Goolwa Cockle
(Donax deltoides)

Sue Murray-Jones and John Johnson

February, 2003

Fishery Assessment Report to PIRSA for the
Inland Waters Fishery Management Committee

South Australian Fisheries Assessment Series 2002/21

Goolwa Cockle *(Donax deltoides)*

This series presents the scientific basis for stock assessments and fisheries advice in South Australia. The documents contained in the series are not intended as definitive statements on the fisheries addressed but rather as progress reports on ongoing investigations.

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Executive Summary

The Goolwa cockle (*Donax deltoides*) is one of many species that is available to the multi-species, multi-method Lakes and Coorong Fishery. This assessment of the Goolwa cockle fishery operating on the Coorong and Goolwa ocean beaches (Kingston to Middleton, South Australia) is made against the biological objectives of the Fisheries Act (SA, 1982) and evaluates fishery, stock and environmental performance. Specific objectives for the management of the Goolwa cockle resource are currently being developed as part of a formal management plan for the Lakes and Coorong Fishery.

The Goolwa and Coorong ocean beaches support a significant commercial and recreational fishery for the Goolwa cockle. Since the late 1980s there has been a marked increase in the catches in this commercial fishery, most notable from 1990 onwards. The total commercial catch peaked in 2000/01 at 1241 tonnes. Catches between 1997 and 2001 were higher than in previous years, and have been generally increasing since catch records have been kept. Annual catch data show a pattern of increasing catches through the late 1980s and 90s. Annual effort patterns are similar to catch patterns, showing effort increasing steadily during the 1980s and into the early 90s. Fishing effort was fairly stable throughout most of the 90s, rose steeply in 1999/2000, and was still high in 2000/01 at 3539 fisher days. Highest recorded effort occurred in 1999/2000, with nearly 4000 fisher days being reported.

Catch per unit effort varies among years in this fishery, but was consistently high between 1992/3 and 1997/8, peaking in 1997/8 at 368 kg per fisher day. Catch rates declined steadily between 1997/8 and 1999/2000, dropping by 25% in 1999/2000, before increasing in 2000/01 to 351 kg per fisher day. Daily CPUE data show similar patterns. Variances in CPUE were extremely high in both sectors, but most notable in the Lakes and Coorong Fishery, indicating very large differences in catch rates on a day to day basis, which reflect differences in individual fishers, location, availability of the resource, skills, and whether or not effort is targeted at cockles for the bait or the human consumption markets.

There were approximately 15 Lakes and Coorong (L&C) licensees and seven Marine Scale Fishery (MSF) licensees active in this fishery in the 2000/2001 licensing year. Up till January 2001, only two to three fishers have been active in the MSF sector. In January 2001 there were 29 L&C commercial licensees with endorsements for cockle fishing gear, and two MSF licensees endorsed to sell cockles. All MSF and rock lobster licence holders have access to the resource although amendments to this access are under consideration.

Latent (unused) effort is a significant issue in this fishery, as large numbers of fishers who are not currently collecting cockles have gear endorsements to do so. Even without gear endorsements all remaining MSF fishers are able to collect cockles for bait, but only by hand. Whilst proposed changes will restrict the level of access to the resource by Rock Lobster and MSF sectors, latent effort in the L&C sector is significant and should not be ignored. A maximum of 130 cockle devices is endorsed in the L&C fishery under current policy and regulation. Current operational practises would mean that only 87 devices should become effective. Presently reported fishing effort constitutes about 45 devices, so the fishery has approximately 48% of its effort still in a latent condition.

The market value of the SA Goolwa cockle harvest increased markedly in the 1999/2000 financial year, reaching a total of $1,684,000. This reflected a 77% increase on the previous year's value of $953,000, and reflected an increase in both market price per kilogram, and the total catch. The species is the most important in the Lakes and Coorong Fishery in terms of value and production. Whilst there has historically been a component of the Goolwa cockle catch for human consumption, the trend for increasing effort and rising prices probably reflects an increasing interest in supply of Goolwa cockles for food over the more historical usage for bait. Mean market price was less than $1 per kilogram throughout the nineties, increasing to $1.55 in 1999/2000. Data for 2000/01 give a mean market price of $1.12.

No information is available on the recreational harvest patterns of catch and effort for this resource, however the catch is thought to be substantial. Research directed to gaining a better perspective of quantifying this harvest is recommended to aid future fishery assessments.

The biology and ecology of *Donax deltoides* in South Australia has been little studied, hence information collected on the fishery, biology and ecology of this species in other states has been included in this report.

Environmental assessment included evaluation of by-product, bycatch, ghost fishing, habitat impact, vehicular impacts, and icon species issues. By-product, ghost fishing, habitat impact, and icon species issues were assessed as being either not significant, or adequately managed. Vehicular impacts on cockle availability and stock distribution are likely to be minor on the eastern beach but may be significant on the Goolwa beach west of the Murray mouth, where there is considerably more vehicular traffic and the major proportion of the recreational fishing occurs.

Bycatch of undersized Goolwa cockles was found to be an operational issue requiring resolution.

Current fisheries management effectively deals with the harvesting operations in the fishery and does not deal with post-harvest issues, although a Shellfish Quality Assurance Program is in place for this fishery. Restrictions on the number of licences and gear endorsements, gear design specifications, fishing season, and size at first capture are in place. A bag limit of 600 cockles per day is in place for the recreational sector.

The multi-species, multi-method nature of the fishery allows for commercial fishers to tailor fishing practises to target different species in line with seasonal variations in abundance, weather patterns, market prices and environmental conditions (natural or human-made).

The data on the commercial fishery would indicate that it is sustainable under the present environmental and exploitation parameters. Whilst there are patches of cockles along the Coorong beach that are not exploited, outflows through the River Murray mouth appear to be an important factor in the maintenance of sizeable population numbers along the Coorong and Goolwa beaches. Exploitation of the cockles is commonly restricted to the intertidal region, and in recent years, commercial fisheries have confined their fishing operations to the east of the Murray Mouth. Pierce and Doonan (1999) classified this fishery as fully exploited.

The trend is for increased human consumption of Goolwa cockles, and this is likely to be further driven by any rises in market demand and/or price. The potential exists for significant increases in recreational cockle harvest, particularly near easy beach access areas (e.g. Goolwa Beach), with a further shift from collecting for bait to collecting for food.

Beach cockle fisheries worldwide share several common trends, particularly highly fluctuating abundances and episodic recruitment. McLachlan et al. (1996) reported that in some fisheries rapid expansion of effort into the fishery particularly through mechanical harvesting is often followed by a dramatic collapse of the fishery. Furthermore recovery of the populations can be slow. Overfishing was perceived as a serious problem in the 1950s and 60s in NSW (Murray-Jones, 1999). This pattern needs to be taken into account in considering risks to the SA cockle fishery. In SA, mass mortality events have occurred and these have the potential to affect the corresponding harvest levels of cockles.

No fishery independent data are available, and stock assessment has been shown to be difficult for this species. McLachlan et al. (1996), in a review of beach clam fisheries world wide, recommended an experimental approach to management through methods such as rotation of fishing areas, creation of spawning stock refuges, and restocking by direct seeding.

Recommendations of this report include:

- Reducing latent effort particularly within the Marine Scale Fishery and the Rock Lobster Fishery, and addressing the excess devices allocated to the Lakes and Coorong Fishery
- Minimising undersize mortality, possibly by requiring sieving of the catch and the live undersized animals being returned to the water
- Obtaining commercial fishery catch per unit effort (CPUE) data in hours fished, instead of days, in order to maximise precision of estimates and to determine the relationship between harvest and effort
- Obtaining more accurate data on the location (site) of the daily fishing operation
- Consideration being given to including an indication on the commercial catch log whether the Goolwa cockle catch is predominantly for human consumption or bait.
- Additional research and development effort aimed at adding value to the landed catch
- Estimating the spatial distribution of commercial fishing
- Determining the factors that influence recruitment strength, including timing, quantity and quality of Murray River flow regimes and surf diatom production
- Investigating the size distribution of Goolwa cockles with respect to distance from the Murray mouth, including collecting spatial information on the size/age composition of the stock
- Investigating the degree to which *Donax deltoides* populations in South Australia vary in spatial and temporal distribution and abundance
- Estimating the extent and pattern of recreational fishing
- In the longer term, as our knowledge of the population dynamics of this species along the Coorong ocean beach increases, consider such approaches as rotation of harvesting areas and creation of spawning stock refuges.

1. Background

1.1 Scope of Reporting

The South Australian Research and Development Institute, Aquatic Sciences (SARDI) conducts field-based stock, habitat and fishery assessment investigations into the health of South Australia's fresh and marine aquatic resources, as well as other operational and strategic research. As research adviser to Fisheries Policy group of Primary Industries and Resources SA and the Inland Fisheries Management Committee, (IFMC), SARDI has been contracted to provide stock assessment advice concerning the fishery resources of the inland waters of South Australia. The Goolwa cockle resource has been assessed against the objectives of the Fisheries Act (SA) 1982.

Goolwa cockles are commercially and recreationally harvested on the Coorong Ocean Beach (from Middleton to Kingston, Fig. 1). A formal management plan for the Lakes and Coorong Fishery, including Goolwa cockle, is currently being developed by PIRSA Fisheries. Detailed performance criteria for assessment are unavailable. This report discusses methods of assessment and some indicators that assist in addressing requirements under the Commonwealth Wildlife Protection (Regulation of Exports and Imports) Act 1982 (Schedule 4).

The biology and fishery of *D. deltoides* in New South Wales has been the focus of a major study (Murray-Jones, 1999). As there is little information available on the species in SA, some information from NSW has been included in this report, including comparisons between the harvesting patterns in SA and NSW.

2. Description of the Fishery

Beach cockles are considered an important fishery resource worldwide. Total reported beach cockle catches world wide are in the vicinity of 50,000 t per annum (reviewed by McLachlan et al., 1996), but for many countries and species, landing figures are unknown e.g. there is no estimated catch for *Donax deltoides* in this review. McLachlan et al. (1996) describes harvesting of beach cockle from every continent except Antarctica.

There is a significant commercial fishery in both NSW and SA, with small commercial components in Queensland and Victoria (Murray-Jones and Steffe, 2000).

Current management restrictions in the Goolwa cockle fisher include; a closed season (1^{st} June to 31^{st} October), a minimum allowable size of 35 mm across the largest axis of the shell. These restrictions apply to all sectors of the fishery. Limited area closures (applying equally to commercial participants) exist in the vicinity of beach access points, largely to protect fishers from conflict with other beach users. A bag limit of 600 animals was introduced for recreational fishers in July 2001.

In particular, there is little information available on landings outside the commercial sector, such as the extent of recreational and artisanal beach clam harvests worldwide. In general, beach cockles form substantial fisheries, with high recreational value due to the accessibility of the resource. There are still large gaps in the knowledge of the ecology and extent of fishing for beach cockles for almost every species.

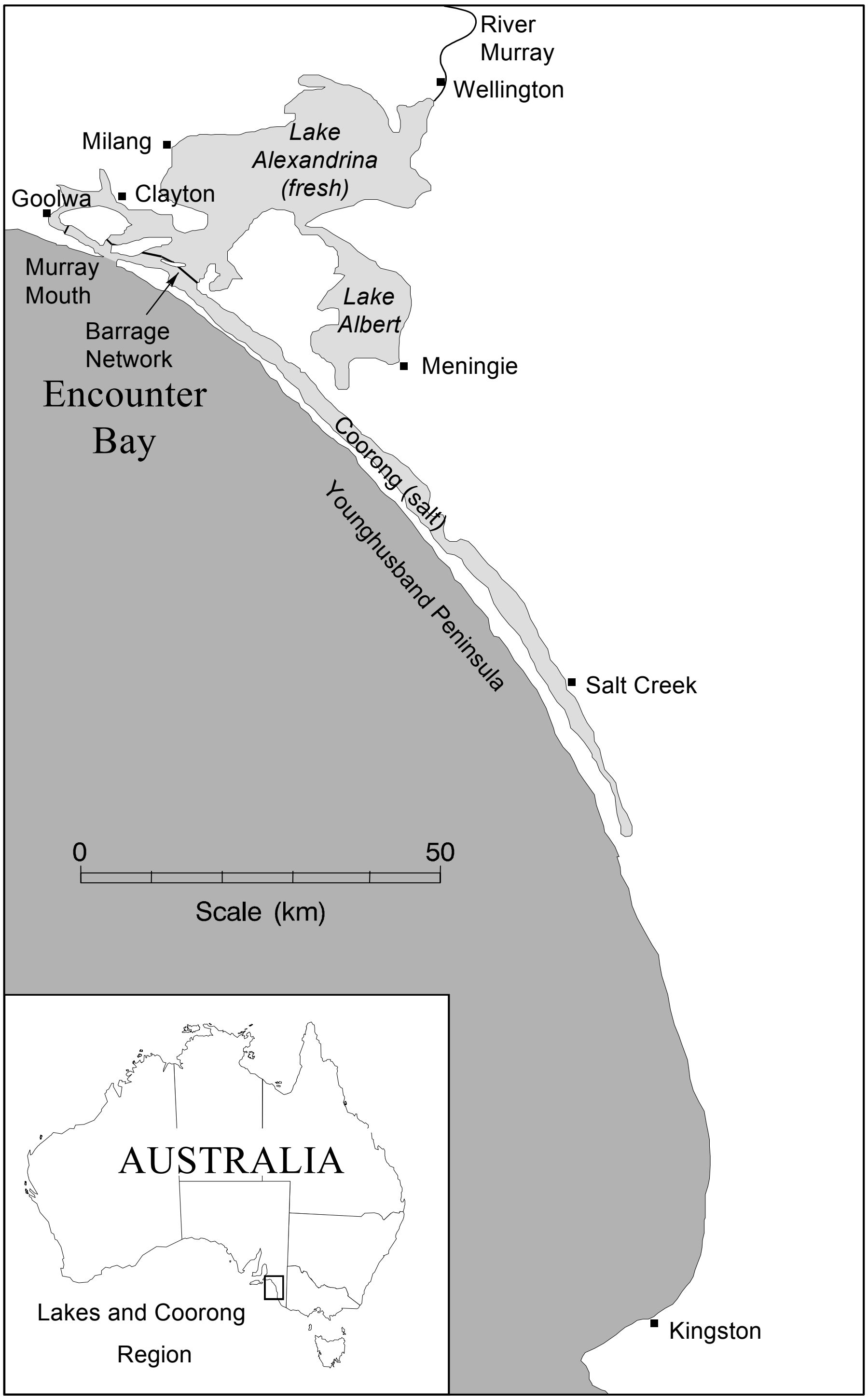


Figure 1. The Lakes and Coorong region (historic River Murray estuary) in South Australia. The Goolwa cockle fishery extends along the coastal beach frontage from Kingston northwards to approximately the limits of the map.

There is a substantial fishery in Australia for *Donax deltoides,* incorporating large commercial and recreational sectors. The combined harvesting from the Coorong Beach may well be one of the largest single fisheries of Donacid bivalves in the world. Recreational fishing for *D. deltoides* occurs throughout the range of the species distribution. Although recreational catch rates can be low, recreational effort can be extremely high, as reported for New South Wales by Murray-Jones and Steffe, 2000. In South Australia recreational fishers are allowed to use one cockle net or cockle rake to assist in taking the resource but are restricted to a daily bag limit of 600 cockles.

2.1 Traditional Fishery

Australian Aborigines have been harvesting *D. deltoides* for at least 10,000 years (Godfrey, 1989). The original inhabitants of the Coorong region depended on the Goolwa cockles for food and trade, particularly during the spring and summer (Luebbers, 1978). Middens in the vicinity of the River Murray mouth are composed almost exclusively of the shells of adult Goolwa cockles (Bourman and Murray-Wallace, 1991). The estimated population of more than 3000 inhabitants at this site represented Australia's largest permanent Aboriginal population (Jenkins, 1979), reflecting the productive capacity of this ecosystem. Traditional inhabitants have occupied the Coorong region for upwards of 16,000 years, and carry on through to the present time (Horton, 1994). Goolwa cockle stocks at this site have been subject to significant exploitation during this period, making estimation of "unexploited" virgin biomass inappropriate. Aboriginal fishers managed the Goolwa cockle and other natural resources through an integrated system of territorial use rights and verbally communicated rules. The descendants of traditional fishers do not currently possess independent artisanal or commercial access to the Goolwa cockle resource. Commercial access is available, as for all people, via the purchase of a commercial access licence. Personal consumption needs can be met within the parameters of the existing recreational fishing daily bag limits.

2.2 Commercial Fishery

The fishery for Goolwa cockles has been long established. Most cockles taken prior to World War II were used as bait by the collectors for other fishing operations rather than for direct sale. After World War II, an increase in leisure time and affluence led to a considerable increase in recreational fishing. This created a correspondingly high demand for Goolwa cockles as bait for finfish such as King George whiting (*Sillaginodes punctatas)*. At the same time, refrigeration technology improved both cost effectiveness and efficiency of transport, and subsequent sale of the cockle as either live or frozen product, for the recreational bait market.

The market for human consumption has not formed a significant proportion of the total harvest in Australia until relatively recently. Elsewhere in the world, Donacid bivalves are highly prized as food. However, the sand content in the animals and general lack of interest delayed the development of the human consumption market to any significant degree before the 1990s in South Australia. Australia's move to a highly multicultural society has seen large changes in the type of food consumed, and increasing interest in new food types. Demand for products such as beach cockles is growing rapidly, and is likely to increase further.

Fishing for cockles in South Australia has traditionally been permitted under several types of commercial fishing licence: (a) Lakes and Coorong; (b) Marine Scalefish; and (c) Rock Lobster (licence holders who retain marine scalefish access privileges and have licence endorsements for cockle rakes or nets). Thus, this single resource may be accessed by commercial fishers operating under three different schemes of management. Note, it is intended that fishery regulations will be revised to limit access in the MSF and Rock Lobster sectors to bait access for personal use only (discussed in relevant sections below). The harvest of Goolwa cockles is currently limited to capture using solely the hands and/or feet, or capture with the aid of a manually operated cockle rake/net. Consciously, the South Australian industry has developed a position that does not support mechanised harvesting of the Goolwa cockle. Similarly PIRSA Fisheries, under existing policy guidelines, does not support mechanised harvesting.. Restricting harvesting to physical/manual capture is seen as a means to limit the level of exploitation of the resource. Figure 2 shows a cockle "rake" being deployed. Cockles are dislodged using the feet, with the rake acting to catch cockles as they are carried seawards in the backwash of a wave. Cockle rakes and cockle nets are currently endorsed as separate device types (recreational fishers are allowed to use one such device). Only cockle rakes are currently defined within legislation, and no difference in construction or use is known between cockle rakes or nets. Nevertheless the gear restrictions act to limit effort levels.

2.2.1 Lakes and Coorong Fishery

The Lakes and Coorong fishery consists of 37 licence holders operating in the Lakes and Coorong region (See Fig. 1). This region is defined as being from the Wellington Punt (ferry) through Lake Alexandrina, Lake Albert, the Coorong estuary and extending seawards out to 3 nautical miles to include the ocean beaches from Kingston jetty northwards to the seaward extension of the Goolwa Beach Road. The history and broad functioning of this fishery have been described elsewhere (Hall, 1984; Evans, 1991; Olsen, 1991; Pierce, 1995). The fishery is regulated through both the South Australian Fisheries (General) Regulations (1984) and the Scheme of Management (Lakes and Coorong Fishery) Regulations 1991 and through conditions placed on commercial fishing licences. These regulations operate under the South Australian Fisheries Act 1982.

The sustainability and economic performance of the Lakes and Coorong fishery relies in part upon the capacity to shift effort across a diversity of species and habitats over time. When a particular resource is relatively unavailable, fishers are able to continue to maximise their returns through the harvest of other species without necessarily being forced to over-harvest a particular species. Goolwa cockles are an important component of this flexible, multi-species fishery. Other key target species include mulloway, yellow-eye mullet, European carp, flounder, callop and black bream. The fishery can take Goolwa cockles and other bivalves within the Suborder Teledonta, however to date this fishery has targeted only Goolwa cockles.

The Lakes and Coorong fishery is a limited access fishery with no additional licences currently being issued. Of the existing licence holders, only those with cockle capture devices endorsed on their licences are currently exploiting Goolwa cockles, however any licence holder could legally harvest cockles for bait if taken without mechanical aids (i.e. by hand/foot). Licensed gear endorsements became fixed circa 1984 (Evans, 1991), as a result of historic capture patterns and use decisions by individual licence holders at that time, and are not distributed equally throughout the fishery. Of the 37 licensed Lakes and Coorong fishers, 29 have endorsements for cockle gear. The licence holder is not permitted to operate with more than two additional agents. This means that an individual licence holder can operate no more than three Goolwa cockle capture devices at any point in time (ie licence holder plus two agents). Most fishers within the fishery operate with two devices actually fishing, and one person, commonly known as a "runner", transferring product into containers and onto transport vehicles or vessels. This is an owner-operator fishery, with a regulation specifying that the licence holder must be present during all fishing operations.

At present, the South Australian commercial fishers continue to be restricted to the use of manual fishing devices such as cockle rakes/nets to limit harvest efficiency. Harvest mechanisation technology exists however, habitat impacts, increased damage to undersized cockles, as well as

Figure 2. Goolwa cockle harvesting on the Coorong ocean beaches employing cockle rakes to land cockles floating in the backwash.

equity issues, currently preclude interest in the use of this gear type. In addition, there is anecdotal evidence from the 1950s and 60s in NSW to suggest that populations do not recover readily from intensive mechanical harvesting (Murray-Jones, 1999).

In South Australia, the fishery generally responds to the location of the cockles. Fishers seek aggregations of individuals clustered along the shore on the low tide cycle with most fishing undertaken during daylight hours. Peak concentrations shift along the beaches over the season. In recent years the commercial fishery has operated to the east of the Murray mouth. This is thought to be unrelated to a change in the distribution of the resource. Vehicular beach traffic along Goolwa Beach has increased in recent years. The traffic poses a risk of injury to fishers, particularly the "runner". Many of the fishers have transferred their fishing operations to the opposite side of the Murray mouth to reduce the likelihood of injury from vehicular beach traffic and because of the perceived impact on cockle distribution as a result of vehicular industry on Goolwa Beach.

Goolwa cockles have been shown to occupy a range of positions on the shore (Murray-Jones, 1999). They may be segregated by size across (i.e. down) the beach, aggregated along and/or across the beach, or they can be widely scattered. Sometimes, they tidally migrate (i.e. move up and down the beach with the tide, described by Ellers, 1995 for *Donax variabilis*), while on other occasions they will remain stranded on the shore as the tide goes out (Murray-Jones, 1999). These behaviours seem typical of surf bivalves everywhere (see Ansell, 1983; Ellers, 1995; McLachlan et al., 1996), although other species may not exhibit such extremes in behaviour at short spatial and temporal scales as *D. deltoides* in NSW and Queensland (Murray-Jones, 1999). Catch rates in NSW were very dependent on the position of aggregations on the shore (Murray-Jones and Steffe 2000). The behaviour and position of cockles on Coorong beach has not been well documented, thus there is little information available on temporal or spatial variation of the species position on the shore in South Australia.

Fishers in South Australia report that after storms, cockle aggregations are widely dispersed along and across the beach.

When fishing in South Australia, cockles are dislodged in the wash zone through foot action, and caught on the backwash in the relevant device (see Figure 2). Some fishers sieve catches higher on the beach on dry ground, onto a tarpaulin. It is recognised that this practice requires further development to ensure greater selectivity of legal sized cockles. Undersized individuals are generally returned to the water. A “runner” then conveys the legal size cockles into hessian sacks holding approximately 27-30 kg of cockles each. At the end of the day/tidal cycle, these bags of cockles are placed onto a purpose-built vehicle, or onto a vessel for transport to cool storage or on to markets. A recent value adding technique is to place cockles into a sand purging system for about 24 hours prior to marketing for human consumption.

2.2.2 Marine Scalefish Fishery

The Marine Scalefish Fishery (MSF) is regulated through both the South Australian Fisheries (General) Regulations (1984) and the Scheme of Management (MSF) Regulations 1982. These regulations operate under the South Australian Fisheries Act 1982.

A large, but capped, number of cockle fishing devices are endorsed to licence holders within the MSF. While relatively few MSF fishers presently choose to fish for significant quantities of Goolwa cockles from the Coorong beaches, all MSF licence operators have the legal right to employ their devices within the Lakes and Coorong Fishery. However, recent changes to regulations have imposed new restrictions. It is intended that only two MSF licensees will maintain access to Goolwa cockles for the purpose of sales and that all other MSF fishers will be restricted to bait access only.

For a history of the MSF and related issues/assessments see Jones et al. (1990) and Rohan et al. (1991).

2.2.3 Rock Lobster Fishery

The Rock Lobster Fishery is regulated through both the South Australian Fisheries (General) Regulations (1984) and the Scheme of Management (Rock Lobster Fisheries) Regulations 1991. These regulations operate under the South Australian Fisheries Act 1982.

The Northern and Southern Zone Rock Lobster Fishery historically operated as MSF licence holders with endorsements to take rock lobster. With the value increase of rock lobster associated with overseas export initiatives, the scalefish access privileges within this fishery were relatively less exploited. However, numerous rock lobster fishers have retained their MSF access through diverse gear endorsements. These licence endorsements include, in some cases, gear for the taking of Goolwa cockles. Only a small number of fishers in this fishery have actively pursued Goolwa cockles over the period of record beginning in 1983, based on mandatory reported catch records. It is intended, in the future, that rock lobster fishers will be restricted to bait access as with the MSF fishers (pers. comm., S. Sloan, PIRSA).

2.3 Recreational Fishery

The recreational fishery for Goolwa cockles on the Coorong beaches has been little investigated. Cierpicki et al. (1997) included cockles (all species, all sites) in a survey of recreational fishing; however, none of the 1116 people surveyed revealed any involvement in cockle harvest. Traditionally, recreational use of Goolwa cockles has been to collect bait for subsequent angling, however some fishers also harvest for human consumption.

Interviews and reports by local fishers also indicate that local residents do the majority of cockle fishing. Most fishers appear to be from Goolwa, Middleton and Port Elliot, where many have holiday homes in the vicinity (Sloan, pers.com.). This underpins the obvious peak in recreational cockle fishing observed from the beginning of summer school holidays until approximately the end of January each year, with additional fishing common around the Easter break.

This contrasts strongly with the pattern of recreational harvesting for *Donax deltoides* in NSW, one of the few places in the world where a direct comparison of commercial and recreational fishing patterns for beach cockles has been conducted (Murray-Jones and Steffe, 2000). For instance, on Stockton Beach, one of the major cockle harvesting sites in NSW, anglers collecting bait expended only 4% of the effort and took less than 2% of the catch. Of the combined recreational and commercial catch of 238 t in 1996/7, commercial fishers took 80%. However effort (fishing hours) was much higher in the recreational fishery compared to the commercial sector. This fishery is open to both sectors all year round and is limited to hand gathering.

Coupled with the highly multicultural nature of nearby Sydney and the increasing numbers of 4WD cars, which make beach access more readily available, the effort for food collection hass been a relatively recent trend. Eighty-five percent of the recreational effort is directed towards human consumption while within the commercial fishery this is only 11% of the effort (Murray-Jones and Steffe, 2000). Increasing effort for food collection has been a relatively recent trend. The majority of recreational harvesters on both Stockton and Seven Mile Beach were not locals.

Access is one of the key limiting elements in recreational beach cockle fisheries (McLachlan et al., 1996; Schoeman, 1996). In NSW, most effort occurs close to foot and 4WD access points (Murray-Jones and Steffe, 2000). Even people with recreational 4WDs did not usually venture more than a kilometre away from access points. Similarly for SA, the majority of recreational fishing occurs on the Goolwa beach side of the Murray mouth. Recreational access to the resource on the eastern side of the Murray mouth is limited. Management planning for the Coorong National Park (DEP, 1989) seeks to contain visitor access to defined points to protect waterfowl and the environment. As a result, the primary access point for cockle fishing east of the Murray mouth is at the South Australian National Parks and Wildlife Service boardwalk, in addition to access closer to Kingston. Natural limitations including remoteness, large seas and a steep beach are contributing factors to reduced access to the eastern beaches.

As is the case with the commercial sector, recreational fishers are restricted to the use of a single cockle harvest device (e.g. cockle rake), but may collect without gear. A bag limit (n=600) on the daily recreational harvest of Goolwa cockles has recently been imposed statewide (SA Recreational Fishing Guide, July 2001, p28). Such a limit is a form of precautionary management, but also allows a clear distinction to be made between legitimate recreational use and illegal "black market" activity. At the same time, it facilitates equitable sharing of the resource. NSW has a daily bag limit as well, although at 50 animals per day it is far lower than the SA limit (Lynch and Prokop, 1993). This reflects the difference in the size of the human populations in Sydney and Adelaide and the potential level of recreational exploitation. No size limits or seasonal closures apply in NSW.

2.4 Poaching

Illegal harvest for sale of Goolwa cockles is known to exist, even though few compliance matters have been recorded with respect to this species. Individuals have been observed collecting cockles on Goolwa and Middleton Beaches in November, during the closed season (B Pierce, pers comm.). The participation and level of harvest derived from this illegal activity has not been quantified, but is likely to represent an additional and unregulated mortality. The growing popularity of this species for human consumption may also see an increase in illegal activity and managers need to be aware of this.

2. 5 Undersized catch

Taking of undersized Goolwa cockles remains an issue in both the recreational and commercial fisheries. Although taking of cockles by hand or with cockle nets should provide a selective mechanism for grading, a large number of individuals are typically taken per unit time. The mesh of the cockle nets become clogged with larger animals and undersized animals are inadvertently trapped within. Assessment of the numeric abundance of undersized animals from a pilot sample of commercial harvest taken during the 1999/2000 season, as well as examination of a number of recreational fishers, indicated that while the proportion of undersized individuals in the catch varied markedly, it was less than 14%. In the 2000/01 season PIRSA Fisheries compliance reported that in some catches the proportion of undersized cockles in the catch reached as much as 50% of the total number.

2.6 Other sources of mortality

2.6.1 Predation

Natural mortality for this species is known to be high (King, 1976). The survival of individual cockles from year to year may be estimated from the relative decline in the presence of that size class or mode in the overall stock. King (1976) found that Coorong beach cockles seldom survived more than approximately 3.5 years and reached an approximate maximum size of 60 mm, with indications of survival several years beyond that evident for Coorong stocks. Stocks of cockles found in NSW grow to 80 mm, however due to problems such as irregular and/or protracted pulses of recruitment and the difficulties of sampling, no mortality figures are available for NSW (Murray-Jones, 1999). Cockles are subject to predation by diverse water birds, various rays, beach worms and sand crabs (Dakin, 1980; Jones, 1995).

2.6.2 Freshwater Flows

Freshwater outflows when released in large volumes may cause considerable mortality of Goolwa cockles along the Coorong and Goolwa beaches. Freshwater outflows may also be beneficial to Goolwa cockles, providing a significant food source through nutrient loading and may provide a cue for spawning; however, this is an opportunity for future research.

With the establishment of the Murray lakes barrages around 1940, outflow events and particularly the initial and final outflow profiles have become relatively more abrupt and unpredictable. When the barrages are opened and outflows occur, a large quantity of water is released over a short time frame. Murray mouth outflows often swirl out to sea before returning back inshore. These freshwater inflows can trap considerable cockle resources, which may die (King, 1976). A mass die-off of cockles was recorded in 1984, when an estimated 2.5 million cockles were found dead on the area of Goolwa beach west of the Murray mouth (Clarke, 1985). The most probable cause of mortality was attributed to reduced salinity. The majority of the dead cockles were adults, rather than juveniles. Furthermore, not all apparent cockle mortalities associated with freshwater outflows through the Murray mouth are necessarily Goolwa cockle mortalities. During an artificially managed outflow event in November 1998, considerable numbers of small cockles were observed dying near the Murray mouth. Subsequent examination revealed them to be species of the genus *Mactra*.

Not all freshwater outflows through the Murray mouth cause cockle mortalities. A better understanding of the influence of freshwater outflows on Goolwa cockle populations and their biology is essential for future management of the resource.

2.6.3 Protracted calm/hot weather

Mass mortalities of Goolwa cockles have also been observed in association with extended periods of still calm conditions during the heat of summer (Anon., 1985). Cockles living along high energy beaches typically experience conditions in which oxygen levels remain consistently high. Laboratory experimentation has indicated that Goolwa cockles begin to suffer significant levels of mortality when oxygen tensions decline below 5.0 mg/l at 17°C; however, LC_{50} data are still in preparation (B. Pierce, K. Hand, unpublished data). Cockles may also be trapped in shallow pools as the tide goes out. On hot days, the temperatures in these pools are enough to kill cockles (pers. obs., Murray-Jones).

2.6.4 Winter Mortality

The extent of winter mortality of Goolwa cockles associated with beach erosion is unknown. Adult cockles are very resilient to high wave energy and erosional forces, although small animals may be less likely to survive. For example, in 1996 a severe storm occurred on the NSW central coast, with 18 m waves recorded at Cronulla, NSW (NSW Fisheries Wave Recorder data, Aldo Steffe, pers. comm.). Well over one metre of sand was stripped off the entire face of Stockton Beach, however the densities of adult cockles were not affected, although the numbers of small cockles were reduced (Murray-Jones, 1999).

2.6.5 Pollution

Most bivalves are sensitive to significant reductions in water quality as both larvae and adults. Haynes et al. (1995) found spatial and temporal variation in the concentration of heavy metals in Goolwa cockles in Victoria. A shellfish quality assurance monitoring program for the Coorong region commenced in the fishery during 2001 in order to monitor the suitability of cockles for human consumption.

Figure 3. Goolwa cockles undergoing sand purging. Note the typical green algal coating on 1+ animals whereas 2+ cockles usually have shells which are polished cleaner.

3. The Resource

3.1 Goolwa cockles

Phylum: Mollusca
CLASS: BIVALVIA
Subclass: Heterodonta
Order: Veneroida
Suborder: Teledonta
Family: Donacidae
Genus: *Donax*
Species: *deltoides*

Donacid cockles are adapted for life on high energy sandy beaches. Only six species of the family Donacidae are found in Australia, and of these *Donax deltoides* is by far the largest. It is the most common large bivalve living in the surf zone of ocean beaches in Australia (Dakin, 1980). The population in the Coorong region probably represents the largest single stock abundance of this species throughout Australia (King, 1976). Other stocks occur on high energy beaches from Southern Queensland around to South Australia, in small to large numbers depending on many factors, such as type, width, length and slope of the beach, sand grain size, wave regime, food supply and freshwater outflows.

3.1.1 Stock Structure

Murray-Jones and Ayre (1997) found no genetic differentiation between populations of *Donax deltoides* over 1200 km of coast, from Fraser Island, Queensland to southern NSW. Thus this species can be considered as a single stock on the east coast of Australia. The Coorong beach populations were not included in this survey. The very different current regimes in southern Australia make it likely that South Australian populations form a separate genetic stock to east coast populations. This differentiation is an opportunity for future research.

3.1.2 Distribution

Goolwa cockles typically inhabit the wash zone at high tide, filtering surf diatoms from the water column (McLachlan and Hesp, 1984). The genus is known for its partial or full tidal migrations, where cockles actively emerge from the sand and use the surf to relocate up or down the beach as the tide changes (Ellers, 1995; also see review in Murray-Jones, 1999). Cockles are vertically orientated in the sand, and can rapidly rebury after disturbance (Ansell and Trevallion, 1969; Donn and Els, 1990; Ellers, 1995). In South Australia, maximum abundance is typically attained just below the low tide level and juvenile organisms live at higher levels than larger animals (King, 1976). In NSW, the largest *D. deltoides* were often found subtidally, with juvenile animals most likely to be in the swash zone (i.e. that portion of the beach that is intermittently washed by waves, and always covered with a film of water). Other sizes were equally likely to be stranded, in the swash, or subtidal at low tide (Murray-Jones, 1999). Fishers in SA report that cockles will migrate up and down the beach in response to storm surges and also with the seasons. Patterns of distribution of sandy beach fauna have been shown to vary in time and space (e.g. Braziero and

Dafeo, 1996; Donn, 1990; James and Fairweather, 1996; Jaramillo et al., 1994), particularly donacid cockles (reviewed in Murray-Jones, 1999).

Goolwa cockles can bury up to 10 cm deep in sand, however the majority of individuals are typically buried 6-8 cm deep (Anon., 1985). The diatom *Asterionella* is the main food for Goolwa cockles in this population (King, 1976), and blooms of this diatom commonly form brown patches in the surf zone of Goolwa Beach in summer (McLachlan and Hesp, 1984).

3.1.3 Age/Growth/Reproduction

Maximum size known for Goolwa cockles is approximately 80 mm (Willan, 1998), although animals from the Coorong typically do not exceed 60 mm (King, 1976). Adult cockles have separate sexes, producing planktonic veliger larvae that probably reside in the water column for 6-8 weeks. Fertilisation in this species is external, and sex ratios are 1:1 (Murray-Jones, 1999). Goolwa cockles mature at approximately 13 months of age, and at around 36 mm shell length (King, 1976). This is remarkably consistent throughout the range (Murray-Jones, 1999).

King (1976) indicated that reproductively mature adult cockles are present throughout the year, and have several spawning peaks. This is consistent with data from NSW, which also showed that partial spawning was common (Murray-Jones, 1999). In SA, peak population spawning activity is said to be in September-October of each year (King, 1976; Anon., 1985). However, examination of King's data (illustrated in King, 1995 and reproduced in Fig. 4), shows a single peak of juveniles in January of 1973, an inferred peak in January 1974 (no January sample collected), followed by almost continuous recruitment between April and September 1974. In a six year study in NSW, recruitment of juveniles was almost continuous (Murray-Jones, 1999). The timing of settlement peaks on NSW beaches did not appear to be linked to peak river flows, and varied among years in the same manner as shown in Figure 4.

Whilst there are no data on the fecundity of Goolwa cockles for South Australia, large natural fluctuations in abundance are a feature of surf clam (cockle) populations worldwide (eg. Coe, 1955; McLachlan et al., 1996). This has been demonstrated for NSW populations of *D. deltoides* (Murray-Jones, 1999). King (1976) considered that wide population fluctuations in this species were probably driven primarily by natural fluctuations in wind or associated hydrologic conditions during the larval phase, rather than fishing pressure or catastrophic mortality of adult cockles. In NSW an almost constant recruitment onto the beach over the course of a five year study suggested that larval supply was not limiting. Mortality of juvenile cockles was extremely high, and only periodic pulses of juveniles survived to establish a definite year class (Murray-Jones, 1998; 1999). Since only two adult year classes are generally present in Goolwa region cockle populations, the relative importance of the contribution of each to the harvest is higher than would be the case in longer-lived stocks. Variation in recruitment of juveniles into the fishery will have only a short lag (1-2 year) before impacting the harvest.

If growth rate is influenced by food supply and the quantity of freshwater outflows then it is likely that the growth rate of Goolwa cockles is likely to vary along the Coorong ocean beach. However research is required to address this question.

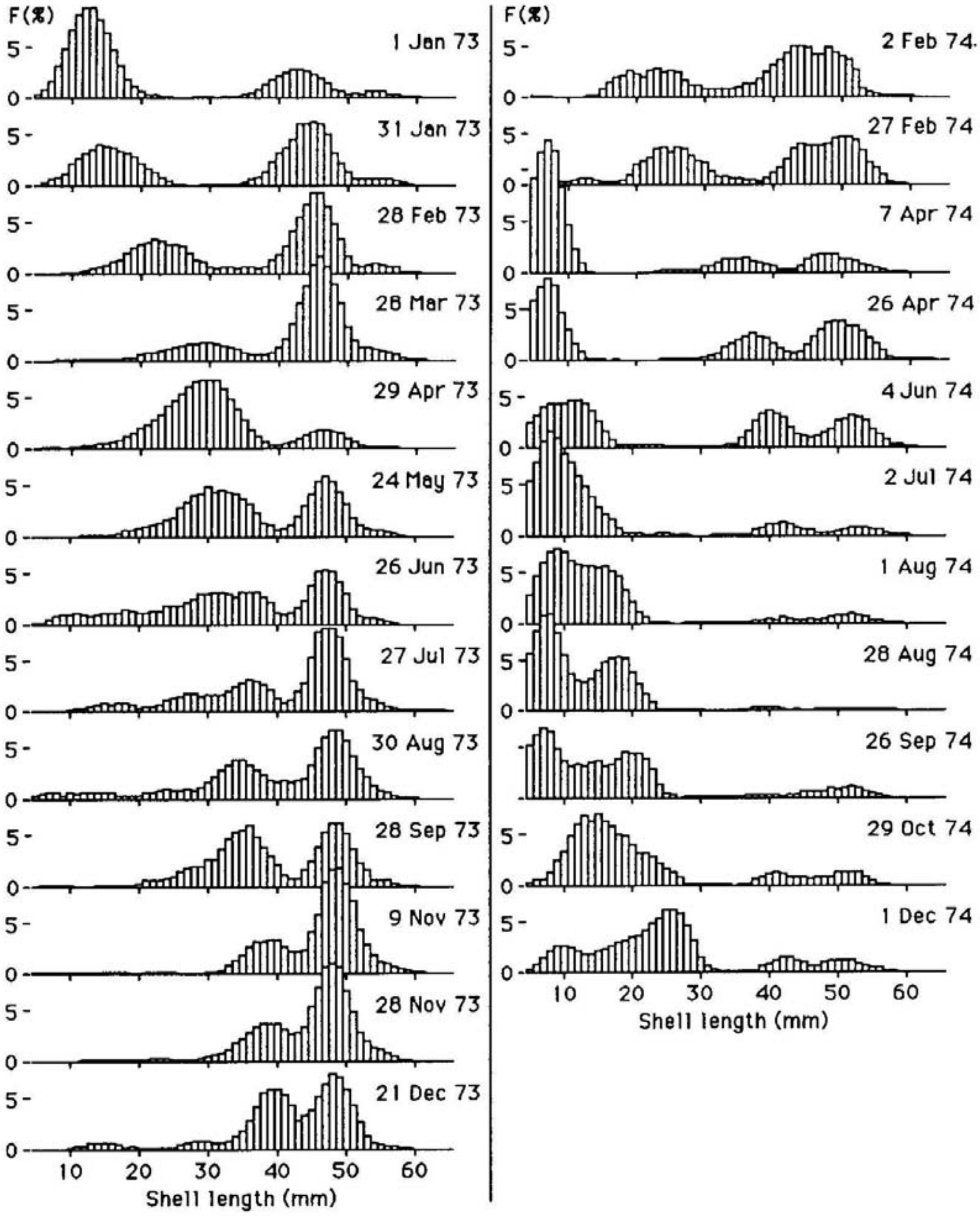


Figure 4. Length-frequency distributions of *Donax deltoides* from the Coorong Beaches (sample size varies between 176 and 712 per event, after King, 1995

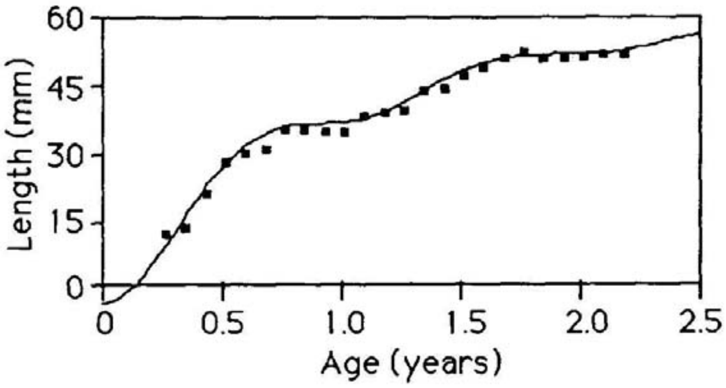


Figure 5. Growth curve for Coorong Beaches *Donax deltoides* (after King, 1995).

3.1.4 Tolerances

The physiology of *D. deltoides* has been little studied, although the genus has attracted considerable attention (e.g. see McLachlan and Erasmus, 1983). Goolwa cockles can tolerate salinities ranging from 20 to 45 ppt (Nell and Gibbs, 1986). Unpublished experiments (Pierce) showed that Coorong beach cockles react to freshwater dilution by withdrawing their siphons and closing. 52% of individuals re-open at 28 ppt after 25 minutes, but only 12% will re-open below 20 ppt after the same period (at 18°C). Re-opening is significantly delayed when freshwater is present, compared to simple disturbance-induced closure. Increasing delays in re-opening were observed with increasing freshwater dilution levels. Extended low salinities may then result in mortality due to starvation or muscle fatigue (Clarke, 1985; King, 1976).

3.1.5 Productivity

King (1976) estimated that the wet meat yield was maximised in this population at between 40 and 44 mm maximum shell length, which equates to an age of 15 to 17 months. The species is highly fecund with an almost continuous spawning period, so it should be capable of recovery from periods of extremely low stock abundance. On Seven Mile Beach, NSW, despite an apparent lack of sexually mature cockles, there was no evidence of depressed recruitment to the beach. However in this situation, despite nearly continuous recruitment, the adult population did not recover within the six year time scale of the study (Murray-Jones, 1999).

4. The Ecosystem

The current Coorong beach morphology effectively formed during the Late Pleistocene and early Holocene sea level rise (6600BP) that drowned the former, lower River Murray estuary (Barnett, 1994). Transport of shell sediments (especially *Donax*) appears to have led to the formation of the Sir Richard and Younghusband Peninsulas that constitute the frontal dunes immediately behind the Coorong beaches (de Mooy, 1959; Bourman and Murray-Wallace, 1991). River Murray outflows have some impact on beach and Murray mouth dynamics; however, wind, wave, and tidal processes predominate. During spring and summer, winds tend to be from the south east to south west with resultant long shore movement. During winter, south west to north west winds significantly shift the direction of beach migration (Edyvane and Carvalho, 1995). These processes are particularly important relative to the dynamics of larval transport in the system. The entire coastline, which constitutes Encounter Bay, is a high-energy system subject to year-round moderate to high-energy south west swells.

During the winter months, considerable erosion occurs, moving beach sand offshore into a series of sandbars running parallel to the beachfront. During this period, gutters running between bars can erode down to hardened shell grit substrate that is unsuitable cockle habitat, since the animals cannot bury in it. During summer, beach sands are carried back shoreward and sand depths rebuild in the range of 1.5 metres. As a result, where winter waves work against the front of the dunes, summer beaches may be typically 30 metres wide.

Donax deltoides reaches maximum abundance on high energy, dissipative beaches. Goolwa/Coorong Beach is one of the few truly dissipative beaches in Australia (Wright and Short, 1983), and is a very long beach. Hence the stock abundance of Goolwa cockles at this site is likely to be very high. Accumulations of surf diatoms are characteristic of dissipative beaches, and provide food for infaunal bivalves. Blooms of *Asterionella* sp. are common on Goolwa beach (McLachlan and Hesp, 1984), and are thought to be the principle source of food for Goolwa cockles (King, 1976).

In SA it is likely that River Murray outflows underpin elevated primary production of phytoplankton, particularly *Asterionella* sp. (McLachlan and Hesp, 1984) and allow high densities of *D. deltoides* to be reached. Average chlorophyll *a* values in ocean waters in the vicinity of the Coorong have been shown to be 0.2-0.3 mg/m^3 (Commonwealth of Australia, 1996), while during spring, Geddes (1984) recorded peaks of over 70 mg/m^3 in Lake Alexandrina.

5. Assessment

5.1 Commercial fishery

Commercial harvest, recorded in kilograms live weight, is the total resource taken by commercial fishers and does not include undersized individuals which are discarded. For ease of reporting, the terms “harvest” and “catch” will be used synonymously in this report.

Although Goolwa cockles are found on surf beaches on the west coast of South Australia, they are not present in commercial quantities. In the past some catch returns have been coded as “Goolwa cockles” in different areas of the state, but have been miscoded and are generally mud cockles. The commercial Goolwa cockle fishery is currently operating in the Coorong region only. Hence, while the figures are presented below as total Goolwa regional catch, they are also the entire SA commercial harvest at this time.

Due to differences in reporting and data collection, as well as issues of confidentiality, details vary among the data sets presented below. Not all types of data were collected for all years (e.g. daily data are not available for all fishers in all years). In presenting commercial catch and effort information, researchers are limited by restrictions on reporting of absolute figures where data concern five or fewer licence holders. Where less than five fishers are included, values for catch, effort and CPUE are not shown, however trends are still apparent. The main focus of this report is the total catch of cockles from this region, hence figures have been combined for the Marine Scalefish fishery and the Lakes and Coorong fishery except for mean daily catch figures. Also because there is little differentiation between gear types, and no data on the relative efficiency of gear, data are combined across all gear types. The collection of commercial fishing data commenced in 1976/77, and data sets prior to 1990 may be incomplete.

5.1.1 Commercial Catch

Total annual reported cockle catches for the total commercial fishing sector in the Goolwa region are shown for each financial year (Fig. 6). There has been a rapid expansion of the fishery since the late 1980s. Catches peaked at 1241 t in 2000/1, and have been substantially higher in the last four years than previously. Annual catch data show a pattern of increasing catches through the late 1980s and early 90s. Recorded catch data show a smaller peak of 1108 t in 1979/80. This was the maximum harvest recorded for the species in Australia until 2000/01. No effort data are available prior to 1983/4, and the catch data prior to this date may also contain inaccuracies.

Daily catch data are available for the majority of fishers for differing periods. These have been summarised for the L&C sector (Fig. 7), and the MSF sector (Fig. 8) separately, in order to determine if there are differences in the fishing patterns of these fisheries. Data points represent the mean of daily catch totals (± SD) for each month. Number of days fished varied between months and years. Both sectors show very high variability in the weight of cockles taken per day. Some months, e.g. November 1999 in the L&C sector, showed very low mean daily catches. However catches were higher in this month in the MSF sector, where the mean daily catch was lowest in May 1999. Both sectors recorded the highest mean daily catches in 2000/1, in February in L&C, and December in MSF. Note that in all cases the variances are high, reflecting differences in effort, individual fishers’ skills, targeting practices (for food or bait), location and availability of the resource.

5.1.2 Commercial Effort

Data are collected in both fisher days and "licensee days" (which combine the effort of all fishers under one licence for a given day). Fisher days are a more sensitive indicator of effort, and have been used throughout this report, however neither measure is particularly informative. The maximum number of fishers deployed under one licence at any time is three, although generally only two are actually fishing. Precise information is not provided in either set of figures of how many people were actually fishing. Similarly, time travelling to and from the site is included in effort estimates, as is time spent grading, sieving or sorting. These activities are likely to vary greatly among fishers, and depend upon local distribution, abundance and behaviour of the cockles, as well as other factors such as wave height and weather conditions. Fishers report that the majority of fishing occurs on an outgoing-incoming tide, thus allowing an approximate five hour fishing window per fishing day.

Total annual figures are presented in fisher days per financial year (Fig. 9). Annual effort patterns are similar to catch patterns, although 1999/2000 was the year of highest effort at nearly 4000 fisher days. Effort rose over the 1980s and early 90s, was fairly stable throughout the 90s, then rose steeply in 1999/2000 and was still relatively high in 2000/1 at 3539 fisher days.

Mean daily estimates of effort for the two sectors are shown in Figures 10 and 11. Again variances are high, reflecting the fact that different numbers of people fish on any given day. Despite daily variation, the average mean daily effort for each month for the MSF sector has been more consistent over time than L&C effort (Figure 11). Mean daily effort in the L&C sector varies more between months. No clear trends are apparent in terms of mean daily effort on a monthly basis. In some years effort is highest at the end of the season, in others over summer, however over the last three financial years, effort tends to be lowest in the last month of the fishing season, May. L&C fishers shift their effort between targeting between bait supply and human consumption. This may explain the higher variation in catch rates compared with the MSF sector.

There were approximately 15 Lakes and Coorong licensees and six Marine Scalefish licensees actually active in this fishery in the 2000/2001 licensing year. However up until January 2000, only two MSF licensees were active in this fishery.

5.1.3 Catch per Unit of Effort (CPUE)

Catch per unit effort (CPUE) here represents the harvest rate, i.e. the total weight of cockles taken off the beach per unit time. It does not include undersized animals returned to the water. The correct estimator of catch rates for data generated from completed fishing trips is the ratio of means, i.e. mean catch/trip length (Pollock et al., 1994). CPUE estimates described below have been calculated in this manner.

CPUE varies among years in this fishery (Fig. 12). Catch rates were high between 1992/3 and 1997/8, peaking in 1997/8 at 368 kg per fisher day. Catch rates have been consistently over 300 kg per fisher day since 1992/3 until 1998/9. The catch in 1999/2000 was 270 kg per fisher day, the lowest since 1991/2. Catch rates declined steadily between 1997/8 and 1999/2000, however recovered in the last financial year to 350 kg per fisher day.

Mean daily catch rates vary greatly for the L&C sector (Fig. 13), particularly between 1999 and 2001. CPUE varied between 657 ± 183 kg per fisher day in December 1996 to 128 ± 90 kg per fisher day in May 1999 in the L&C sector.

CPUE in the MSF sector is more stable from month to month. Catch rates were high in early 1999, but have been consistently lower since May 1999 (Fig. 14).

In both sectors, CPUE was lowest in May 1999, and was very low for the last few months of the 1999/2000 season. CPUE increased strongly towards the end of 2000/01. High variations in CPUE are recorded, indicating very large differences in catch rates on a day to day basis.

5.1.4 Value

The market value of the SA Goolwa cockle harvest increased markedly in the 1999/2000 financial year, reaching a total of $1,684,000 (Fig 15). This reflected a 77% increase on the previous year's value of $953,000, driven by an increase in both market price per kilogram, and the total catch. The Goolwa cockle is now the most important species in the Lakes and Coorong fishery in terns of value and production. No estimates of farm gate value or added value exist. The only known value-adding carried out is purging the animals before selling for human consumption. The mean market price is obtained by dividing the total value by the total weight of the harvest for each year. Trends in mean price indicate that prices fluctuated markedly in the 1980s, when catches were relatively low. The mass die off mentioned previously may have been the reason why catches stayed relatively low during the 1980s, while limited numbers on the market may have led to price increases. The mean price of the catch was relatively stable throughout most of the 90s, but rose steeply in 1998/9 and 1999/2000. Mean market price was less than $1 per kilogram throughout the 1990s, increasing to $1.55 in 1999/2000. Data for 2000/01 give a mean market price of $1.12; however, the overall value was the record highest ($1.406 million) due to the highest ever reported Goolwa cockle harvest in this period.

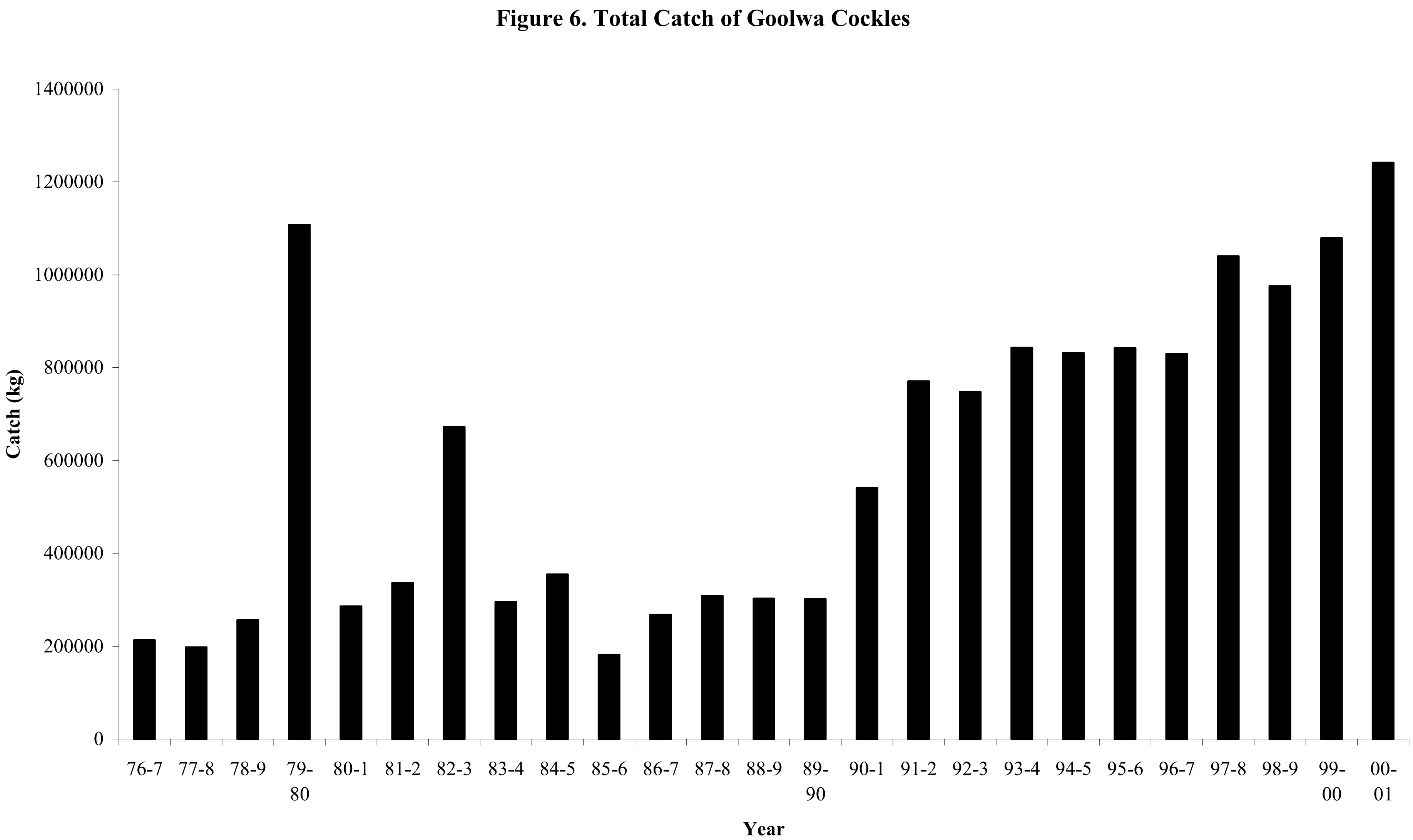


Figure 6. Total annual commercial catch in kilograms for Goolwa cockles from the Goolwa region, all fishers, all sectors and all gear types combined. Years are financial years.

Figure 7. Mean Daily Catch of Goolwa cockles, Lakes and Coorong Sector

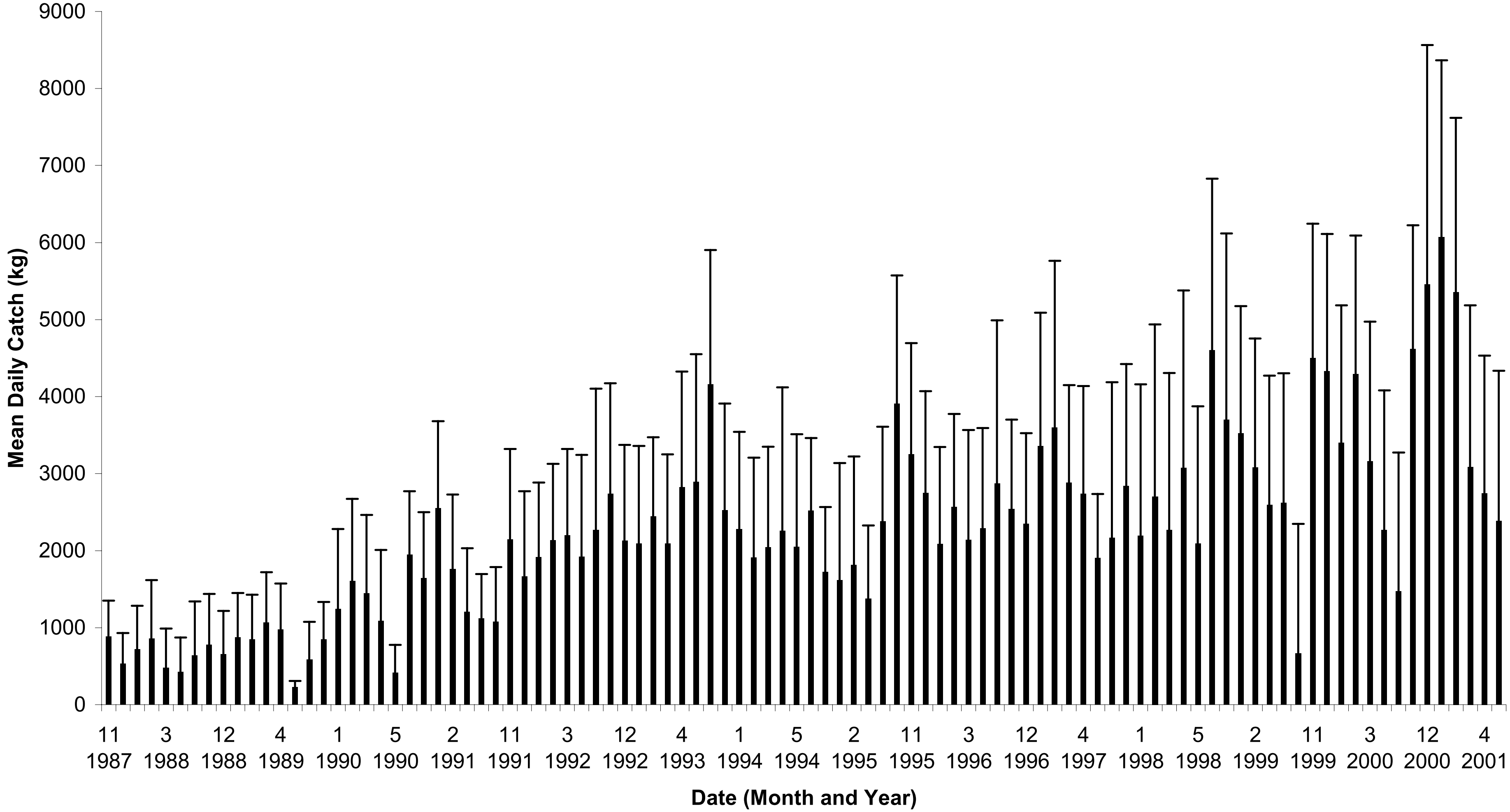


Figure 7. Mean daily commercial catch (± standard deviation) in kilograms for Goolwa cockles from the Goolwa region, Lakes and Coorong Sector. Only fishers for whom daily data are available have been included. Data points represent the mean of all daily catches for each month.

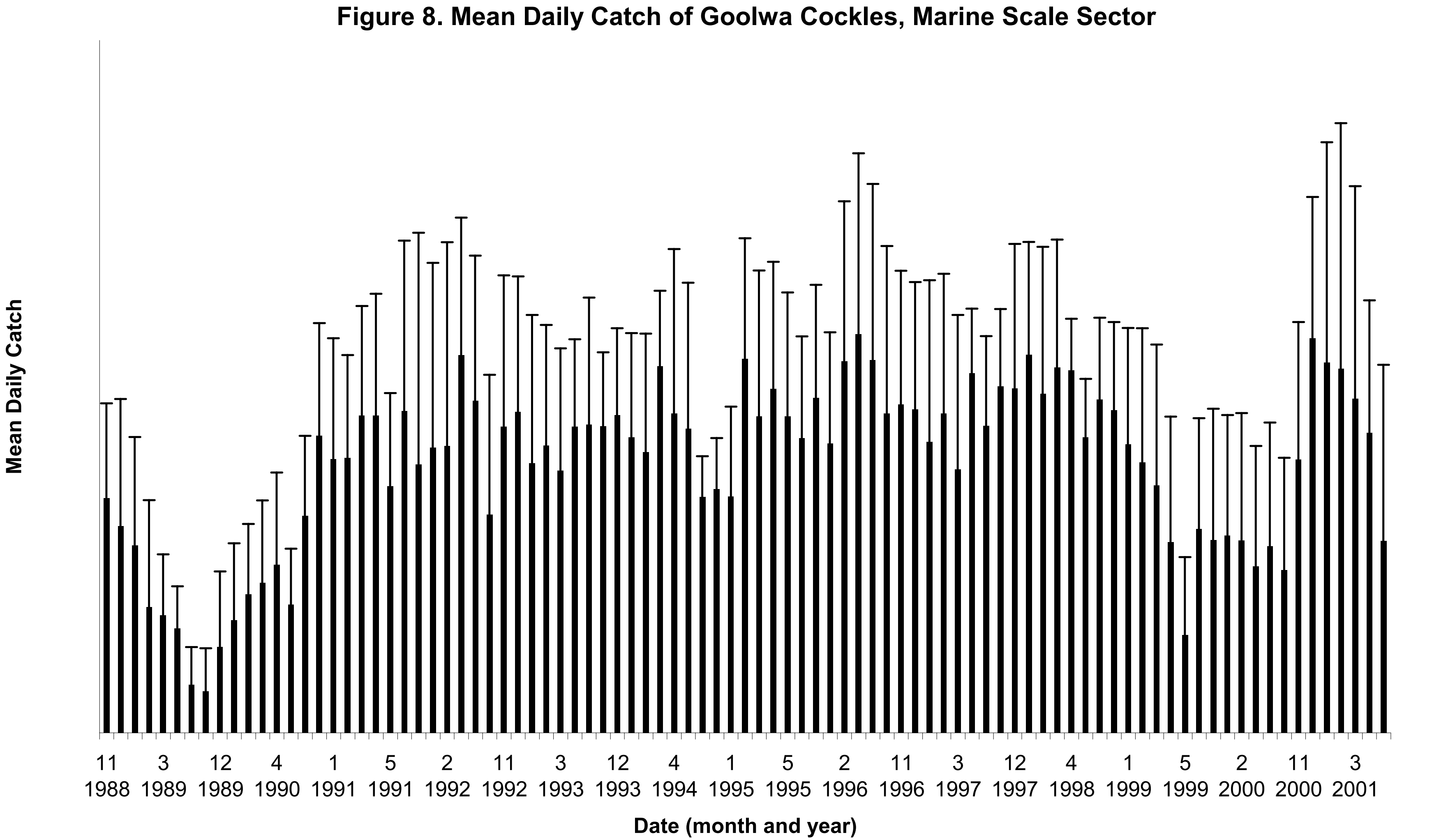


Figure 8. Mean daily commercial catch (± standard deviation) for Goolwa cockles from the Goolwa region, Marine Scale Sector. Data points represent the mean of all daily catches for each month. As the number of fishers in this sector is generally <5, catch values have been removed.

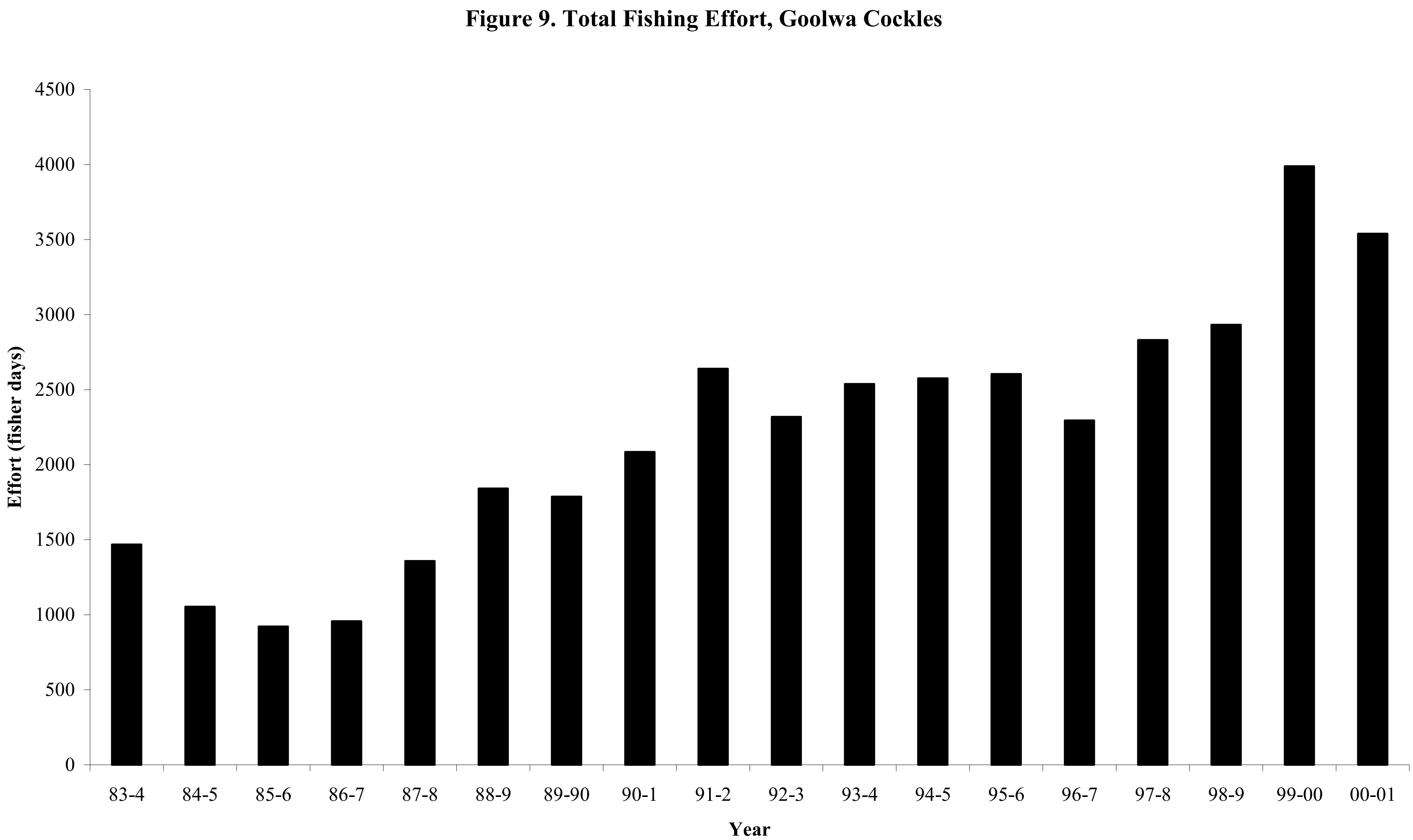


Figure 9. Total annual commercial fishing effort in fisher days for Goolwa cockles from the Goolwa region, all fishers, all sectors and all gear types combined. Years are financial years.

Figure 10. Mean Daily Fishing Effort for Goolwa Cockles, Lakes and Coorong Sector

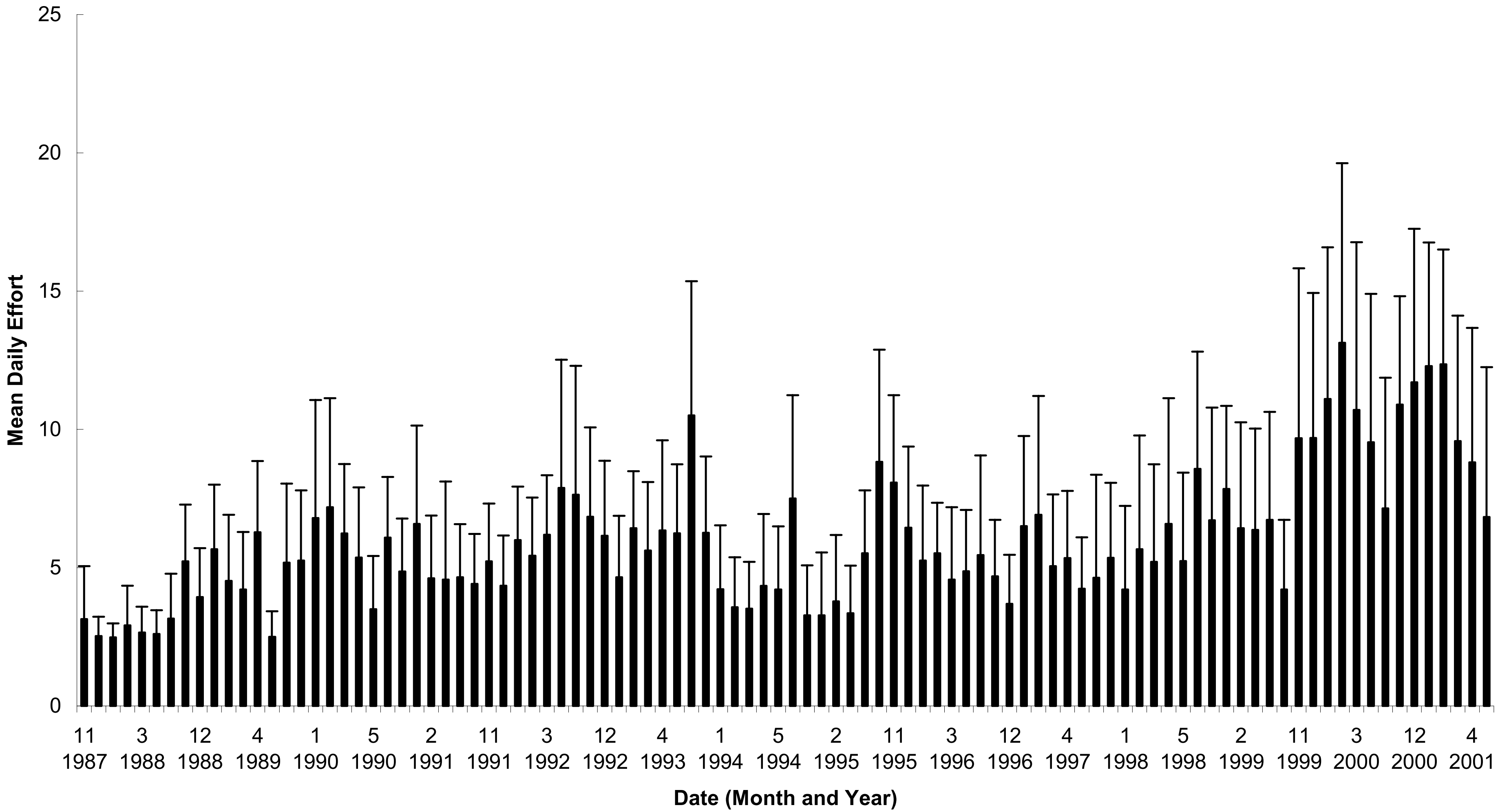


Figure 10. Mean daily commercial fishing effort (± standard deviation) in fisher days for Goolwa cockles from the Goolwa region, Lakes and Coorong Sector. Only fishers for whom daily data are available have been included. Data points represent the mean of daily effort figures for each month.

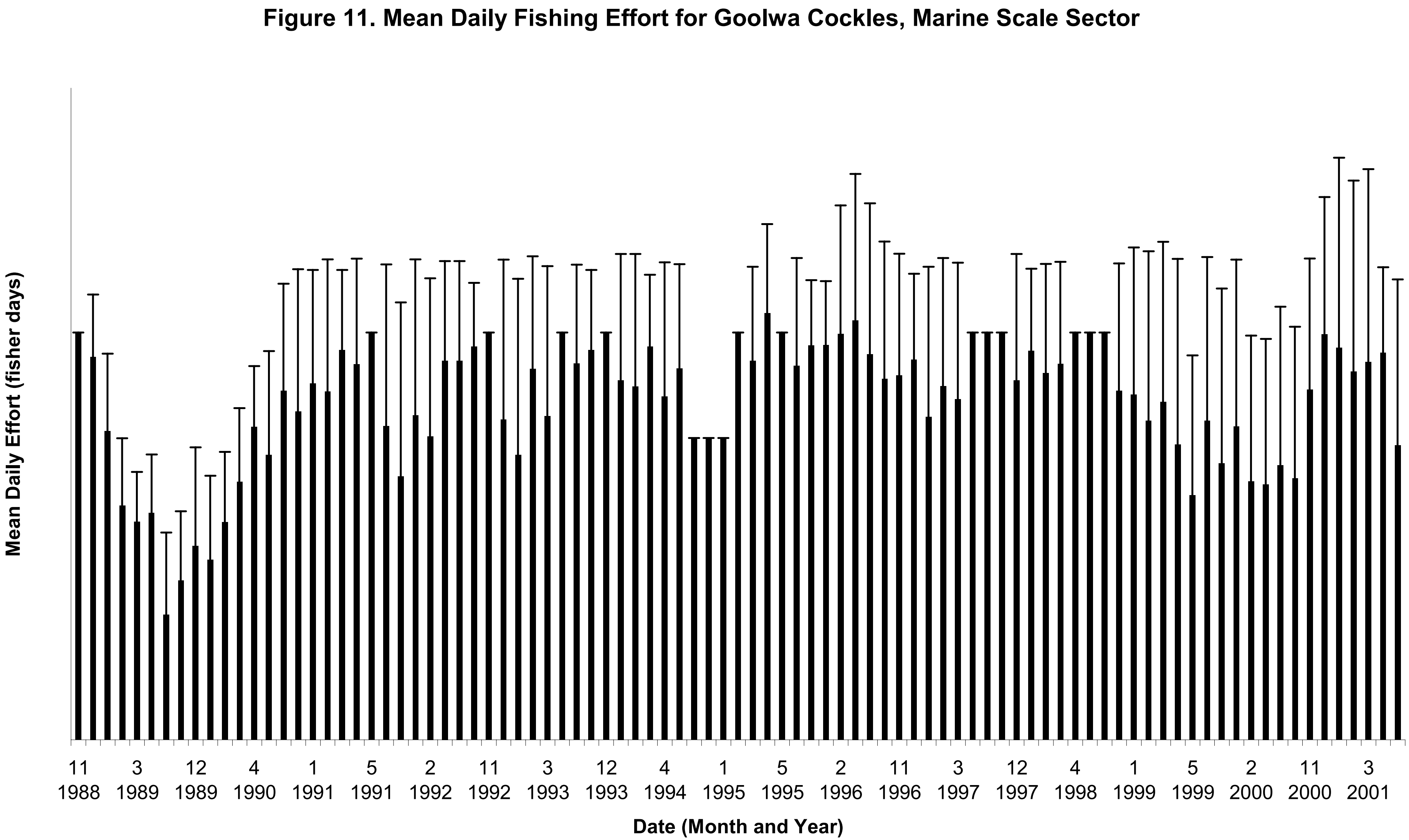


Figure 11. Mean daily commercial fishing effort (± standard deviation) for Goolwa cockles from the Goolwa region, Marine Scale Sector. Data points represent the mean of daily effort figures for each month. As the number of fishers in this sector is usually <5, effort values have been removed.

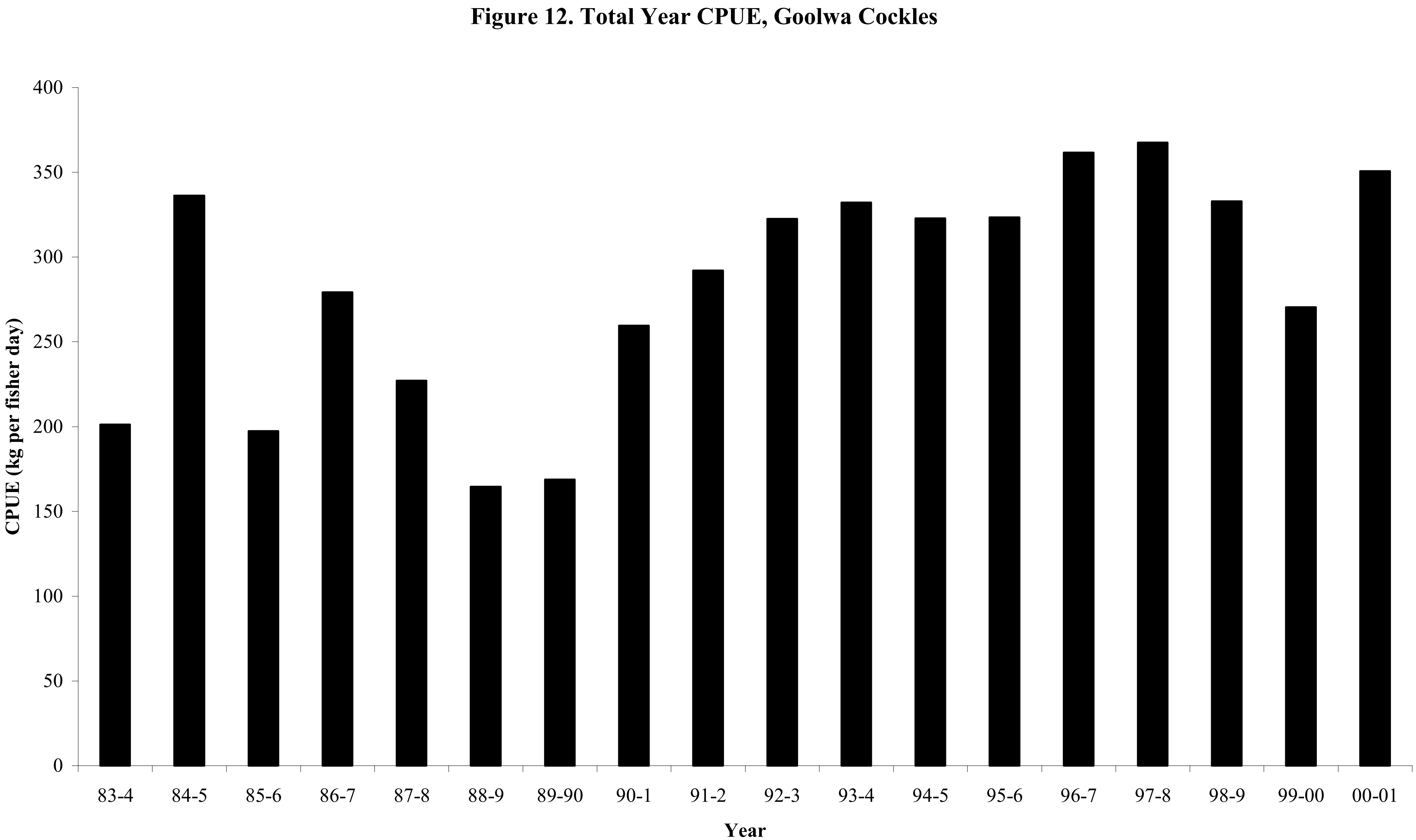


Figure 12. Total annual commercial catch per unit effort in kilograms per fisher day for Goolwa cockles from the Goolwa region, all fishers, all sectors and all gear types combined. Years are financial years.

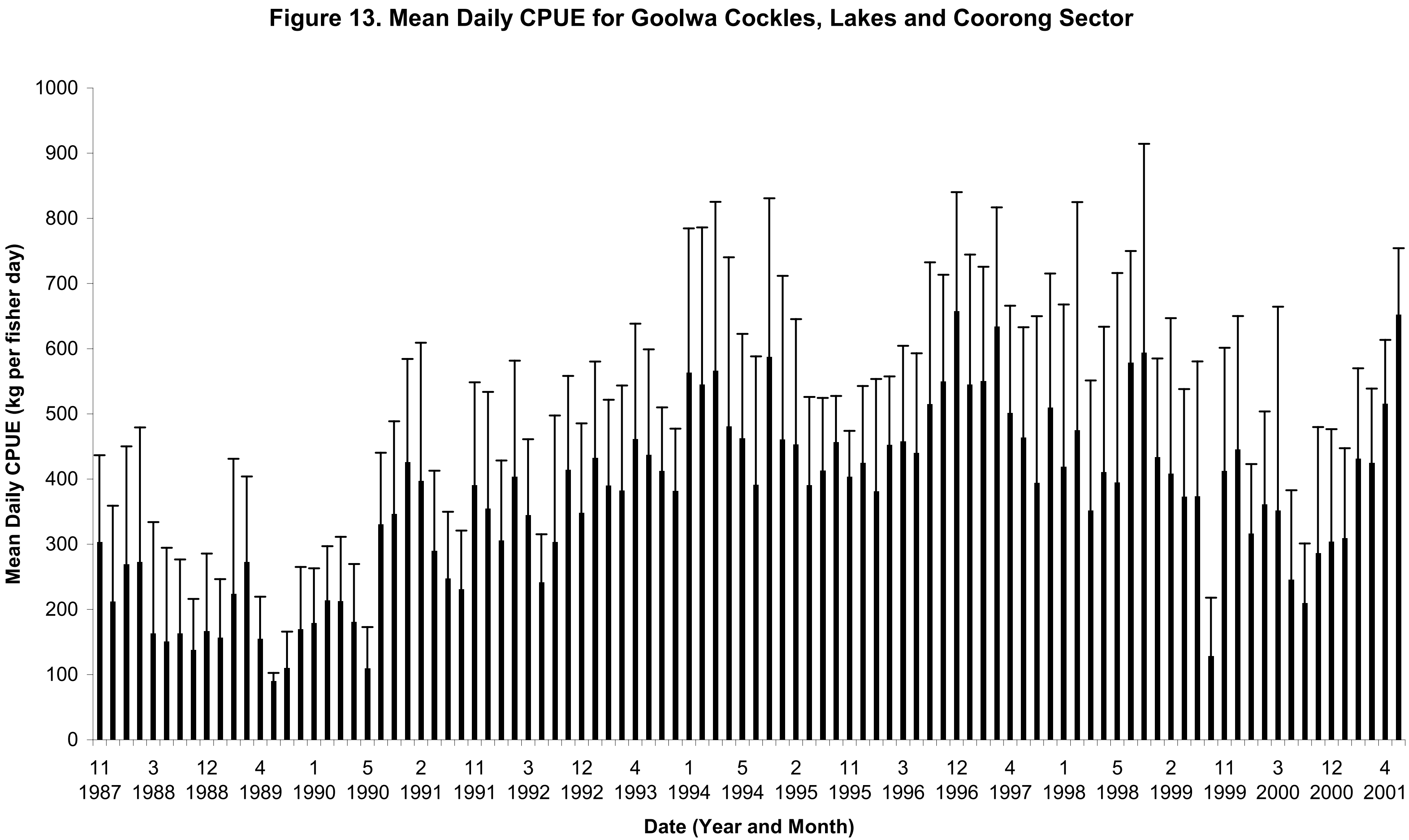


Figure 13. Mean daily commercial catch per unit effort (± standard deviation) in kilograms per fisher day for Goolwa cockles from the Goolwa region, Lakes and Coorong Sector. Only fishers for whom daily data are available have been included. Data points represent the mean of daily CPUE figures for each month.

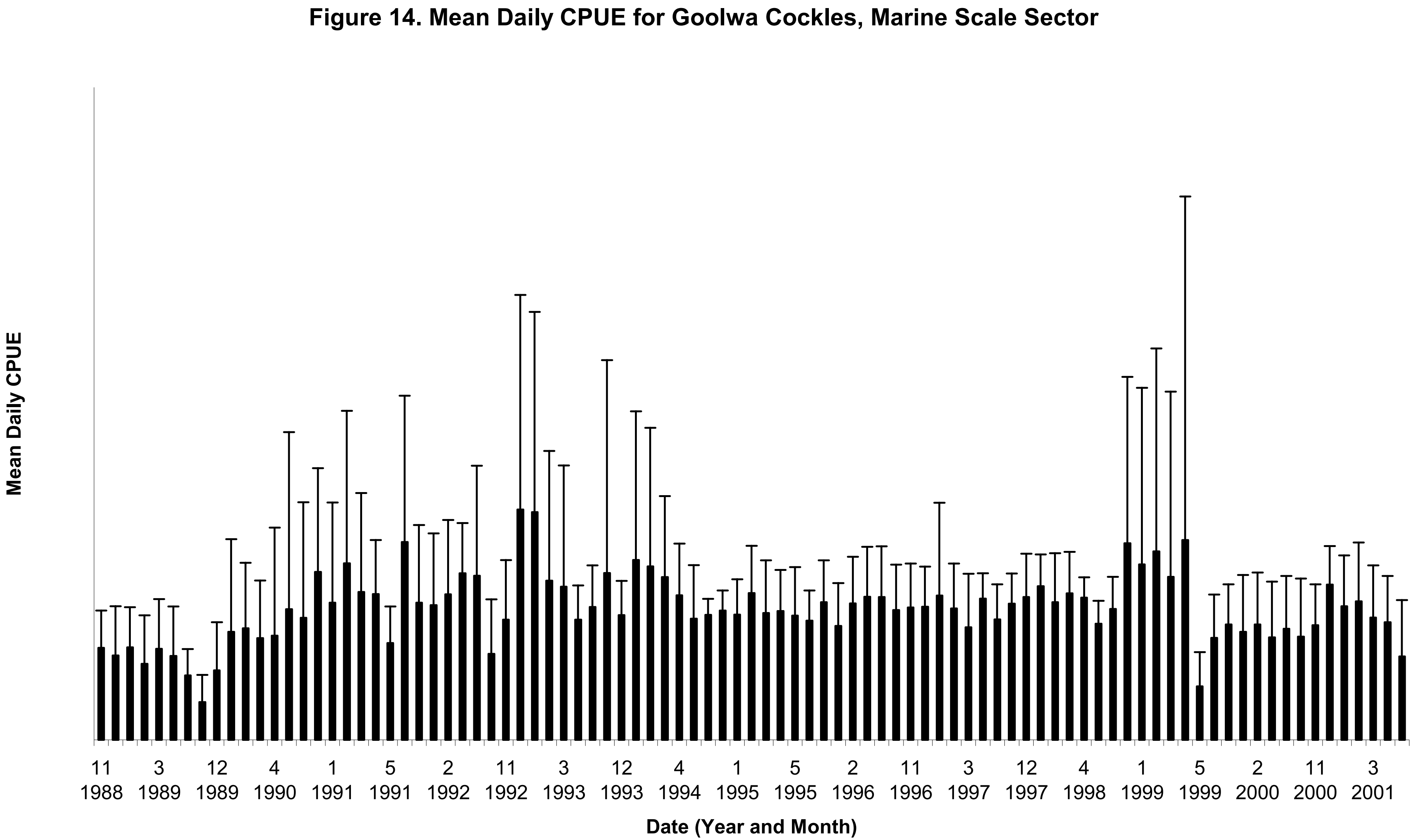


Figure 14. Mean daily commercial catch per unit effort (± standard deviation) for Goolwa cockles from the Goolwa region, Marine Scale Sector. Data points represent the mean of daily CPUE figures for each month. As the number of fishers in this sector is usually <5, CPUE values have been removed.

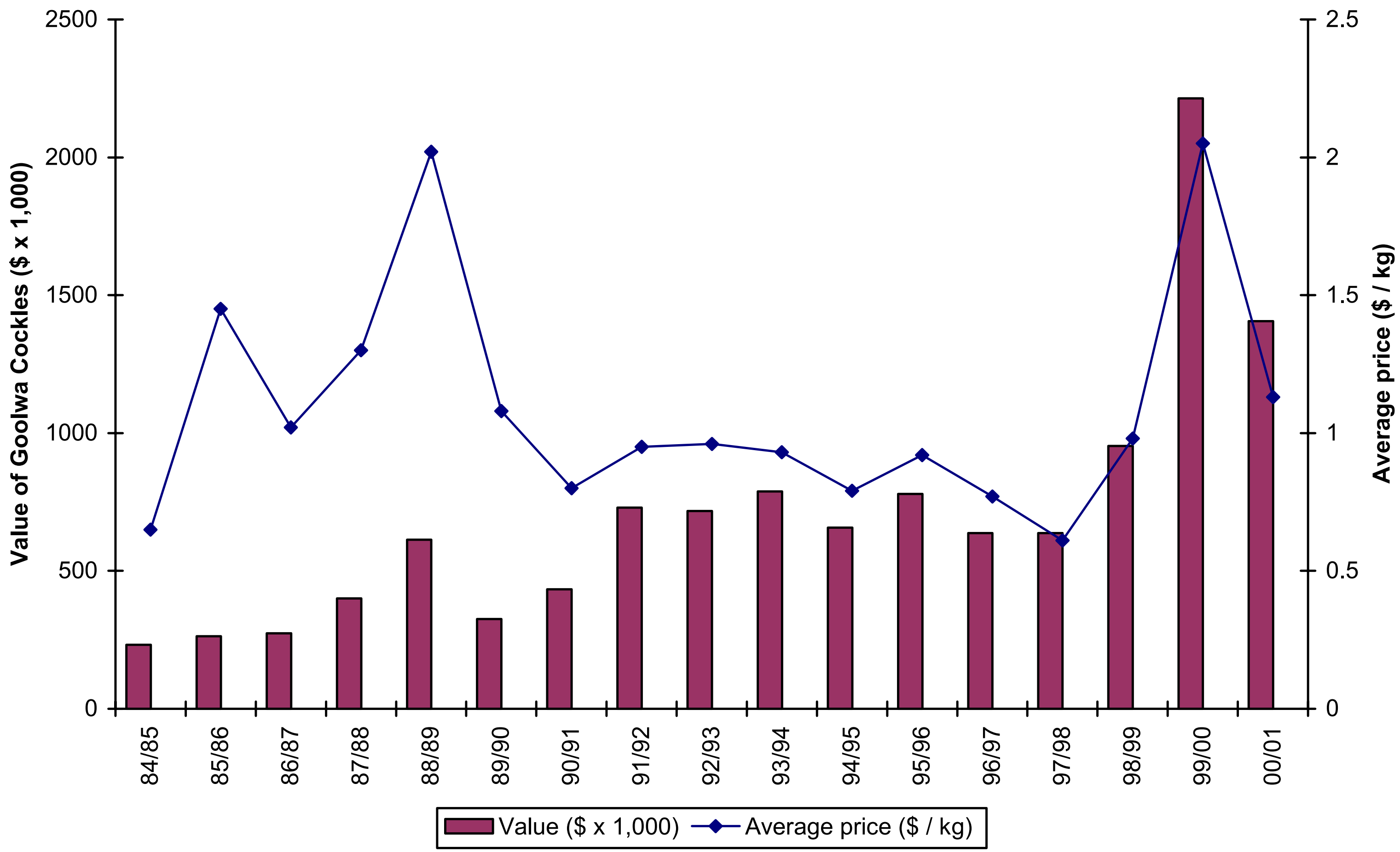


Figure 15. Total annual commercial value for Goolwa cockles from the Goolwa region, all fishers, all sectors and all gear types combined. Years are financial years. Columns are total value of entire catch, points represent yearly mean price per kilogram. Total value in 2000/01 was $1.406 million at an average price of $1.12 per kg.

5.2 Resource Assessment

Population distributions of *Donax deltoides* in other states vary greatly, both along and across the shore, in position, degree of aggregation, accessibility and number of year classes present. Distribution and abundance may vary at scales as short as days, and 100s of metres (James and Fairweather, 1995; Murray-Jones, 1999). Discussions with SA commercial fishers confirm that this also applies to the populations along the Coorong ocean beaches. This makes estimating abundance by means of transects impractical and assessment of the total available resource difficult.

The degree to which SA populations exhibit spatial and temporal variability in distribution and abundance is not known, however as previoulsy discussed, such variability is typical of sandy beach fauna. Any proposed sampling scheme should be designed to take such variability into account.

In NSW studies the juvenile animals tend to be less variable in location than sexually mature animals (Murray-Jones, 1999), however estimating pre-recruit indices for this fishery is unlikely to be of practical use. There is such a short time lag between settlement and recruitment into the fishery (1-2 years) that any management response would need to be almost immediate if numbers of pre-recruits were low. Also, in NSW, "settling" cockles were present in often large numbers for most of the year, however there were still only one to two recruitment pulses per year into the fishery, suggesting that pre-recruitment mortality is very high (Murray-Jones, 1999).

Current data availability limits assessment to tracking abundance trends based on reported commercial catch and effort data at this time. Future assessment could incorporate age-structured models, subject to the need for periodic intra-annual sampling to deal with the continuous recruiting nature of the resource, and the resolution of intermittently contagious distributions that are highly mobile, variable, and not generally visible.

5.2.1 Fishery Dependent Assessment

The Goolwa cockle fishery shows variability in catches and CPUE at different temporal scales, despite increasing effort over time. Variability in catch is not only likely partially reflect the fact that different fishers are working in different areas, where stock abundances may vary, but also the purpose for which the cockles are being taken. Effort variability is influenced by local variation in cockle abundance, current market value of cockles, the degree to which cockles are aggregated, weather conditions, and changes in value and abundance of other species targeted.

The SA cockle fishery shows large fluctuations in CPUE particularly at the scale of days and months. This is similar to that observed on the east coast of Australia. (Murray-Jones, 1999). Because of the aggregating nature and patchiness in distribution of this species, CPUE is not likely to be a good indicator of abundance for this species (Murray-Jones, 1998; Murray-Jones and Steffe, 2000). For example, while the mean daily catch rate by hand over the entire year for the Stockton Beach, NSW, fishery was 28.8 kg per fisher hour, CPUE varied greatly both at short and long time scales, and ranged from a maximum of 172 kg per fisher hour down to 0.5 kg per fisher hour. When numbers of cockles were high, experienced fishers often took around 100 kg per hour by hand.

Unfortunately, in the SA fishery effort data does not discriminate between time spent travelling, locating cockles, sorting, sieving, grading and packing, and actual harvest time. These activities are likely to vary both among fishers and over time. A study in NSW which collected precise catch and hourly effort data found that some fishers would work until they collected their “target” number of cockles (as opposed to working for a fixed number of hours), and this could take widely varying amounts of time (Murray-Jones and Steffe, 2000). Discussions with commercial fishers indicate that there has been no change since the 1980s in distances travelled along the Coorong Beach to harvest cockles. However managers may like to give consideration to encouraging fishers to record travelling time to harvest aggregations in order to acquire more precise estimates of the extent of the areas being exploited. Consideration should be given to introducing new catch and effort records that enabled the fishers to record separately "searching" and "fishing" times.

Variation in CPUE may be the result of a number of factors. As short-lived aquatic species, an age class of Goolwa cockles effectively is only present in the fishery for two to three years. Hence there may be considerable variation in individual year class strength as any particular year class enters the fishery. Given that both cockle larvae, which are present in the water column for up to several weeks and post-settlement cockles, are dependent upon planktonic food, there may be a correlation between the fertilising effects of River Murray outflows and the strength of cockle year classes. However, for cockles on the east coast, variation in abundance and position on shore can be extremely marked, even at the time scale of days (Murray-Jones, 1999), and unlikely to be influenced only by food supply. Differences in CPUE appeared to be driven more by changes in the degree to which cockles were aggregated, and their position on shore. Highest catch rates were recorded when cockles were stranded high on the beach at low tide, in dry, “fluffy” sand (Murray-Jones and Steffe, 2000).

Changes in CPUE over time are often used as an indicator of stock abundance and the sustainability of the fishery. While CPUE data for this species need to be treated with caution as described above, CPUE did decline between 1997-2000 (Fig. 12). Declines in CPUE in the late 90s were not reflected in catch figures, as effort also increased. Annual and mean daily figures all reflected a drop in CPUE in 2000 (Figs 12, 13 and 14), the year of maximum effort and highest value.

Any consistent decline over time should give rise to managers making a closer examination of factors that could be giving rise to this decline, particularly as there are no other data available to assess the stock effectively or to monitor this fishery. Whilst the low number of cockle year classes within the fishery would also suggest the managers need to be mindful of the potential for collapse of the resource, this does not appear to be the case at the present time as the fishers are not exploiting the cockles throughout their distribution along and across the Coorong and Goolwa ocean beaches. An option available at this time, because the increase in market value (Fig. 15) of the resource has the potential to increase the level of exploitation of the resource, is to cap or remove the latent effort in this fishery.

The potential Goolwa cockle fishing effort capable of being employed on Coorong Beach stocks is poorly understood. There are a large number of fishers in the MSF and L&C sectors who have endorsements to collect cockles but who are not currently using their endorsements. Increases in market returns, or other economic incentives could trigger major effort shifts towards targeted fishing for cockles. Indeed, even without taking into account gear endorsement, effort has the potential to rise considerably, as cockles are readily collectable by hand. The entire NSW catch of around 300 - 500 t pa is taken by hand, with catch rates of 100 kg per fisher hour being recorded by several fishers during the winter (Murray-Jones and Steffe, 2000). No gear is allowed in this fishery. In the 2000/2001 licensing year, there were approximately 15 Lakes and Coorong licences and seven Marine Scalefish licences active in this fishery. However there are large numbers of fishers who could potentially fish cockles by hand, including all 38 Lakes and Coorong fishers, as well as Marine Scale fishers.

A fishery is generally considered to be fully exploited when fishing mortality is near to the level that will produce a maximum sustainable yield (MSY). As MSY is unknown for the Goolwa cockle fishery, the fishery can be considered as fully exploited if increasing effort leads to a lowering of CPUE. Pierce and Doonan (1999) classified this fishery as fully exploited. While the relationship between commercial harvest and effort appears to be linear for this fishery (Fig. 16), the combination of episodic recruitment, increasing value and effort, decreasing CPUE in a year of high effort (1999/2000), the general lack of information on the population dynamics for the species and the difficulty of conducting fishery independent stock assessment suggest that this fishery should be treated as fully exploited as a precautionary measure.

Figure 16. Harvest/Effort relationship for Goolwa cockles (1983/4 - 2000/1)

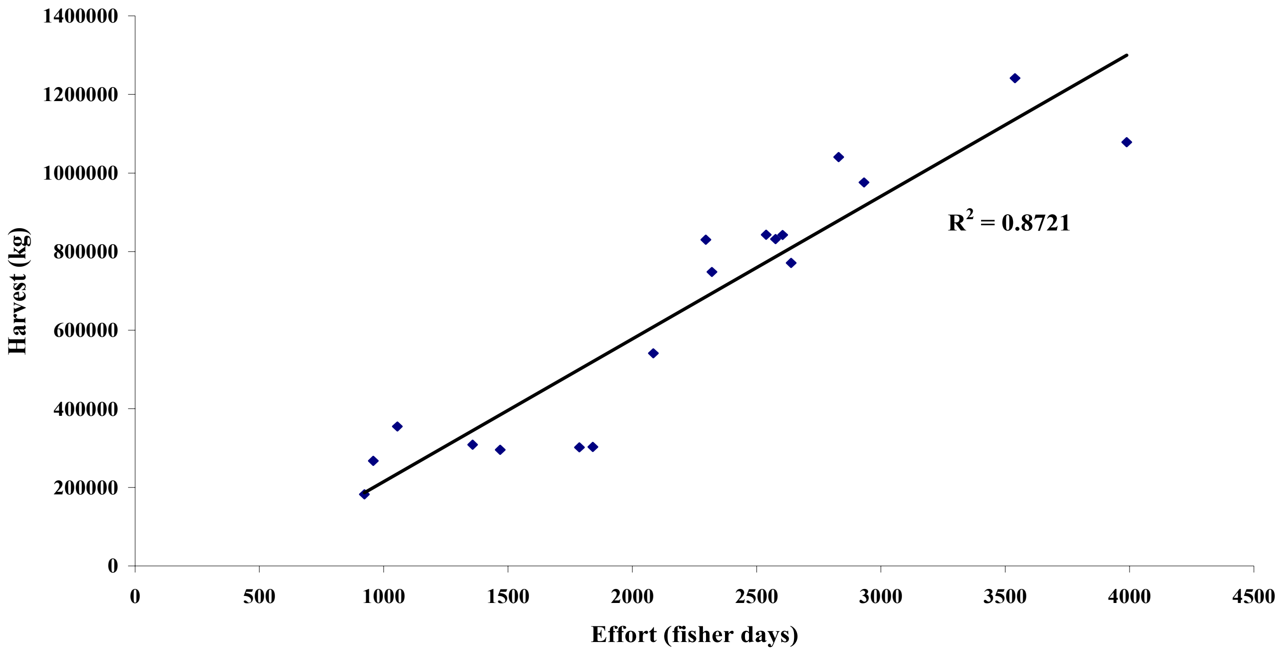
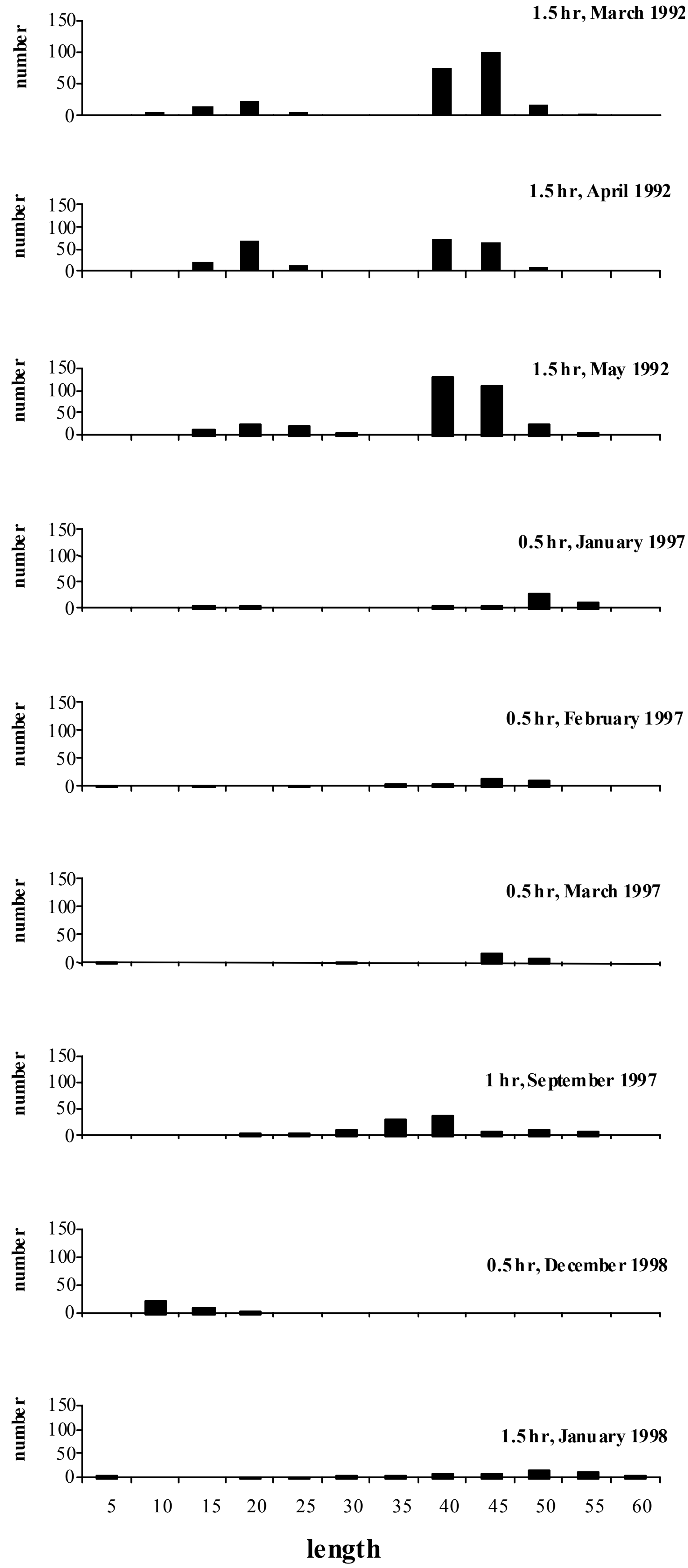


Figure 16. Relationship between harvest and effort for Goolwa cockles from 1983/4 to 2000/01. Each point represents one year. Harvest in kilograms live weight, effort in fisher days. Linear relationship fitted.

5.2.2 Other data

A small amount of length frequency data have been collected independently from the western end of the cockles' distribution along the Goolwa Beach by Keith Jones (SARDI) in various years. These data are presented all to the same scale, to facilitate comparisons of numbers and sizes available both among years and at different seasons (Fig. 17). Approximate time taken to collect the sample is noted. Samples were collected haphazardly, at different times of the tidal cycle and different parts of the beach, and were not intended to be quantitative. However, some trends are apparent. There were larger numbers of adult cockles present in 1992 collections. For example a total of 321 cockles were collected in 1.5 hours in May 92, compared to 53 in January 99. The December 1998 sample contained no animals larger than 20 mm in length, although this could be due to size differential tidal migration rather than a real lack of adult stock.

Figure 17. Length frequency distributions of Goolwa cockles collected haphazardly from different regions of Goolwa Beach on different dates. Sizes grouped by maximum shell length into 5 mm size classes. Frequencies are number in each size class. Approximate time in hours to collect sample is included for each date.



In addition, some sampling was carried out to determine available and fished sizes. Figure 18a shows the percent frequency each size class of cockles caught by fishers to the east of the Murray mouth on Coorong Beach on December 6, 2000 (data pooled from catches, n = 1025). Figure 18b shows the percent frequency of cockles caught by fishers on May 2, 2001, and includes data from fishers' catches and from collections made by Pierce and Hand working alongside fishers, using a smaller mesh net (n = 2505). Data have been pooled and raw data are not available, hence no comparison between sizes available and sizes fished is possible. However both Figures 18a and 18b show a mode of 40-45 mm in length, with few animals over 55 mm present.

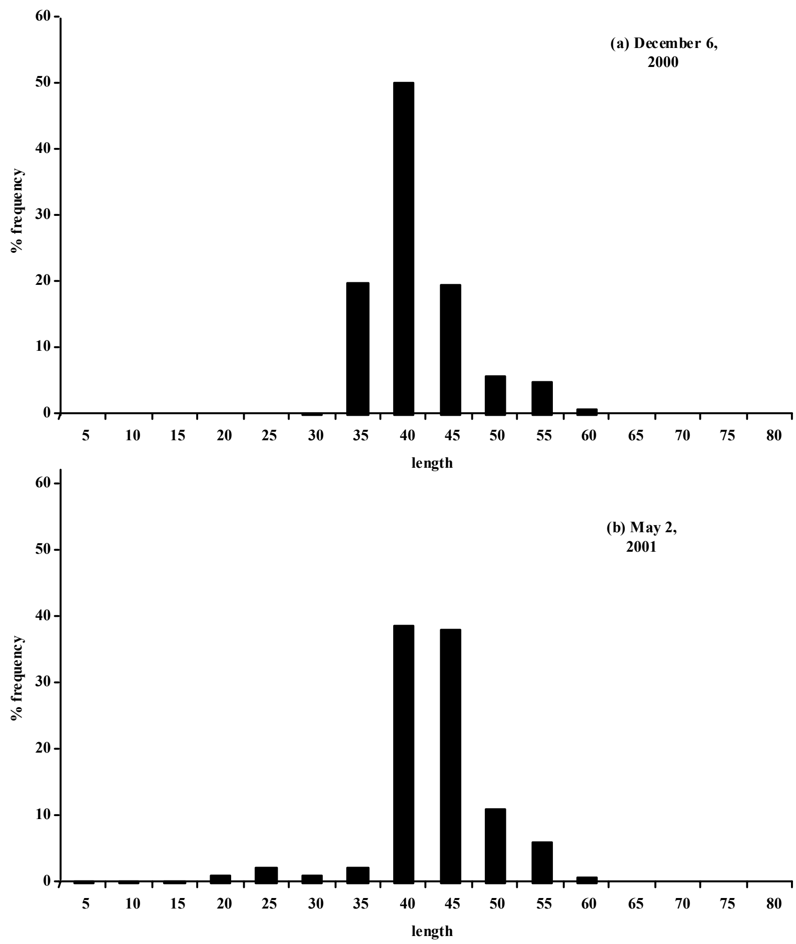


Figure 18. Length frequency data from two collections from Coorong Beach. (a) December 6, 2000 collection. Data pooled from fishers' catches, n = 1025. (b) May 2, 2001 collection: data from both fishers' catches and from collections made by B. Pierce and K. Hand working alongside fishers, using a smaller mesh net, n= 2505. Data pooled. Length in 5 mm size classes, % frequency plotted.

5.3 Environmental Assessment

Environmental performance and impacts of fishing are important to the community as well as to the sustainability of the fishery, and are now legal reporting requirements for all Australian export fisheries, under the Environment Protection and Biodiversity Conservation Act (Cwth) 1999. Environmental impacts (outside those through direct reduction of the target stock) may occur directly or indirectly as a result of fishing and across the diversity of the ecosystem involved. These assessments of the impacts of the Goolwa cockle fishery are primarily qualitative at this time, except as noted, with no distinction between recreational and commercial sector impacts unless specifically indicated. Environmental assessment considers by-product, bycatch, ghost fishing, habitat, vehicular and icon species impacts.

5.3.1 By-product species

No by-product species (species harvested and sold incidental to Goolwa cockle fishing) are taken in the pursuit of this fishery.

5.3.2 Bycatch

Bycatch within the fishery includes the discards, that is, species (plant and animals) that are not landed but taken and killed as part of the fishing practice. The primary bycatch in the Goolwa cockle fishery is the harvest of undersize cockles during the fishing operation. Because of the large number of individuals caught during most operations (e.g. a 10 litre bucket can contain 250-300 legal size cockles, and weigh over 10 kg), some undersized animals can slip through even multiple checks. Sieving (size grading) to remove the undersize cockles and to return these to the water, is common in the commercial sector. Checks without notification of commercial harvest subsamples during 1999/2000 revealed bycatch of undersize animals ranging from slightly less than 2% to 14 % of the sample, by number (Heycock, G. PIRSA Fisheries Compliance, pers. comm.).

During the early 2000/2001 season, the PIRSA Fisheries Compliance unit found commercial fishers with as much as 50% of their catches undersize at this time (Heycock, G. PIRSA Fisheries Compliance, pers. comm.). There are at least two possible reasons for such a large proportion of undersized animals being taken. A recruitment pulse may have resulted in a very large year class of immature cockles, so that fishers found it difficult to avoid small animals. Alternatively, numbers of adult cockles may have be depleted, so that fishers are able to only target smaller year classes. No information is available to clarify this issue, although it more likely to be the result of a strong recruitment than depletion of adults. Consequently studies to examine the size distribution of Goolwa cockles along the Coorong ocean beach relative to the distance from the Murray mouth, as well as regular monitoring of recruitment, could assist in addressing these issues in the future.

While data on the Goolwa cockles along the Coorong beach indicate that the species spawns almost continuously in some years, recruitment to the fishery tends to be in pulses (King, 1976). These may be produced in association with favourable outflow conditions. Entry of these pulses into the population is not necessarily associated with a precise time of year. Episodic recruitment is typical of NSW stocks as well, but does not appear to be correlated with river flow regimes (Murray-Jones, 1999).

There is no specification for the mesh size of cockle rakes, hence a selectivity curve cannot be used to minimise harvest of small animals. In any case, large cockles effectively block the mesh so that quite small individuals may be trapped. Also the mesh size and configuration becomes distorted as the net is filled. Hence mesh size adjustment would not necessarily reduce the catch of undersize Goolwa cockles in this fishery.

Many fishers already minimise bycatch of undersize cockles by selectively exploiting patches of cockles containing primarily legal sized individuals, or by sieving harvested cockles, with undersize animals being returned to the water intact. Such action is voluntary at this time, with approximately 2/3 of fishers currently operating in this manner. Sieving itself is an issue when tarpaulins are not used. Some fishers sieve directly onto the sand, and leave undersize animals to die. The level of mortality associated with this practice is not known, but may be high. Waste, and the perception of waste, are both important issues (Commonwealth Policy on Fishery Bycatch, Commonwealth of Australia, 2000). Deliberate resource waste is unacceptable. Many members of the community would also consider leaving animals to die in the sun to be an ethical issue. Provisions exist in regulation to deem cockles taken onto higher ground to be "taken" and as such, undersize animals left on the sand could attract prosecution. Alternatively, it may be preferable to implement specific regulations to explicitly deal with this issue. A Code of Practice has been developed for the mud cockle fishery to ensure that sieving occurs where animals are taken.

Small invertebrates, such as worms and crustacea, typically inhabit the high energy intertidal and subtidal zones of the Coorong ocean beaches. Most are adapted to rapid reburial if disturbed. Few are retained by the mesh of the cockle rakes. Green beach worms approximately 75 mm long are caught in cockle rakes at very low rates (ie, 1-2 per week per rake) and returned to the environment alive. Other minor bycatch in this fishery is the incidental capture of juvenile (<20 mm) sand crabs (*Ovalipes australiensis*). For 4-6 weeks in the early life of these crabs, they are present in the sand in the shallow "swash" zone, and susceptible to capture in cockle rakes. Numbers of juvenile sand crabs caught are about one per 12 kg of cockles harvested (2000/2001 season data estimated from one fisher). Juvenile sand crab bycatch occurs mainly over a period of 4-6 weeks near the beginning of the cockle season. Undersize crabs are released alive. The majority of crabs are undamaged and released in the immediate vicinity of their capture. Approximately 1% of crabs observed are inadvertently crushed by the feet of fishers during the fishing operation. Juvenile sand crab bycatch mortality from this cause is roughly 200-300 crabs per season (1999/2000 fishery year for commercial sector, estimates from data supplied by fishers). This is minor compared with the relative harvest mortality associated with the South Australian commercial sand crab fishery (29-148 tonnes per annum; Knight et al., 2001) and recreational sand crab fishery.

5.3.3 Other Impacts

Assessment of habitat damage caused by Goolwa cockle harvesting due to manual netting activity has been broadly assessed. Given the nature of the high energy beach zone, the highly mobile substrates are re-sorted on each tidal cycle. Hence no habitat damage is likely from cockle fishing in the intertidal zone.

Infauna are exposed to wave action, and are adapted for life in this shifting environment and will not be damaged by disturbance. Most undersize animals not harvested will rebury in the immediate vicinity of the original disturbance. Some increased predation is likely, but *Donax* species show a very rapid rate of reburying when exposed (Ansell and Trevallio, 1969; Trueman, 1971).

Shell damage following fishing activity has been demonstrated for the surf clam *Mesodesma mactroides* (Defeo and de Alava, 1995). Assessment of the proportion of animals damaged during harvest activity in the Goolwa region has been undertaken. Samples taken during the 1999/2000-fishery year (both undersize and legal size), showed a damage rate of 3% (n=5112, Pierce, unpublished data). Damage to cockles was either to the shell, or the soft tissues (siphon or foot). Siphons are capable of regenerating within days after even quite severe cropping by birds and fish (Hodgson, 1986), however loss of or damage to the foot may make it less capable of retaining position within the shifting substrate. Likewise, shell damage varied greatly, and was mostly minor, however the effects upon feeding success, reburial, predation rate and water loss can not be reliably assessed without further field experimentation. Assuming that the rate of damage to bycatch individuals is similar to that of the total sample, bycatch induced mortality caused by the commercial or recreational sectors is unlikely to have a major impact.

5.3.4 Vehicular Impacts

Impact of vehicular activity along the beach is a factor that needs to be addressed in assessing this fishery. One of the few published studies addressing recreational 4WD impacts, conducted on a mid-Atlantic beach, did not find any significant mortality or shell damage in fauna associated with traffic (Wolcott and Wolcott, 1984). Digging out Goolwa cockles by hand after deliberately driving over a section of beach did not show shell damage in 220 individuals across the full size spectrum, (B. Pierce, unpublished data, Jan. 1998). On the east coast of Australia, cockles move upwards when vehicles pass over them (the trigger is likely to be acoustic shock, *sensu* Ellers 1995). If cockles are in the swash zone when disturbed, they will surf downwards on the next wave. If they are stranded in the mid-intertidal where the sand is hard packed, this upward movement of the cockles results in very visible "bumps" in the sand, which can in fact be used for rapid rough assessment of densities (Murray-Jones, 1999) and is used by fishers to locate fishing sites. No mortality from vehicles was observed during a six-year study on *D. deltoides* in NSW, although the hooves of horses being exercised on the beach were seen to cause shell damage (Murray-Jones, pers. obs.).

In the case of the Coorong beach fishery, some fishers suggest that vehicular activity on the beach causes a behavioural reaction in adjacent cockle stocks resulting in disaggregation and reduced catchability of the resource. This impact has not been quantitatively examined, although it is likely to enhance rather than reduce sustainability of the resource by lowering harvest efficiency. Any such behavioural impact is likely to be associated with potential increased predation or reduced reproductive success. No such change has been reported elsewhere for Donacid bivalves. Disturbed cockles simply tend to re-aggregate on the next tidal cycle. The distribution of the cockles includes areas with no vehicle access and therefore the overall impact is not likely to be major, although further research is needed to quantitatively address vehicular impacts.

There is some concern in the community regarding a perceived lack of large Goolwa cockles on the Sir Richard Peninsula (Goolwa) beaches. While undersize cockles are still common, adult cockles seem more scattered in recent years, which is interpreted locally as the result of commercial overfishing, however there are no data to substantiate this. Data collected by K. Jones do indicate a lack of larger animals in recent years (Fig. 17). Effort data separated between the Sir Richard and Younghusband beaches indicate that commercial effort has declined to very low levels on the former. Commercial fishers advise that the increase in recreational vehicles along the Goolwa Beach endanger their safety and consequently have transferred their operations to the southern side of the Murray mouth.

The recreational fishery on Goolwa Beach (Sir Richard Peninsula) is observed to be greater than that on the Coorong Beach (Youghusband Peninsula). It is difficult to know whether the apparent decrease in larger cockles is a natural fluctuation in abundance, a result of vehicular traffic or fishing activity, or a change in beach dynamics e.g. erosional changes to beach slope, which has made the habitat less suitable for cockles. Because the Goolwa beach is “flatter” than the Coorong ocean beach, 4WD impacts may be greater than on the eastern side of the Murray mouth because the 4WDs can access a wider proportion of the beach at low tide.

5.3.5 Bird Species Impacts

A potential indirect impact associated with access to the Goolwa cockle fishery is associated with the nesting period of the hooded plover. During the nesting season, this species reacts to the presence of humans by attempting to hide in shallow depressions, as are typically formed through the footprint of a vehicle tyre track in the sand. As a result, this bird is vulnerable to mortality from vehicles following older tyre tracks. Commercial operators in this region are aware of this issue, and most cockle fishers voluntarily drive on the wet sand at low water to avoid the plovers.

The South Australian National Parks and Wildlife Service restricts access to the Coorong Beach during the key plover reproductive period, which considerably limits beach traffic over the season (DEP, 1989). Vehicle use of the Younghusband Peninsula component of the Coorong Beach (North from Tea Tree Crossing) is closed to all but commercial fishers and permitted (usually SA NPWS) vehicles from 25 October to 25 December of each year (inclusive, by regulation). Commercial cockle fishers operating over this period typically employ wide balloon-type tyres on their transport vehicles, which materially reduce the depression left in beach sand and hence lessen potential impact on this vulnerable species.

There may be impacts on wading birds if the resource were to be seriously depleted. For example, pied oystercatchers rely heavily on *D. deltoides* for food, and preferentially target large cockles (S. Murray-Jones, unpublished data).

6. Management Implications

6.1 Risks/Threats

Murray-Jones (1999) reviewed available information about the ecology and fishery of *D. deltoides* in NSW and methods of sampling, and concluded that a precautionary approach to exploitation was required, due to the difficulties of conducting stock assessments for this species.

No fishery independent data are available for the Coorong fishery. The drop in CPUE in the year of highest effort (1999/2000) indicates the adoption of a cautious approach with management of this fishery. McLachlan et al. (1996) in a review of beach cockle fisheries world wide, recommend an experimental approach to management through methods such as rotation of fishing areas, creation of spawning stock refuges, and restocking by direct seeding. Attempts to aquaculture surf cockles have generally not been successful to date.

Beach cockle fisheries worldwide share several common trends particularly highly fluctuating abundances and episodic recruitment. McLachlan et al. (1996) reported that in some fisheries, rapid expansion of effort into the fishery (particularly through mechanical harvesting) is often followed by a dramatic collapse of the fishery. Furthermore recovery of the populations can be slow. Overfishing was perceived as a serious problem in the 1950s and 60s in NSW (Murray-Jones, 1999). This pattern needs to be taken into account in considering risks to the SA cockle fishery.

Specific risks or threats to the sustainability and optimal utilisation of Goolwa cockle stocks on the Coorong beach system relate to latent effort, changes in gear, habitat modification, including the regulation of River Murray outflows.

6.1.1 Latent Effort

Latent effort within this fishery is significant. The efficiency of a single gear unit per day can be very high, without the need for either significant investment or training. Latent effort present within the Marine Scale and Rock Lobster fisheries is of concern however a recent review process has recommended that: a) only the two MSF licensees, that had demonstrated a catch history for cockles, maintain access to sell cockles; b) all other MSF licence holders retain bait access only; and c) all Rock Lobster access be removed (Anon. 2000). These recommendations are yet to be considered by the Minster for Agriculture, Food and Fisheries. The issue of adequate gear definition and gear endorsements requires attention, as does the issue of whether or not hand and dab nets constitute cockle harvest devices (Appendix).

The owner operator provision used in this fishery at present helps to limit effort. It makes it physically difficult for fishers to work both low tidal periods per day. Also, not every day is fished by each license holder, as rest days, sick days, truck overhaul and gear maintenance time are needed. Furthermore the multi-species nature of the Lakes and Coorong fishery allows transfer of effort to other species and thus reducing the reliance on the Goolwa cockle resource.

Effort data indicate that the primary increases in effort/gear entry to this fishery have occurred in the Lakes and Coorong fishery. A maximum of 130 cockle devices is endorsed in this fishery under current policy and regulation. Current practice (i.e. two people fishing, one carrying cockles) is such that only 58 are likely to become effective. Current effort constitutes about 30 devices, so the fishery has around half of its effort still in a latent condition. There is also large latent potential effort in the recreational sector.

6.1.2 Management Responsiveness

In a short-lived species such as Goolwa cockles, it is important that management measures provide protection against over fishing. The ability to respond quickly to emergency situations is critical to sustainability. The current conservative management approach has enabled the resource to remain healthy across sectors. However, future research and management not only needs to monitor population levels but also develop and understanding of the role of river outflow on the population biology of this species.

6.2 Future Research

While much research could be undertaken with respect to this fishery, only a few areas of research are critical.

The factors determining recruitment, including flow regimes at the Murray mouth, clearly need research. Outflow timing, quantity and quality of freshwater, and nutrient loading may be significant drivers of cockle production in the region. Experimental management of outflows, using Goolwa cockle recruitment as an indicator of stock health and sustainability, may prove to beneficial to the fishery. It may be possible to tune management of over-barrage outflows to maximise Goolwa cockle production. Understanding the relationships between outflow parameters and Goolwa cockle recruitment patterns may allow the surf beach ecosystem productivity to be maximised, and the fishery enhanced.

The pattern of spawning in SA appears very variable. An understanding of recruitment dynamics would enhance future management of the fishery.

Attention needs to be given to finding other methods of assessing the sustainability of the harvest. CPUE estimates can be made more sensitive by asking for fishing data in more precise units and to separate searching from fishing time. The degree to which *Donax deltoides* in SA vary in size distribution as well as the species spatial and temporal distribution and abundance along the Coorong beach warrants investigation. This would clarify whether the same difficulties confound *in situ* methods of stock assessment in South Australia as have been reported for NSW. In addition, regular monitoring of the size/age composition of the stock and the catch would provide information about the relationship between pre-recruit and adult abundance, the proportion of undersize catch, and assist in ongoing assessment of the availability of the resource.

Little is known of the recreational harvest levels in this fishery. Better understanding of the dynamics and quantitative aspects of the recreational fishery would provide essential baseline information on total fishing mortality. The trend is for increased human consumption of Goolwa cockles, and this will be further driven by any rises in market demand and/or price. The potential exists for significant increases in recreational cockle harvest, particularly near easy beach access areas.

Alternative management methods such as rotation of fishing areas, creation of spawning stock refuges, and restocking by direct seeding should also be considered.

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9. Appendix: Gear definitions

The following definitions are specified within the Fisheries (General) Regulations and apply to recreational and commercial fishers alike:

> "**cockle rake**" means a device designed and constructed to be held in the hand and consisting of a pole attached to one end of which is a cross-bar mounted upon which is a rake; and a net bag;
>
> "**hand net**" (including a dab net, dip net or shrimp net) means a net being conical in shape attached to a hoop or ring and extending not more than l metre in depth from the hoop or ring, the hoop and ring being attached to a rigid handle and having a diameter that does not exceed 1 metre;
>
> "**mussel dredge**" (no specific cockle dredge is defined) means a device designed and constructed to be held in the hand so as to facilitate the taking of fish by scraping the bed of any waters and being no more than one metre wide and having attached to it a net being no more than one metre deep.

World standard classification of fishing gear types generally follows the standard "Classification of Catching Methods" (von Brandt 1989). SARDI/PIRSA gear codes, where distinct, are also specified as follows:

> <u>Cockle Rake (SARDI Gear Code: A for the Lakes and Coorong commercial fishery; CR elsewhere)/Cockle Net(SARDI Gear Code: CO)/Cockle Dredge (lacking a distinct SARDI Gear Code)</u> (von Brandt Gear Type: Bag Net - 7.1.1. Scoop Net). For research and stock assessment purposes, these three devices are assumed to be identical in practice as falling within the same legislative definition (for cockle rakes) and single von Brandt classification.

There is no uniform definition of a Goolwa cockle capture device under current regulation, and there is little difference in the definition of the cockle rake as specified within regulation, as compared to a hand or dab net. Since Goolwa cockles are taken from the beach by movements of bare feet in the shallow surf backwash zone which dislodges the cockles and causes them to be suspended in the shallow water, cockles may be interpreted as being "landed" by placing the cockle rake or other device on the ocean side of the operator such that the backwash from each wave causes the cockles to float into the net (cockles may, to some extent, be automatically size graded based on the mesh size employed).

Many license holders possess hand nets, dab or brail nets as part of their endorsed fishing tool kit. Given the ambiguity in definitions, it could be argued that hand nets represent a legal cockle capture and landing device. Likewise, the definitions of hand or dab nets are sufficiently general to include the configuration of a cockle rake as generally constructed. In the event that hand nets are taken to represent legal Goolwa cockle capture devices, the potential capped effort in the Lakes and Coorong, and other fisheries, that is capable of being directed at harvesting Goolwa cockles is considerably greater than is presently perceived.