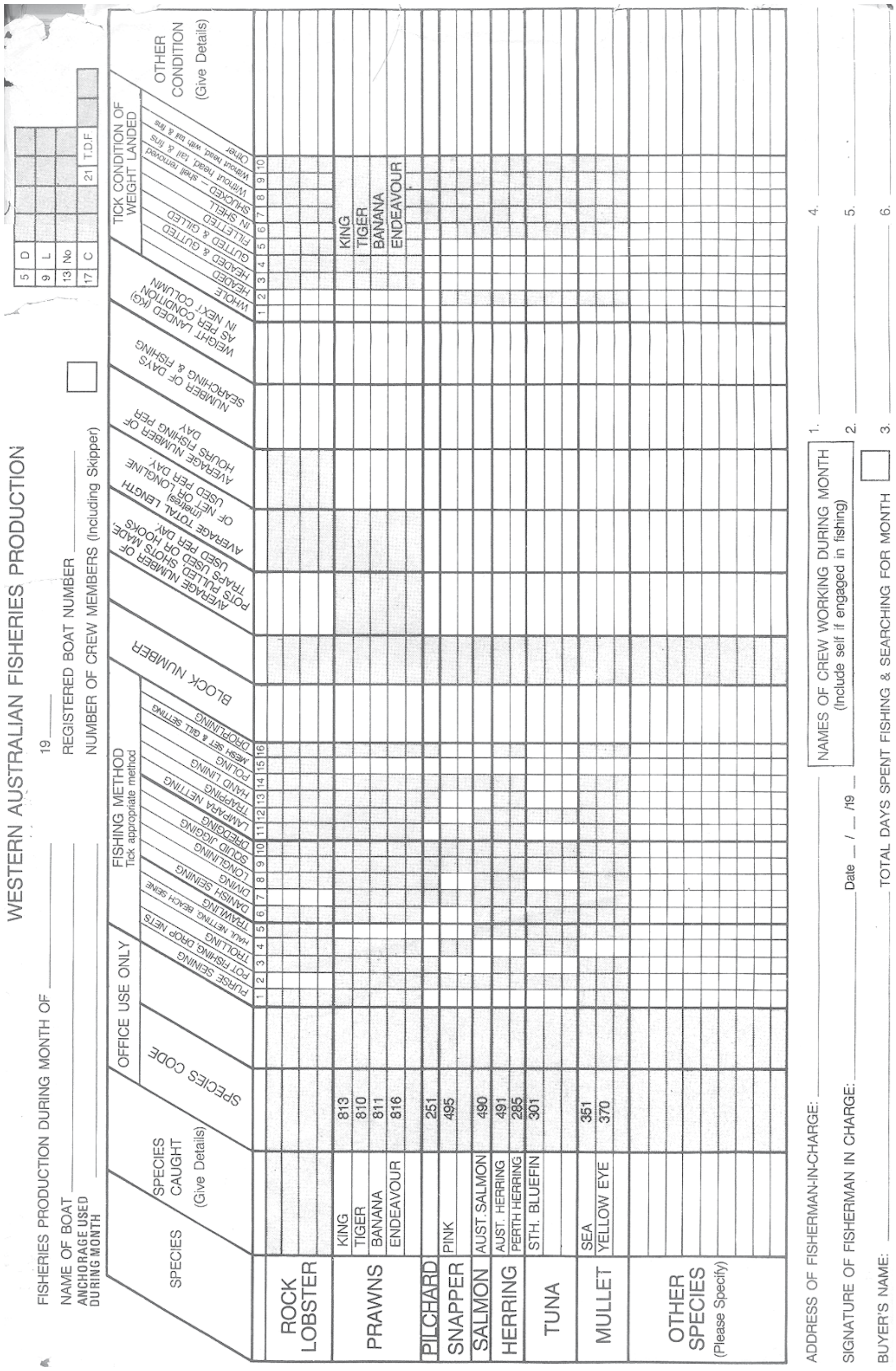


Figure 11b. Mean (+ s.e.) annual body weight of key species retained by Melville Amateur Angling Club during their Swan Estuary fishing competition, 1986 to 2003.

9.0 Appendices

Appendix 1. Pre- July 1989 format of commercial fisher compulsory monthly catch returns



WESTERN AUSTRALIAN FISHERIES PRODUCTION

FISHERIES PRODUCTION DURING MONTH OF ______ 19____

NAME OF BOAT ______ REGISTERED BOAT NUMBER ______

ANCHORAGE USED DURING MONTH ______ NUMBER OF CREW MEMBERS (Including Skipper) ______

5 D	9 L	13 No	17 C	21 T.D.F

SPECIES	SPECIES CAUGHT (Give Details)	SPECIES CODE	OFFICE USE ONLY	FISHING METHOD Tick appropriate method	BLOCK NUMBER	AVERAGE NUMBER OF POTS PULLED TRAPS USED SHOTS MADE, USED OR HOOKS USED PER DAY	AVERAGE TOTAL LENGTH OF NET OR LONGLINE (metres) USED PER DAY	AVERAGE NUMBER OF HOURS FISHING PER DAY	NUMBER OF DAYS SEARCHING & FISHING	WEIGHT LANDED (KG) AS PER CONDITION IN NEXT COLUMN	TICK CONDITION OF WEIGHT LANDED	OTHER CONDITION (Give Details)
ROCK LOBSTER												
PRAWNS	KING	813									KING	
	TIGER	810									TIGER	
	BANANA	811									BANANA	
	ENDEAVOUR	816									ENDEAVOUR	
PILCHARD		251										
SNAPPER	PINK	495										
SALMON	AUST. SALMON	490										
HERRING	AUST. HERRING	491										
	PERTH HERRING	285										
TUNA	STH. BLUEFIN	301										
MULLET	SEA	351										
	YELLOW EYE	370										
OTHER SPECIES (Please Specify)												

FISHING METHOD: 1 PURSE SEINING, 2 POT FISHING, DROP NETS, 3 TROLLING, 4 HAUL NETTING, BEACH SEINE, 5 TRAWLING, 6 DANISH SEINING, 7 DIVING, 8 LONGLINING, 9 SQUID JIGGING, 10 DREDGING, 11 LAMPARA NETTING, 12 TRAPPING, 13 HAND LINING, 14 POLING, 15 MESH SET & GILL SETTING, 16 DROPLINING

TICK CONDITION OF WEIGHT LANDED: 1 WHOLE, 2 HEADED, 3 HEADED & GUTTED, 4 GUTTED & GILLED, 5 FILLETTED, 6 IN SHELL, 7 SHUCKED, 8 Without shell removed, 9 Without head, tail & fins, 10 Other head, with tail & fins

ADDRESS OF FISHERMAN-IN-CHARGE: ______

SIGNATURE OF FISHERMAN IN CHARGE: ______ Date __ / __ /19 __

BUYER'S NAME: ______

TOTAL DAYS SPENT FISHING & SEARCHING FOR MONTH ☐

NAMES OF CREW WORKING DURING MONTH (Include self if engaged in fishing)

1. ______ 4. ______

2. ______ 5. ______

3. ______ 6. ______

Appendix 2. 2003 format of commercial fisher compulsory monthly catch returns

Original post to Department of Fisheries   Duplicate - retain for your records

Office Use

Netting: catch and effort return

Fish Resources Management Regulations 1995 Regulation 64

Year	Month	Boat registration LFB	Boat name
2005	SEPT	A 199	BLUEFIN

Fishing Boat Licence FBL	Managed fishery licence(s) MFL
1432	SCEP 23

Anchorage	Master's CFL No.	Master's name (Authorisation holder or agent)
ALBANY	1000	J. CITIZEN

Months you propose not to fish	Phone no.	Address
OCT	9845 3210	1 HIGHWAY RD ALBANY

No. days fished.	Crew number (inc master)	Fuel purchased (litres)	I certify that the information on this form is correct (Master, authorisation holder or agent)	Date signed
12	3	1200		4/10/05

Fishery eg. SGL, SCPS, SCEP (one fishery per column)	SCEP	SCEP			
If applicable Zone fished (one zone per column)					
Netting methods eg. PS (one method per column)	GN	GN			
Block number (one block per column)	9507	8511			
Days fished	4	4			
Hours fished per day	8	6			
Shots/pulls per day	1	1			
Net length (m) per shot	1000	800			
Mesh size range (mm)	64-102	102			

Species (include all retained catch)	Condition codes	kg	kg	kg	kg
YE MULLET	WH	123			
WHITING KG	WH	14			
WS WHITING	WH	10			
COBBLER	HG	6			
BLACK BREAM	WH		251		

Fishery eg. WL, EXEM	WL	
If applicable Zone fished		
Other methods eg. HR	HR	
Block number	9603	
Days fished	4	
Hours fished per day	4	
Pots/traps pulled per day		
Hooks per day	6	
Shots/pulls per day		
Net length (m) per shot		
Mesh size range (mm)		

Species (include all retained catch)	Condition codes	kg	kg
WHITING KG	WH	150	
PINK SNAPPER	GG	105	

Dealer/processor	Crew names
BAYFISH PROCESSORS	A.FISHER O.SHUN

Have you had an interaction with a protected species?	Species, location and other comments
Yes ☑ No ☐ If yes, was animal released Alive ☑ Dead ☐	15/9 STOKES INLET - PELICAN TANGLED, CUT OUT OF NET, FLEW AWAY.

Notification of months when no fishing occurred is required on this form. A signed facsimile of this form may be submitted

List of Fisheries Research Reports

Not all have been listed here, a complete list is available online at http://www.fish.wa.gov.au

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