



Are the spiny lobster fisheries in Australia sustainable?

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Abstract

Australia has a wide range of spiny (rock) lobster species but this review concentrates on the four largest commercial and recreational fisheries and their management. *Jasus edwardsii* supports significant commercial fisheries in South Australia, Tasmania, Victoria and southern Western Australia, with an insignificant amount taken in southern New South Wales. Most of the southern rock lobster commercial fisheries in Australia operate under quota management with annual Total Allowable Catches (TACs) set for the fisheries; the exception to this is in Western Australia where the small *J. edwardsii* fishery currently operates as an input-controlled fishery. Although the New South Wales eastern rock lobster (*Sagmariasus verreauxi*) catch is small it forms the basis of an important cultural fishery. There has been an artisanal fishery on the tropical lobster (*Panulirus ornatus*) in the Torres Strait and the east coast of Papua New Guinea for hundreds of years. Commercial fishing is restricted to the indigenous Torres Strait Islanders a small number of non-indigenous Australians. It is managed under treaty arrangements with Papua New Guinea (PNG). The western rock lobster fishery for *Panulirus cygnus* is Australia's largest commercial rock lobster fishery. Effort in this fishery is controlled by the regulation of pot numbers and the number of days that fishing is permitted in the season. There have been a number of dramatic changes in several of Australia's commercial spiny lobster fisheries in recent years including declines in annual landings. This paper outlines changes that have occurred in these fisheries, summarises new management arrangements, and discusses the status of the stocks and the current economic and social situation of each fishery.

Keywords: Spiny lobster fisheries, sustainability, Australia, *Jasus edwardsii*, *Sagmariasus verreauxi*, *Panulirus cygnus*, *Panulirus ornatus*

Introduction

Variouly known as 'crayfish', 'crawfish', rock' or 'spiny' lobsters (and even rocklobsters in Australia), depending on local traditions and trade requirements, they provide a valuable source of seafood and exports for a large number of countries. Eight rock lobster species are found in Australian waters and four of them support significant

commercial and/or recreational fisheries. *Panulirus cygnus* is found on the lower coast of Western Australia; *Panulirus ornatus* in northern Australia, particularly the Torres Strait and far north Queensland; *Jasus edwardsii* in southern Australia - South Australia, Victoria, Tasmania and Western Australia; and *Sagmariasus verreauxi* on the central east coast, New South Wales and occasionally in

small numbers in Victoria and Tasmania.

For earlier details on the Australian fisheries on these species discussed here see Booth (2006) and Phillips and Melville-Smith (2006) and Phillips *et al.* (2007). There have been a number of dramatic changes in several of these fisheries in recent years and in this paper we will summarise the management arrangements, describe the changes that have occurred, and discuss the status of the stocks and the current economic and social situation of each fishery.

The catch and effort data in this paper are up to 2007/08. However, where possible these and other data (e.g. economic and community data) have been sourced to the end of 2009. The current management arrangements in all of the rock lobster fisheries in Australia are summarised in Table 1. However, special management arrangements will be mentioned under individual fisheries.

Tropical rock lobster *Panulirus ornatus*

Management arrangements: The fishery for *P. ornatus* in the Torres Strait is managed under the Torres Strait Fisheries Act and the Torres Strait Treaty (Article 22) between Australia and Papua New Guinea. The management has special regard to protecting the tradition way of life and livelihood of the inhabitants but also allows some exploitation by non-indigenous fishers.

Fishing is conducted by divers, with fishers free diving (1-4 m depth) or using hookah (4-20 m depth) from small outboard powered dinghies and returning their catches to land-based processors or processing vessels. In 2009 there were about 400 licensed boats in the fishery. Twenty six mobile freezer vessels with 63 tenders also operate in the fishery, acting as mother ships for teams of divers. The lobsters were originally sold as frozen tails on the Australian and overseas (mainly U.S.A) markets.

Table 1. Current commercial fishing management measures in *Panulirus*, *Jasus* and *Sagmariasus* fisheries in Australia

	<i>Jasus edwardsii</i>				<i>Sagmariasus</i>		<i>Panulirus</i>	<i>Panulirus</i>	
	Tasmania	Western Australia	Victoria West	Victoria East	South Australia North	South Australia South	<i>verreauxi</i>	<i>ornatus</i> <i>cygnus</i>	
Year ITQs Introduced	1998	NA	2001	2001	2003	1993	1994	N/A	To be introduced in 2010/2011
TACC (tonnes)	1323	NA	320	66	310	1400	128	749	5500 target
Number of licenses	314	38	71	47	68	181	112	393	387
Legal minimum size carapace length (mm)	110 males	98.5	110 males	110 males	105	98.5	104 (or 115 tail length)	90	77
	105 females		105 females	105 females					
Maximum legal size (mm)	No	No	No	No	No	No	180	No	Females 95 Zone C and 105 Zones B and A
Berried females protected	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Number of active boats	215	16	60	24	55	181	112	378	387
Type of gear specified	Pots	Pots	Pots	Pots	Pots	Pot	Pots & Diving	Diving	Pots
Number of pots	10507	4552	5162	2138	3950	11923	No	N/A	31700
Characteristics of pots defined	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Escape gaps	Yes	Yes	Yes	Yes	No	No	No	N/A	Yes
Sanctuaries	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes
Closed season	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Recreational fishing allowed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

However, many are now exported to a strong market now available for live lobsters in Asia.

Island communities operate dinghies throughout the fishery with the principal fishing grounds being around Thursday Island, Orman Reef and Warrior Reefs, which are the areas most accessible to the major population centres. Catches peak in March-August and there is now a closed season during October – December (Fig. 1).

Recreational and traditional fishers are restricted to a bag limit of three lobsters per dinghy/day.

Status of the stock: The main management objective is to maintain spawning stock levels that meet or exceed the level required to produce maximum sustainable yield (MSY).

Since 1989 the abundance of *P. ornatus* over the approximate 25,000 square km of the Torres Strait fishery was estimated using a dive/transect technique.

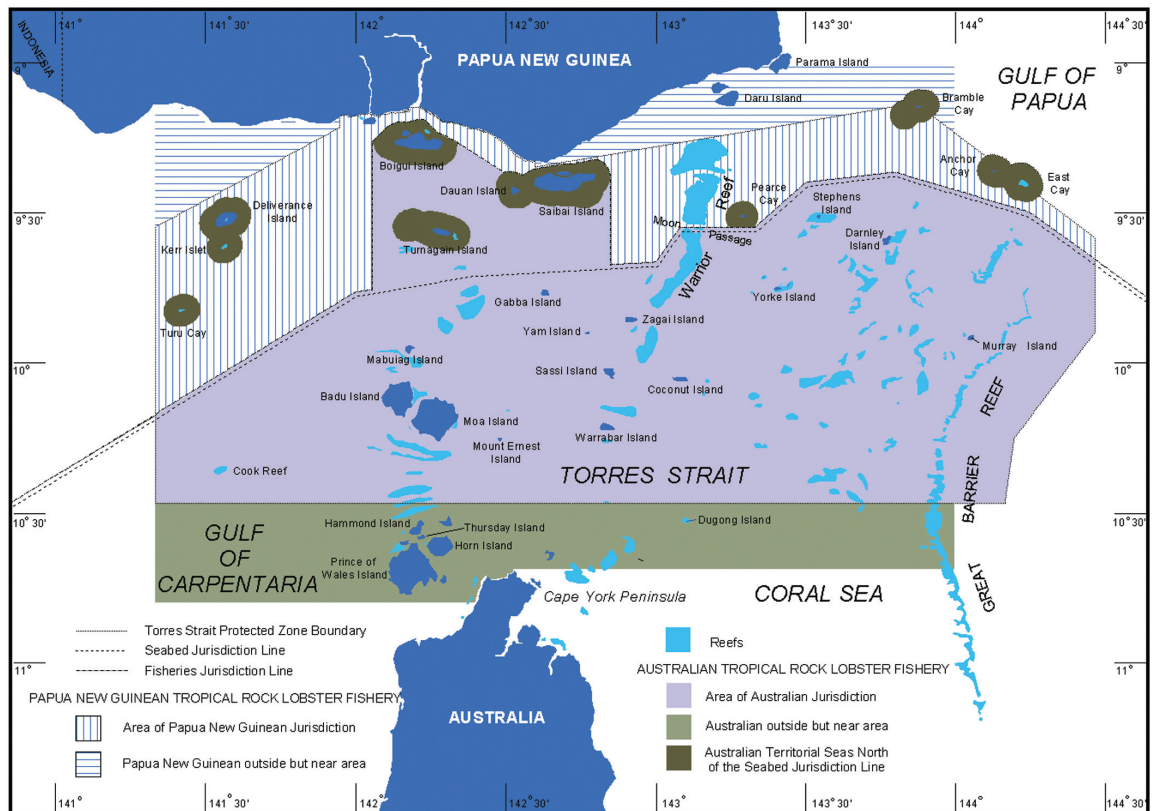


Fig. 1. Management areas of the Torres Strait tropical rock lobster fishery for *Panulirus ornatus*. Supplied by the Bureau of Rural Sciences, Canberra, Australia

Management of the stock is affected by a minimum legal size of 115 mm tail length or of 90 mm carapace length (CL) measurement. There are no controls on fishing effort. The current input controls have been moderately successful at controlling fishing effort, but concerns about growth in fishing effort remain. A move to quota management system is being discussed (Bensley *et al.*, 2009).

The annual fishery-independent surveys of the relative stock abundance, and catch sampling, have contributed to the development of a simple cohort dynamics model of the fishery for a range of fishing mortalities. It estimates the potential yield one year in advance, which is valuable to managers in considering development options and negotiating catch-sharing agreements and access rights (Bensley, 2008).

In 2007 the surrender of 13 licences in return for an ex-gratia payment from the Australian Government reduced, slightly, the effort in the non-indigenous sector of the fishery.

Based on the assessment models an informal TAC of 835 t live weight was estimated for the 2007 season, but the fishery recorded a catch of only 679 t (Bensley *et al.*, 2009). Catches were even lower in the 2008 season and the Australian fishery recorded a catch of 286 t, 43% below the nominal TAC of 505 t. PNG reported a catch of 41 t, or 13% of the total reported catch of the fishery. The PNG fishery had a nominal TAC of 244 t (Fig. 2).

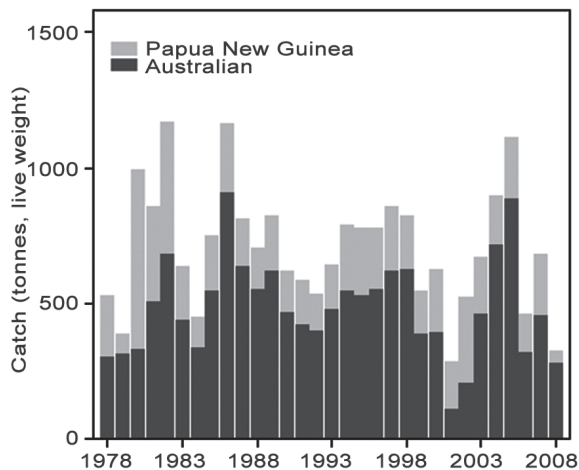


Fig. 2. Catch history of the Torres Strait tropical rock lobster fishery for *Panulirus ornatus*. Supplied by the Bureau of Rural Sciences, Canberra, Australia

Economics and social effects: Real gross value of the production was A\$9.4 million in 2007/08. The price of live lobsters sold into Asia in the 2007-08 season was approximately A\$28 kg.

Economic drivers such as high fuel prices and a downturn in the market are thought to have contributed to reduced effort over the last three years.

Eastern rock lobster *Sagmariasus verreauxi*

Although the New South Wales (NSW) rock lobster *S. verreauxi* catch is small it forms the basis

of an important fishery. The eastern rock lobster is considered the premier seafood of New South Wales, enjoying a high public profile and fetching substantially higher prices than rock lobsters imported from other Australian states.

S. verreauxi is found along the entire New South Wales (NSW) coast (Fig. 3), from inshore to the edge of the continental shelf (200 m). The fishery was initially focused inshore with fishers using small boats to set traps around headlands and shallow reefs. In the late 1960s, lobsters were found further offshore and the fishery expanded out to the edge of the continental shelf.



Fig. 3. Map of the geographic range of the New South Wales Lobster Fishery. Restrictions on lobster fishing occur within Marine Parks and Critical habitats

Management arrangements: The fishery has undergone significant changes in management since the early 1990s, with limited access introduced in 1992 and the introduction of a Total Allowable

Commercial Catch (TACC) in 1994. The fishery is a share management fishery with the TACC allocated to individual shareholders in proportion to shareholding (NSW DPI, 2000). The TACC is reviewed and set annually by a statutory and independent TAC Setting and Review Committee. Shares can be traded and quota can be transferred between shareholders throughout the fishing period. There are currently 9,727 shares distributed among 112 shareholders in the commercial fishery. A description of the fishery, summary of regulations and management objectives, performance indicators and trigger points are contained in a Share Management Plan (NSW DPI, 2000) and Fishery Management Strategy (NSW DPI, 2007).

The vast majority of commercial catches (> 99%) are made using a variety of designs of pots and traps. Small “beehive” pots and rectangular traps, with a soak-time of 1-3 days are used to take lobsters from shallow reefs and headlands (< 10 m). Larger rectangular traps (up to 2 m maximum dimension) that soak for several weeks at a time are used in the deep-water fishery. A minor component of the commercial catch (< 1%) is taken by free-diving.

Controls in the fishery include a minimum legal size of 104 mm carapace length, a maximum legal size of 180 mm, a ban on the taking of egg-bearing females, restrictions on trap dimensions (≤ 1.2 m maximum dimension in depths ≤ 10 m; ≤ 2 m max. dimension in depths > 10 m) and restriction of the mesh size on traps to a minimum 50 mm in depths > 10 m. There is no closed season.

Recreational fishers are restricted to a bag limit of two per day and are allowed to use only one trap, or dive and capture with their hands, without the use of compressed air. These regulations confine the recreational fishery to shallow inshore waters.

Status of the stock: The commercial catch can be divided into reported and unreported (illegal market) components. Although catch and effort reporting by commercial fishermen has been more reliable since the introduction of a TACC (Montgomery *et al.*, 1997; Liggins *et al.*, 2009), it is considered that substantial quantities of the commercial catch went unreported in earlier years

(Fig. 4). Although the accuracy of estimates of unreported commercial catches and recreational catches is questionable, it has been assumed in recent assessments that, since 1994-95, 83% of the commercial catch of *S. verreauxi* has been reported and that there has been a recreational catch of 26 t per annum (Liggins *et al.*, 2009).

Following its introduction in 1994-95, the TACC was increased incrementally from 106 t to 150 t in 2001-02. However, annual catches did not increase correspondingly during this period, with only 68% of the 150 t TACC caught in 2001-02. TACC subsequently decreased to a low of 102 t in 2004-05. Since 2004-05, TACC has again been increased incrementally, to 128 t in 2008-09 and commercial catch has increased correspondingly from 98.1 t in 2004-05 to 122 t in 2008-09, the TACC having been effectively caught in each year (i.e. > 95% of TACC caught).

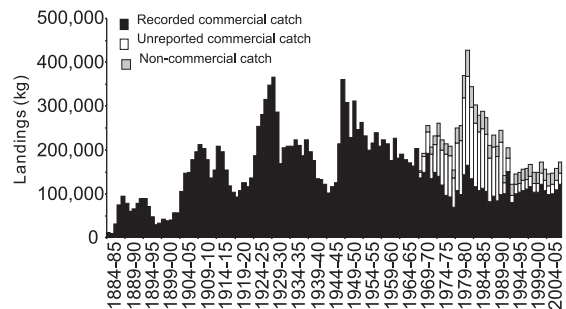


Fig. 4. Annual catch of the spiny lobster *Sagmariasus verreauxi* from the waters of New South Wales (1884-85 - 2007-08): reported commercial catch, estimates of unreported commercial catch; and recreational catch

Catch rates of *S. verreauxi* have declined over the long history of this fishery, reaching minimum levels in the late 1980s and early 1990s (Montgomery 1995; Liggins *et al.*, 2009). However, since the significant changes to management of the fishery in the early 1990s, catch rates have increased. Catch per unit of effort in 2007-08 was the greatest observed since the mid 1970s (Liggins *et al.*, 2009).

A biomass dynamic model developed for the fishery (Chen and Montgomery, 1999) suggested that there was a decline in biomass over most years between 1900 and 1993-94, but that it has increased

since then. This biomass dynamic model has since been replaced in the annual resource assessment by a length-structured model; calibrated using a combination of observed CPUE data and commercial size-distributions. The base-case scenario of this model, presented in the 2008-09 resource assessment (Liggins *et al.*, 2009), estimated a median total biomass at the commencement of 2008-09 that was 35% of the pre-exploitation level and estimated to have increased by a median 88% since 1994-95. The median estimate of spawning biomass in 2008-09 was estimated to be 26% of the pre-exploitation level, having increased by a median 173% since 1994-95.

The depleted level of the spawning stock has been a particular concern in this fishery. The legal minimum size of 104 mm CL is well below 166 mm CL, the size at which the animals are considered to first breed. Length frequency sampling of commercial catches in the early 1990s (Montgomery, 1995), showed that only 10% of animals sampled were larger than size at first breeding. Consistent with this observation, the base-case scenario of the length-structured population model used in the 2008-09 resource assessment (Liggins *et al.*, 2009) suggested that spawning biomass was maximally depleted in 1992-93 to 10% of pre-exploitation levels.

A fundamental objective of management of the eastern rock lobster fishery as stated in the Share Management Plan for the fishery (NSW DPI, 2000) has been to increase the stock biomass. An expanded range of goals and performance indicators contained in the Fishery Management Strategy (NSW DPI, 2007) includes the maintenance of spawning stock above 25% of the pre-exploitation level. A range of performance indicators and trigger points contained in this strategy are based on both (i) model-derived estimates of components of biomass and (ii) recent trends in indices of abundance derived from fishery-dependent data and fishery-independent surveys.

Sagmariasus verreauxi on the New South Wales coast is assessed to have been heavily exploited in the past. The current management strategy is aimed at rebuilding the depleted stocks and maintenance of the stock at a biologically sustainable level. Recent

assessments suggest that this is being achieved (e.g. Liggins *et al.*, 2009). Indeed, in their most recent review of the TACC (TAC Committee, 2009), the committee noted that: the steady recovery of New South Wales rock lobster continues; the TAC/ITQ system is working effectively; and the market price for shares has almost tripled in the past 4 years. Moreover, as fisheries managers become increasingly confident that the stock has rebuilt to a sustainable level, a priority in the near future will concern the consideration of long term targets, designed to maximise the economic yield from the resource.

Southern rock lobster *Jasus edwardsii*

Jasus edwardsii has the widest distribution of any of the rock lobster species in Australia. The species supports significant commercial fisheries in South Australia, Tasmania, Victoria and southern Western Australia, with an insignificant amount taken in southern New South Wales (Fig. 5).

Aboriginal harvesting of southern rock lobsters has occurred for thousands of years and continues under special provisions in each state. The commercial fishery dates back to the period of early European settlement with records of harvesting in Hobart, Tasmania in 1804 (Winstanley, 1973). Management restrictions were introduced earlier than for most Australian fisheries with size limits, gear restrictions and prohibitions on the harvest of ovigerous females or soft-shelled rock lobsters were first introduced in 1889. In the context of this paper it is interesting that these rules were introduced due to concern that the fishery was not sustainable. In 1882 the 'Royal Commission on the Fisheries of Tasmania' concluded that: "*The destruction of crayfish [rock lobster] is so serious in some localities as to threaten extermination at no distant date*" (Saville-Kent, 1882).

Recreational fishing has also had a long history across the range of the fishery and was mainly shore based with the use of baited rings in the first half of the 20th century. An increase in recreational boating has led to movement of the recreational fleet into deeper water.

The long history of management rules has been combined with effective enforcement so that animals

below legal size are rarely seen and virtually all commercial product is harvested by licensed commercial fishers.

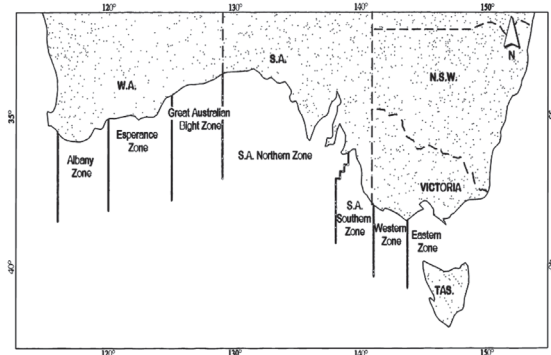


Fig. 5. Map of the geographic range of the *Jasus edwardsii* lobster fisheries in Australia

Management arrangements: Management is by six discrete zones that have different policies and rules. Fishers use baited traps that are typically hauled between one and four times per day depending on the region, weather and catch rates.

Boat and trap restrictions: Catch was originally constrained through limits on effort in all *Jasus edwardsii* fishery jurisdictions but this has changed in recent years and now only Western Australia retains this form of management. Victoria, in addition to quota management, retains licence limitation and restricts the number of pots. Trap limits have been retained under ITQ, which combined with limited entries means that there is an upper limit on the number of pots and vessels. Table 1 shows the number of boats and traps licensed to fish *J. edwardsii* in each state. Maximum and in some cases minimum trap entitlements per vessel have also been set and most states (Western

Australia, South Australia and Tasmania) have defined the size and design of traps, including the incorporation of escape gaps or large mesh to reduce the handling and hence the mortality of undersize animals.

Seasonal closures: Table 2 lists the various seasonal closures for each of male and female *J. edwardsii*. Tasmania (Haddon and Gardner, 2008) and Victoria (Hobday and Ryan, 1997) have longer closed seasons for females than males to give them added protection.

Recreational fishing: Recreational fishing for *J. edwardsii* occurs in all states. Table 3 lists the main regulations governing the southern rock lobster recreational fisheries. Recreational fishing is usually confined to shallow, sheltered waters although effort is tending to shift further offshore as the fleet of recreational vessels expands. Recreational fishers are licensed and unlike commercial fishers, are able to take lobsters by diving with compressed air.

Size limits are the same as described for commercial fishers and season lengths are generally similar although can vary by a week as the recreational seasons generally commence on Saturdays. Tail marking is by cutting or punching a hole in the telson and is intended to prevent black market sales. The minimum age for license holders is 10 years in Tasmania.

Tasmania

Stock summary: The Tasmanian lobster fishery had a steady increase in stock size from 1994 to 2006, so that exploitable biomass almost doubled through this period. This increase resulted through both a constraint in catch by the TACC (1523 t for

Table 2. Season openings for *Jasus edwardsii* spiny lobster fisheries in Australia

State	Males			Females		
	Start	End	Total weeks open	Start	End	Total weeks open
Tasmania	15 Nov	30 Sep	46	15 Nov	30 Apr	24
Western Australia	15 Nov	30 Jun	35	15 Nov	30 Jun	35
Victoria - west	15 Nov	15 Sep	43	15 Nov	1 June	28
Victoria - east	15 Nov	15 Sep	43	15 Nov	1 June	28
South Australia - north	1 Nov	31 May	28	1 Nov	31 May	28
South Australia - south	1 Oct	31 May	32	1 Oct	31 May	32

Table 3. Recreational fishing regulations for *Jasus edwardsii* fisheries in Australia in 2008/09

Regulation	TAS	WA	VIC - west	VIC -east	SA - north	SA - south
Dive activity occurs	Yes	Yes	Yes	Yes	Yes	Yes
Licence required	Yes	Yes	Yes	Yes	Yes	Yes
Trap activity occurs	Yes	Yes	No	No	Yes	Yes
Licence required	Yes	Yes	N/A	N/A	Yes	Yes
Gear limits (traps/person/boat)	1	2	N/A	N/A	2	2
Ring fishing activity occurs	Yes	No	Yes	Yes	Yes	Yes
Licence required	Yes	N/A	No	No	No	No
Gear limits (per person/boat)	5	N/A	2	2	3	3
Daily bag limit (per person/boat)	5	8	2	2	4 /8	4 /8
Possession limit(per person)	10	N/A	2	2	15	15
Vessel limits	No	Yes	No	No	No	No
Tail marking required?	Yes	Yes	Yes	Yes	Yes	Yes

most of this period), and also though high settlement in 1995

Since 2006, the stock has trended downwards with declines in catch rates in all assessment areas and state wide as shown in Fig. 6 (Haddon and Gardner, 2008). The recent peak in exploitable lobsters in 2006 corresponded to a catch rate of 1.2 kg / potlift which fell to 1.0 kg/potlift in the 2008/09 season. Catch rates have fallen in seven of the eight assessment areas, especially in the southern, slower growth regions of the south (by 28% in the worst affected area in the south east). This decline in catch rate is presumed to relate to a decline in biomass with legal, sub-legal and total biomass levels close to their lowest levels in the last 10 years in several assessment areas.

Aside from changes in production across the fishery, there have also been strong regional trends in the distribution of effort and catch in response to changes in production around the State. Effort and catch are at or near record low levels in the north of the State and are unusually high in the southwest. This southwestern region has very low growth but high recruitment and undersize biomass. Interannual variation in recruitment into the fishery in this region is thought to be strongly influenced by changes in growth rate, not only settlement of puerulus.

Egg production from the State remains stable and high relative to most fisheries with total production above 40% of the unfished state.

However, production is highly regional and northern areas with faster growth are depleted so that egg production remains below 20% of the unfished state.

Current management considerations: In late 2009 the Tasmanian commercial industry proposed a management response to the current recruitment decline which is an 18.8% reduction in the total allowable commercial catch (TACC), to be implemented over three years in steps of 10%, 5% and 5%. This follows a 3% reduction in the 2009–10 season. This provides a total reduction of 21.2% over 4 years and has now been implemented by the Tasmanian Government.

The proposal for change in the TACC attempted to do two things. The first was to respond to the immediate problem of rapidly declining stock. Management in the Tasmanian fishery uses measures of legal-sized biomass and egg production to ensure that the stock is sustainable and these changes provided a high probability that the stock would remain above limits in the short term (5 years). The commercial industry also tried to set themselves on a longer-term pathway to higher catch rates and improved profitability. Their target is a catch rate of 1.4 kg potlift in 10 years, which would represent an increase in catch rate of almost 50 per cent and more than double profitability compared to the status quo.

Eastern Tasmania has an additional management problem which is that an urchin species is undergoing

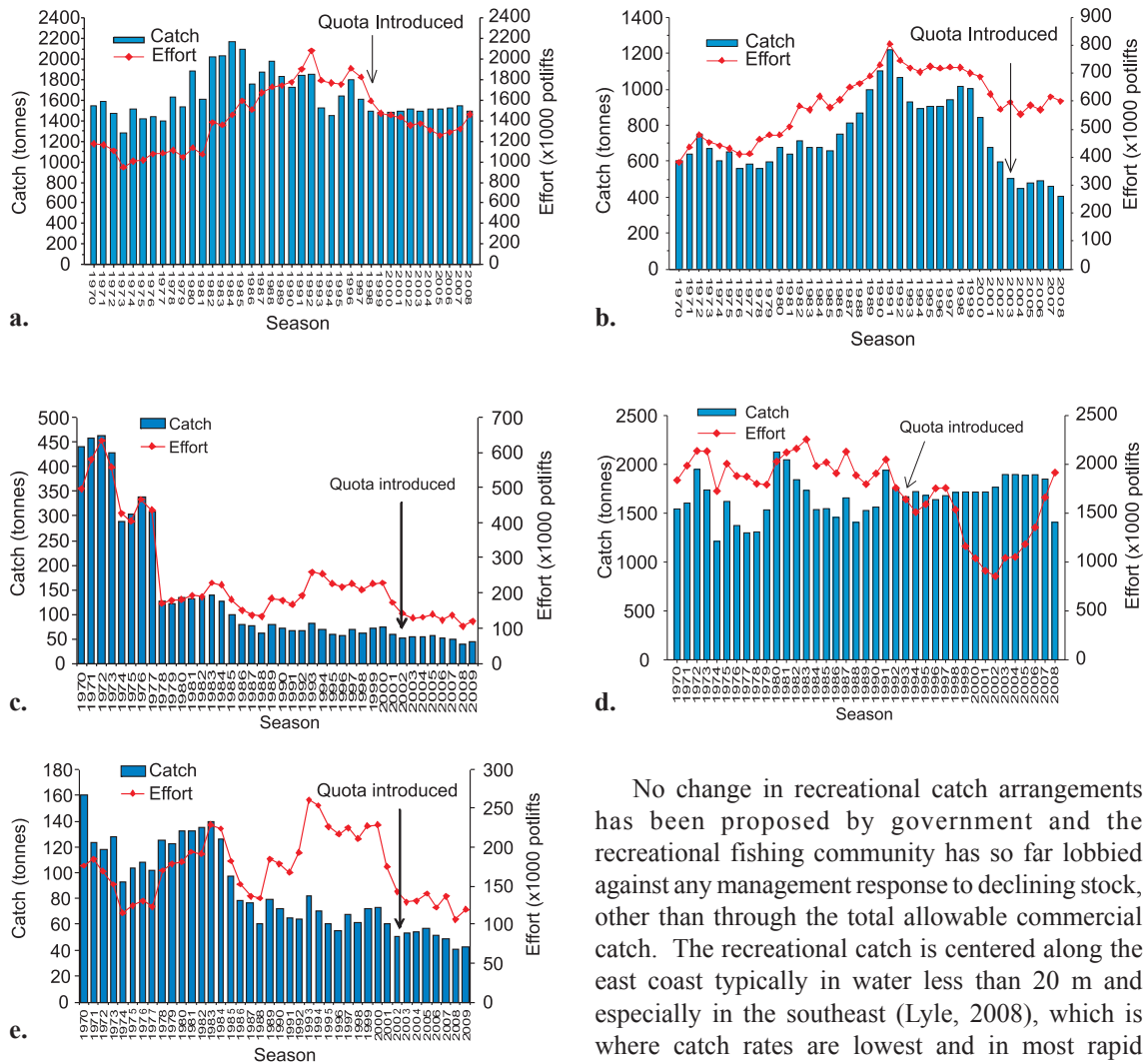


Fig. 6. Annual catch and effort of the southern rock lobster fisheries for *Jasus edwardsii* in Tasmania (a), South Australia Northern Zone (b), South Australia Southern Zone (c), Victoria Western Zone (d), and Victoria Eastern Zone (e) from 1970 to 2008

a range and population expansion associated with climate change (Ling *et al.*, 2008). Over the last two decades this has led to grazing of all macroalgae from large areas of reef so that these habitats become unsuitable for lobsters to inhabit. Very large lobsters (>145 mm CL; Ling *et al.*, 2008) are a known predator of these urchins and the management aims to increase lobster stocks and the formation of urchin barrens.

No change in recreational catch arrangements has been proposed by government and the recreational fishing community has so far lobbied against any management response to declining stock, other than through the total allowable commercial catch. The recreational catch is centered along the east coast typically in water less than 20 m and especially in the southeast (Lyle, 2008), which is where catch rates are lowest and in most rapid decline. Recreational catch in this region is typically greater than 50% of the total harvest (Lyle, 2008).

Marine protected areas (MPA) have been expanded in Tasmania through a regional approach within Tasmania with greatest coverage in the southeast at present although expansion is expected. Their impact on lobster populations was evaluated by Buxton *et al.* (2004) through population modelling. The abundance of lobsters inside these closures have obviously increased but the impact of MPAs on the total stock was predicted to be a reduction in biomass and egg production. This is because displaced catch was not removed and because of spatial differences in the productivity of closed and open areas.

South Australia-Northern Zone rock lobster fishery (NZRLF)

In 2008 (i.e. the 2008-09 season), the TACC in the NZRLF was 470 t. The total reported commercial catch from logbook data was 402.7 t, the lowest catch on record (Fig. 6b). It represents the 6th consecutive season in which the TACC was not caught (Linnane *et al.*, 2009a). It also represents a 60% decrease since 1998 (1015.8 t) and a 20% decrease since the introduction of quota in 2003 (503.3 t). Effort has not decreased comparatively. In 2008, it was 600,347 potlifts representing a 16.7% decrease since 1998 (720,816) and a 0.5% increase since 2003 (596,961). As a result, the 2008 zonal CPUE estimate of 0.68 kg/potlift represents a 54% decrease in catch rate since 1999. It is the lowest CPUE on record.

There is close agreement from both qR and LenMod fishery models in relation to the current status of the NZRLF (Linnane *et al.*, 2009b). Both qR and LenMod fishery models indicate that biomass and egg production have decreased markedly in the NZRLF over the last two decades. Outputs suggest that biomass in 2007-08 was ~1,400-1,600 t, the lowest estimate on record. This represents a decrease in biomass of ~57% from that estimated in 1990 (3,300-3,800 t). Similar declines in egg production were observed, with 2007-08 values representing only 10-15% of virgin stock levels. Both models suggest that the exploitation rate has increased over the last three seasons with 2007-08 estimates ranging between 29 and 32%.

Recent stock assessment reports have concluded that TACCs are not being set at levels that constrain catch which is inconsistent with the aim of stock rebuilding defined in the Management Plan (e.g. Linnane *et al.*, 2009a). As a result, biomass has continued to decline. As highlighted in previous stock assessment reports for the fishery, the sporadic nature of settlement (and subsequent recruitment) in the NZRLF emphasises the need for conservative TACCs where spikes in recruitment may need to be protected for extended periods in order to sustain biomass. Recent reports highlight that in the absence of TACCs that constrain catch, the biomass of

lobsters has declined to a historically low level and therefore the NZRLF should be considered as an overfished resource. They therefore conclude that there is now an immediate need to establish a TACC that constrains catch, protects existing biomass and facilitates the aim of stock rebuilding as defined in the Management Plan for the NZRLF. Based on recent assessment reports, the TACC for 2009 was set at 310 tonnes (Table 1).

While annual changes to nominal fishing effort in southern rock lobster fisheries are well documented, the associated changes in effective fishing effort levels are difficult to quantify. It is generally accepted that the most significant of all technological developments was the uptake of GPS technology, which by the mid 1990s had become fully operational on almost all Australian commercial fishing vessels (Baelde, 2001). In particular, GPS facilitated the accurate location of grounds and positioning of gear and combined with greater fleet mobility, provided opportunities for vast spatial expansion. Over time, fishers were also able to locate and fish more discrete lobster ground as well as return to these specific sites on a regular basis. A clear example of the impacts which spatial expansion can have on catch rates can be seen in the NZ fishery of South Australian during the 1980's and 90s (Linnane *et al.*, 2010). During this period, the CPUE was relatively stable, fluctuating between 1.1 and 1.5 kg/potlift. However, the average number of Marine Fishing Areas fished per licence holder increased from 2 to 5. It is now accepted by managers, scientists and many commercial fishers in the industry, based on declining biomass estimates (which accounts for increases in effective effort), that overall reductions in nominal CPUE within eastern and inshore regions of the fishery were masked by compensating catches in virgin grounds as the fishing fleet expanded westwards and into deeper waters offshore. Thus, this would appear to be a classic example of fishery hyperstability where expanded search effort, facilitated by technological advances such as GPS, allowed fishers to serially locate and target areas of high lobster abundance, thus maintaining high catch rates.

South Australia-Southern Zone rock lobster fishery (SZRLF)

In 2008 (i.e. the 2008/09 season), the TACC in the SZRLF was 1,770 t. The total reported commercial catch from logbook data was 1,407.3 tonnes (Linnane *et al.*, 2009c). While the catch was under the TACC by 6 tonnes in 2006 and 50 t in 2007, this is the first time that catch has been significantly below the TACC. Effort in 2008 was 1,916,436 potlifts, an increase of 15.3% from 2007 (1,661,428 potlifts). Since 2003 (1,042,233 potlifts), when the TACC was first increased to 1,900 tonnes from 1,770 t, effort has increased by 84% (Fig. 6c).

For the sixth consecutive season, catch per unit effort (CPUE) decreased in the SZRLF in 2008. Zonal CPUE was 0.73 kg/potlift, a decrease of 33% from 2007 (1.1 kg/potlift) and the lowest estimate on record since 1978 (0.72 kg/potlift). Catch rates do not take into account discards due to high-grading, but in 2008 only 20 tonnes were recorded as having been returned.

Model outputs agree with fishery dependent data in relation to the current status of the SZRLF resource (Linnane *et al.*, 2009d). Both qR and LenMod fishery models indicate that biomass and egg production have decreased markedly in the SZRLF over the last 4-5 seasons. Model estimates suggest that biomass in 2007-08 was ~3,300-4000 tonnes, representing a decrease of ~32% since 2002/03. Similar decreases in egg production were observed, with 2007-08 values representing 10-13% of virgin egg production. Both models indicate that exploitation rate is now in the range of 45-57%, representing an increase of ~55% since 2002-03 and the highest on record since 1997-98.

In summary, recent stock assessment reports have concluded that the resource on which the SZRLF is based, has declined (e.g. Linnane *et al.*, 2009d). CPUE has decreased over the last six seasons. This reflects a corresponding decline in biomass which in turn reflects low recruitment over this period. Pre-recruit indices (no. of undersized lobster/potlift) in 2007 and 2008 were two of the lowest on record. This suggests that recruitment into the fishable biomass will be low in 2009. Based on these data, the reports have advised that setting a TACC that

does not restrain catch is likely to result in further decreases in biomass. As a result, a precautionary TACC for the 2009 season was strongly recommended. The TACC for the 2009 season was set at 1,400 t (Table 1).

Victoria

The Victorian Rock Lobster Fishery Management Plan requires an annual stock assessment workshop to be held involving all key stakeholders. This requires the fishery to be assessed using a range of prescribed performance indicators, biological reference points, triggers, rebuild rates, and risk levels associated with uncertainty in rebuild rates. The current TACC in each Zone is consistent with the stock rebuilding strategy; however, the model projections for the Western Zone are more pessimistic than for the Eastern Zone. For stock assessment purposes, 8% of the population in the Western Zone and 16% in the Eastern Zone are assumed to be within Marine Parks and, in addition to the commercial catch, recreational catches are assumed to be 16.0 t in the Western Zone and 6.6 t in the Eastern Zone.

The status of the rock lobster resource in Victoria is different in each zone

Western Zone: Catch rates declined continuously from the 1950s until the early 1990s, then marginally recovered into the initial period of quota management (2001/02–2004/05), and subsequently declined to an all-time low (2009-10). The Western Zone catch for ‘assessment year’ 2009/10 (April–March) was 217.7 t (down 22.3 t from 2008-09 and 39% of peak production during 1980-81). The progressively reducing annual TACC, set initially at 450 t (‘licensing year’ 2002-03, April–March) and subsequently revised to 380 t (2007-08), 320 t (2008-09) and 240 t (2009-10), was close to being fully caught only during the first 4 years. An interim TACC of 55.2 t set for April–June 2009 to adjust for the change in ‘licensing year’ from April–March to July–June was not caught. From ‘assessment year 2008-09 to 2009-10, fishing effort increased marginally (<0.2%), but remains at a 20-year low following an overall decline over the past decade (Fig.6d). Catch rate fell progressively over the past

6 years from 0.71 kg per potlift to an all-time low during 2009-10 of 0.37 kg per potlift. This downward trend in catch rate triggered a review of the TACC, but the decision was to leave the TACC at 240 t for 2010-11.

The Western Zone ‘spawning biomass’ (mass of all mature animals in the population) during 2009-10 is estimated by Victoria’s length-structured stock assessment model at 48% of the 1951 level (derived using raw CPUE as an index of abundance), which is above the target biological reference point of 40% and limit biological reference point of 20%. The Western Zone ‘available biomass’ (mass of all animals in the population larger than the legal minimum length) during 2009-10 is estimated by the model at 19% of the 1951 level and is therefore below both the target (40%) and limit (20%) biological reference points.

In June 2009 (Hillard, 2009) the Victorian Government announced the results of a \$5 million by-back scheme to remove effort in the fishery by removing 14 licences and 29.3 t of quota in south-west Victoria. This was to reduce effort in the fishery making the industry more sustainable into the future, and to make the industry much more financially viable (www.premier.vic.gov.au).

Eastern Zone: Catch rates declined continuously from the 1950s until the mid-1990s, then rose into the early period of quota management (200-02–2006-07), before a subsequent decline back to the level of the mid-1990s. The Eastern Zone catch for 2009-10 was 42.8 t (up 2.1 t from 2008-09 and 30% of peak production during 1983/84). The TACC, initially set at 60 t (2002-03) and revised to 66 t (2007-08) with an interim TACC of 6.9 t during April–June 2009, has never been caught. From 2008-09 to 2009-10, fishing effort increased by 12%, while catch rate fell from 0.38 to 0.36 kg per potlift. The drop in catch rate triggered a review of the TACC, but the decision was not to alter the TACC for 2010-11.

The Eastern Zone ‘spawning biomass’ is estimated at 29% of the 1951 level (derived using November–April CPUE) and is therefore below the 40% target. The Eastern Zone ‘available biomass’

is estimated at 20% of the 1951 level, which is therefore below the 40% target and at the 20% limit.

Western Australia

Stock summary: The southern rock lobster fishery in Western Australia is part of a multi-species pot fishery known as the ‘Southern Crustacean Fishery’. The fishery is managed by input controls and in addition to lobsters, most commercial fishers in this fishery are permitted to land western rock lobsters (*Panulirus cygnus*) and deep-sea crab species: giant crabs (*Pseudocarcinus gigas*), crystal crabs (*Chaceon albus*) and champagne crabs (*Hypothalassia acerba*).

The southern rock lobster fishery in Western Australia has had an interesting history. Catch statistics going back to the late 1960s show the fishery to have achieved small, but relatively stable catches of 10-20 tonnes per annum right up to the 1990s. At the start of the 1990s the catches increased dramatically to peak at ~100 t per annum for a few seasons in the mid-1990s. The large catches in this period coincided with the discovery of deep-water fishing grounds for southern rock lobsters in depths of >100 m, as well as the establishment of a modern processing operation in the centre of the fishery for exporting the catch. Since the mid-1990s catches have declined steadily and in the last five years have hovered at ~30-50 t per season (Fig. 7).

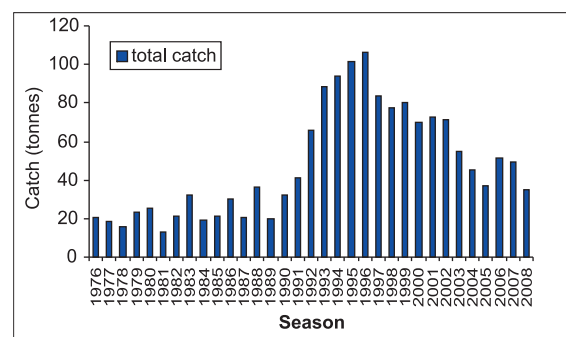


Fig. 7. The catches of the southern rock lobster fishery for *Jasus edwardsii* in Western Australia

The future of this fishery remains uncertain. It is clear that the catches of the mid-1990s were not sustainable and there is some uncertainty about the sustainability of the smaller catches of recent years.

This is because recent research modelling larval release and return locations of southern rock lobsters (Bruce *et al.*, 2007), has shown that Western Australian waters are likely to receive nearly all of the settling pueruli from brood stock in the States waters, with very little contribution from the much larger stocks of this species to the east. Given that the status of the breeding stock of southern rock lobsters in Western Australian waters is uncertain (Melville-Smith and Thomson, 2009); it is possible that future recruitment could be limited by the reduced size of the breeding stock that must inevitably have followed the high landings of the 1990s.

There is acceptance that there is a large amount of latent effort in this fishery and this has been one of the prime motivating factors behind moves which are afoot, to revise the management of this fishery. The consultation phase relating to these proposed arrangements is underway (Anon., 2009a).

Overall summary: The catches of *J. edwardsii* in all the states are shown in Fig. 8. The species is considered to be fully- or over-exploited across the range. This status is partly a function of the management environment that is applied. For example, size limits do not respond to large variation in growth across the range of the species with only two systems used. Better matching of management controls to lobster biology would thus result in lower harvest rates for the same TACC. Options for better long term yield exist and include: better matching of harvest rate and size limits to regional growth; transfer of effort away from depleted inshore stocks to offshore areas with zonal management; and translocation of recruits into areas with higher productivity (Gardner and van Putten, 2008).

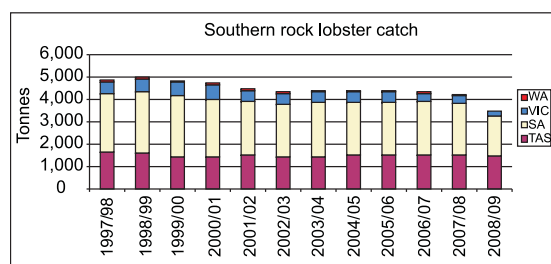


Fig. 8. The catches of *Jasus edwardsii* in Tasmania, South Australia, Victoria and Western Australia

Stock assessment modelling has progressed in recent years through collaboration between South Australia, Victoria and Tasmania in the construction of length-based population model for assessing stocks and harvest strategy evaluation. Outputs from this model included estimated egg production, which has declined to low levels in many areas of the fishery, especially in western areas which are believed to be more important larval sources (Bruce *et al.*, 2007). Egg production in Tasmania is considered to be around 15% of pristine in the northern areas, but above 80% in the south west (Gardner and Ziegler, 2010). In Victoria egg production is considered to be at about 47% in the Western Zone and about 30% in the Eastern Zone and in South Australia between 10 and 20% of the historic unfished situations. Long-term trends in egg production are being monitored by South Australian, Tasmanian and Victorian researchers to inform management.

Rising foreign exchange rates and oil prices are significant issues in the *J. edwardsii* fisheries. Declines in real price and increase in costs such as these apply pressure for a lower TACC to maintain or raise profit and the capitalisation of quota units.

Declines in exploitable biomass of *J. edwardsii* in Tasmania, South Australia and Victoria are attributed to below average recruitment of stock into the fishery from 2004 onwards (Fig. 9). This decline in recruitment was detected through puerulus catch data and length-based model estimated recruitment (fitted to length sampling data plus catch and effort data). In addition, average weights of lobsters in the north-east have been trending upwards in combination with falling catch and catch-rate, which has been interpreted as recruitment decline. Similar data are not available for Western Australia.

Each state has responded to declines in recruitment with cuts to the TACC through agreement between industry and government. The process for selecting the change in TACC has varied between regions with some states targeting pathways to higher economic yield based on model projections while others have used advisory committee consensus to respond to signals in total catch and catch rate.

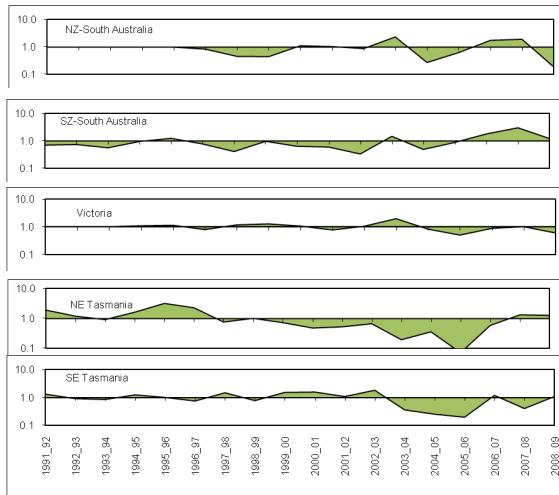


Fig. 9. Puerulus catch data pooled for sites in South Australia, Victoria and Tasmania. Data are shown as the proportional difference from the average for each region. Hence, a value of 1 implies the catch is equal to the long-term average. Years where the catch is double or half the long term average have values of 2 and 0.5 respectively. The vertical axis is plotted on a log scale

There are other processes affecting harvest rate across the range that have not been included in the process of reducing the TACC. These are the displaced catch from marine parks and changes in recreational catch. However, the total magnitude of the increase in harvest rate from these factors is far smaller than that of the commercial catch but these can accelerate any decline in the stock.

Western rock lobster *Panulirus cygnus*

The western rock lobster occurs on the western seaboard of Australia and is found in commercial quantities from Augusta in the south to Shark Bay in the north, an area along approximately 1000 km of coast (Fig. 10). The fishery is Australia's most valuable single-species fishery; landings are valued at more than US \$245 million per year, with a flow-on value of approximately US\$500 million per year (de Lestang *et al.*, 2008). The stock is fully exploited (Phillips and Melville-Smith, 2005).

Management arrangements: The fishery is managed with input controls and has three management zones – the Abrolhos Islands (Zone A), the Northern Coastal Zone (Zone B) and the

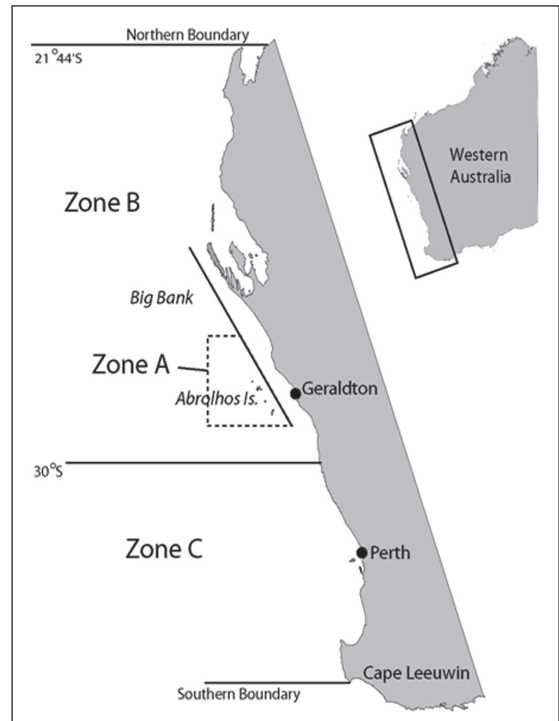


Fig. 10. Distributional range of the western rock lobster fishery for *Panulirus cygnus*

Southern Coastal Zone (Zone C). Currently (2009-10), 387 boats in the commercial fishery will operate some 31700 pots (traps) over the season. The legal minimum size for the fishery was set in 1900 at 76 mm carapace length (CL). It remained unchanged up to the 1993-94 season when it was increased by 1 mm to 77 mm, but only for the first 2.5 months of the 7.5 month fishing season, as a way of reducing fishing mortality and thereby improving the brood stock (Hall and Chubb, 2001). From the 2009-10 season the 77 mm size will be in place for the full 7.5 month season for all management zones.

A maximum size of 115 mm and 105 mm CL was introduced in 1993-94 the southern and northern zones of the fishery, respectively, in an attempt to improve the state of the brood stock throughout the fishery. Midway into the 2008-09 season the maximum size was reduced to 95 mm in Zones A and B and since 2009-10 to 105 mm in Zone C.

There is also a recreational catch component to this fishery. Licensed recreational fishers are

permitted to catch lobsters by diving, or by using up to two pots per person per day over the same season as commercial fishers and currently (2009-10 season) can keep up to five legal-sized lobsters per person per day. Since the late 1990s, recreational fishers have accounted for catches of between ~150-500 tonnes each season.

Compliance

An obvious threat to the sustainability of any commercial fishery, namely compliance of regulations, was addressed early on in the development of the fishery. In the 1960s, effort limitations were introduced and it was probably not a coincidence that illegal fishing activity became widespread. Subsequently, undersized animals and egg-bearing lobsters stripped of their brood were being processed and this illegal market spread from the local to markets in the eastern Australia.

Management introduced measures to counteract the problem, specifically legislation to restrict processing to licensed establishments, more inspectors, fines for offences were increased, convictions were recorded against the vessels rather than their skippers, and licenses could be cancelled after the third offence. These measures helped to make this a highly compliant industry. Even today, much effort goes into ensuring compliance and research into improving the efficiency of compliance (McKinlay and Millington, 2000; McKinlay, 2002). Currently as few as 1 to 2 individuals are illegal for every 1000 animals checked by enforcement officers.

Catches: Annual commercial catches since the mid-1980s have fluctuated between about 8000 and 14,400 tonnes, but on average have yielded around 11,000 tonnes.

Commercial catches from 1945-46 to 2008-09 for *P. cygnus* are shown in Fig. 11. Catches since the mid-1980s and increasingly in the last five years, have been constrained by management measures which have been introduced to limit effort in the fishery. The 2008-09 season for example, had a predicted catch of 9200 t, but through a range of management measures to reduce fishing pressure, the catches were limited to 7600 t (preliminary catch

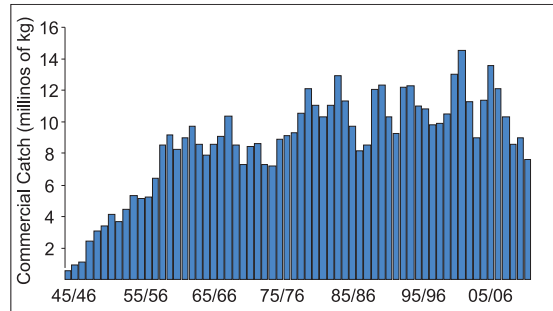


Fig. 11. Seasonal catches in the commercial western rock lobster fishery for *Panulirus cygnus* from post war years to date

figure to be updated later). The fishery will be constrained in 2009-10 to a target catch of 5500 t, but given that it is input controlled, it is acknowledged that there will be a likely range of around 4950-6050 t. These constrained catches are likely to make it possible for the fishery to maintain similar landings in the 2010-11 and 2011-12 fishing seasons (Anon., 2009b).

Status of the stock: After almost a decade of good to average puerulus settlements, below average and very low settlements were observed in the western rock lobster fishery of Western Australia in 2006-07, 2007-08 and 2008-09 (Fig. 12). There is a close relationship between pueruli settlement levels and recruitment into the fishery 3 and 4 years later (Phillips, 1986; Caputi *et al.*, 1995a, b). These findings have been developed into a predictive system that is recognized by industry, government, and fishers.

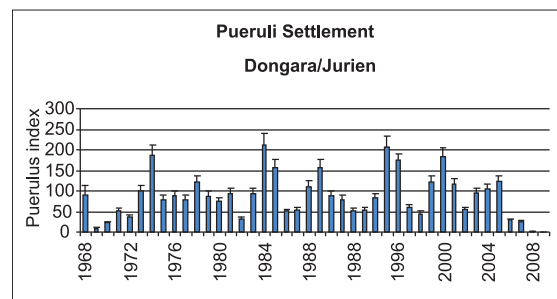


Fig. 12. Puerulus settlement index in the central region of the western rock lobster fishery for *Panulirus cygnus* (Dongara and Jurien) from 1968 to date

This relationship provides the background behind the concern expressed in the reduction in catch levels enforced in 2008-09 and being set in 2009-10.

There are two major research and management issues associated with the series of low settlements, the first being the causes that have led to the low settlement and the second, the management measures required to deal with the effects of the low settlement. These low settlement years will have a major impact on recruitment into the fishable stock commencing in the 2009-10 fishing season. The low recruitment will flow on to the catch of rock lobsters in combination with more restrictive effort management actions. However, without management actions being taken to significantly reduce exploitation on the rock lobster stock the recent years of low puerulus settlement would also have the potential to result in much lower breeding stock levels four to six years after settlement.

Predicting the catch: Although there are very significant peaks and troughs in the inter-annual catch, they are not considered due to fishing pressure. Rather, they are mainly due to environmental perturbations that drive the success of the post larval (puerulus) settlement. The El Niño Southern Oscillation (ENSO) influences the strength of the Leeuwin Current and the frequency and strength of westerly winds, which in turn are important factors in determining the level of puerulus settlement (Phillips, 1986; Pearce and Phillips, 1988; Caputi *et al.*, 1995a, b).

This relationship appears to have broken down. The current understanding of the influence of environmental factors (as measured by ocean temperature and wind conditions) on the last three low puerulus settlements seasons is that:

- the below average settlement of 2006-07 was explained by environmental factors (water temperature and wind) at all settlement sites,
- the very low settlement of 2007-08 was not well explained by the environmental factors at most settlement sites, and
- the extremely low settlement of 2008-09 was not explained by the environmental factors at

nearly all the settlement sites, in fact it went against the previous trends, based on the environmental conditions, i.e. settlement should have been average or better.

Breeding stock: One of the most serious threats to the fishery in the past – and one that still requires vigilant attention – is that the potential over-exploitation of the brood stock. Although western rock lobsters are considered to be a single stock; they do have regional differences in their biological characteristics. For example, both sexes mature at a much smaller size in the offshore Abrolhos Islands than near the coast, and even on the coast there are substantial differences in size at maturity. Fishing a population below or around the size-at-maturity during the rapid somatic growing phase generally optimizes the catch. Unless properly managed however, this is a risky management strategy because it could overexploit the parent stock, which in turn could lead to overfishing of recruits.

The state of the brood stock is currently measured by two different methods. The first, described by Chubb *et al.* (1995), uses commercial monitoring data from the northern and southern coastal management zones. The weakness of this index is that it does not automatically account for increases in fishing efficiency, which are inherent in the use of commercial catch-and-effort data. Although these data are adjusted to make up this deficiency (Brown *et al.*, 1995), there is inevitable uncertainty about the modified data.

The fishery-independent method of establishing an egg-production index was established for the Western Rock Lobster Fishery in the early 1990s (Caputi *et al.*, 2008). In brief, a survey is conducted each year at the same GPS positions on a number of sites covering the full extent of the commercial fishery. Standard fishing gear, bait, and lunar phase are used to limit the variables that could influence catch rates. Regional egg production is calculated from the number and size of breeding females caught in the pots, taking into account size-fecundity relationships. The weakness of this approach is that uncontrolled environmental factors such as temperature and swell at the time of sampling can affect catch rates.

New model: In recent times, a size structured population model has been developed for the fishery (Caputi *et al.*, 2008) which encapsulates among many other data inputs, the fishery independent and dependent breeding stock indices for each region fishery. The model is currently being used to derive breeding stock indices for the fishery and evaluate the status of the egg production and catches into the future, under different scenarios of effort reduction.

New management considerations: In 2008 and 2009 there have been a raft of new management arrangements introduced into the fishery to compensate for the very low settlements that have been observed since the 2006-07 season (see Fig. 12).

Primary sustainability objective: To ensure that the breeding stock in each zone remains above the threshold level (Fig. 13), and the probability of it still being above it still being above this level in five years time is 75%.

Other objectives are to:

- Build up breeding stock levels in northern part of the fishery, which is considered to be the most important egg production region in terms of larval survival and therefore future recruitment to the fishery.
- Allow for carry over of lobsters into future seasons and thereby provide more certainty and consistency for industry.
- Smooth catch peaks for marketing purposes.
- Reduce cost of fishing and thereby increase profitability (in line with the principals of maximum economic yield theory).
- Maximize the quality of landed lobsters.

While these are general objectives for the 2009-10 season, a far more detailed set of sustainability and economic objectives, set out as decision rules for the fishery, is being canvassed for comment (Donahue *et al.*, in press).

In practical terms the new arrangements mean that in the 2009-10 season the catch will be restricted to between 4950 and 6,050 t with target of 5500 t. To optimise economic benefits and address equity

issues, catch targets and limits have been set for each management zone in the first and second halves of the season.

A 5500-t catch is likely to be worth just over A\$ 156 million, compared with A\$ 300 million in 2007. The number of boats has declined in 2009-10 by about 20%. In the northern zone (zone B), for example, in December 2008 there were 89 boats authorised to fish, now there are 71. The number of licensed pots has not changed, but fishers will only be able to fish 40% of the pots they own, they will only be permitted to fish on weekdays, and then only on four days of the week. The numbers of days of closure will be adjusted to ensure that the target catch is achieved. Recreational fishers will also be constrained from 8 to 5 lobsters per day, per person.

All of these controls are designed to limit effort in the fishery to thereby ensure that the breeding stock level is not further depleted. The controls are also intended to smooth the catch and reduce the economic impact of the record low puerulus settlement in the last three years.

The target and threshold harvest rate values used in these graphs (Figs. 13 and 14) were based on the period up to 2007-08 and are therefore indicative

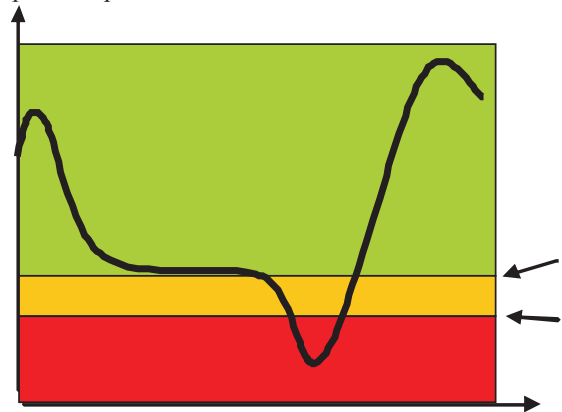


Fig. 13. Hypothetical example of variation in rock lobster egg production of *Panulirus cygnus* over time with reference to biological sustainability reference zones. Variation in WRL breeding stock abundance as a percentage of unfished biomass over time in relation to two biological reference points, the 1980 level (BRP) and 20% below this level (BRP20). The two BRP represent different levels of management action required

only. The Maximum Economic Yield based target and threshold values are highly unlikely to be static. They will vary through time based on the current stock size, incoming recruitment levels and a variety of cost and price inputs.

Reference values for indicators are defined as:

Target: The optimum value (range of values) for the fishery from a sustainability/biological and/or economic perspective.

Threshold: An upper or lower boundary outside of which a management response may be required.

Limit: An upper or lower boundary outside of which an immediate, significant and more prescribed management action is required, *i.e.* management options become narrower and their implementation is urgent if the limit is breached.

The performance of the fishery in terms of harvest rates for Zone B, selected as an example, is shown in Fig. 14.

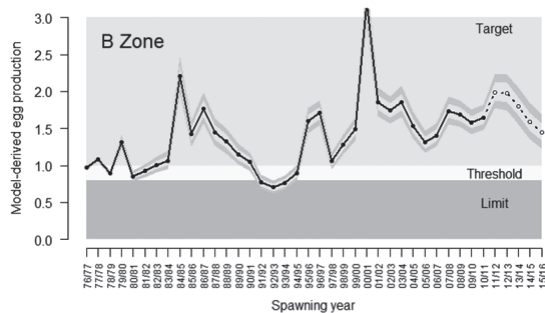


Fig. 14. The northern coastal zone (Zone B) in the *Panulirus cygnus* fishery as an example of the model derived egg production index. Solid lines represent estimates based on known levels of puerulus settlement to date and different management scenarios. Dotted lines represent the continuation of these effort scenarios assuming future puerulus settlement remains at 2008-09 levels (*i.e.* extremely low, which is the worst case scenario). The light and dark grey areas represent the 75 and 90% confidence regions around the estimates

The catch prediction model is shown in Fig. 15. The catch prediction indicated that higher catch levels would be possible, but the catches will be limited to ensure the long-term sustainability of the fishery.

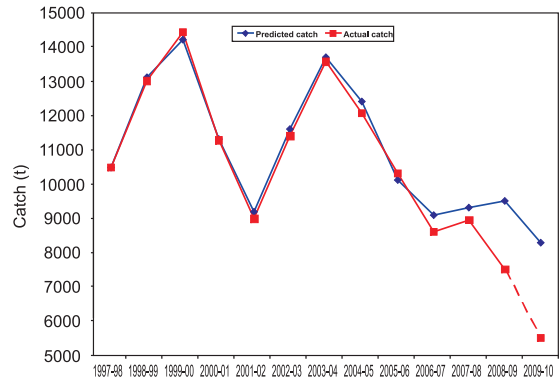


Fig 15. Catch predictions of *Panulirus cygnus* showing the effects of catch limits imposed in 2008-09 and 2009-10

Economics and social factors

The current shift in focus towards maximizing economic returns has generated new controversies, notably whether the industry's management committees should be advising government on short-term market benefits or concentrating on stock sustainability issues alone (Donohue, 1998 a, b). More recently economic concerns have risen about the impact of increases in fuel costs on the fishery.

To assist in the decision-making process, the economic impacts on fishers of the different management measures were evaluated to assess the short-term (1-2 years) effect on the net revenue (Thomson and Caputi, 2005). Management options (such as reductions in the number of traps allowed to be used in the fishery, seasonal closures and changes to the maximum size of lobsters taken) to achieve the 15% reduction in total allowable effort for the zone vary in the way they could impact on the fishers' financial position, because they have different impacts on the value of both the income and expenses. The analysis showed that the most efficient management options were those that involved closing the fishery during periods when the catch rate of rock lobsters is low. These periods (ranked from the most efficient to the least efficient in Year 1), included: (a) 21 days from 15 January to 10 February; (b) 16 days from 15 November to 30 November; (c) late season closures for 3 to 7 days around the full moon; (d) June closure; and (e) early season closures for 3 to 7 days around the full

moon. By the second year all of these closures resulted in increased net revenue due to the cost savings and the reduced negative impact on catch.

Lobster pot units were trading at A\$10,000 each in December 2009, one third of the price in 2000 when the fishery was achieving high catches.

The western rock lobster fishery has moved away from having the attainment of MSY as an objective, towards ensuring that harvest rates for the fishery are consistent with the principles of Maximum Economic Yield (MEY).

Conclusions

In Australia we define sustainability of our natural resources under the expression, ecologically

sustainable development. It is a dynamic concept that seeks to integrate short and long-term economic, social and environmental effects into the decision-making of government and industry. We have attempted to approach the conclusions on the sustainability of the spiny (rock) lobster fisheries in Australia along these guidelines and to include the information of the stock, the economic situation and also social effects. However, every fishery jurisdiction has slightly different ways of expressing the outputs of the assessments.

There have been significant reductions in the catches of *P. ornatus* in Torres Strait for three years, factors other than stock size are believed to be involved. A reduction in effort caused by a voluntary

Table 4. Annual performance for commercial spiny lobster fisheries subject to export approval under the Australian Governments Environmental Protection and Biodiversity Conservation Act 1999

Species	Location	Current performance in 2007/08 or 2008	Performance measure
<i>Panulirus ornatus</i>	Torres Strait	Acceptable	The PZJA to initiate a management response if total catch is likely to be higher than the estimated catch at Maximum Sustainable Yield
<i>Sagmariasus verreauxi</i>	New South Wales	Acceptable	Multiple performance indicators and trigger points specified in Fisheries Management Strategy. A key measure is maintenance of spawning biomass at or above 25% of pre exploitation level.
<i>Jasus edwardsii</i>	Tasmania	Acceptable	Bycatch, protected species interaction, egg production and biomass acceptable relative to thresholds
<i>Jasus edwardsii</i>	South Australia (Northern Zone)	Acceptable	A range of measures that mainly address bycatch mitigation within the fishery
<i>Jasus edwardsii</i>	South Australia (Southern Zone)	Acceptable	A range of measures that mainly address bycatch mitigation within the fishery
<i>Jasus edwardsii</i>	Victoria (Western Zone)	Review of TACC triggered as available biomass fell below 20% of 1951 level	Spawning biomass and available biomass to remain above trigger limit of 20% of 1951 levels
<i>Jasus edwardsii</i>	Victoria(Eastern Zone)	Acceptable	Victoria (Eastern Zone)
<i>Jasus edwardsii</i>	Western Australia	Acceptable	Catch to remain below 40 tonnes for the Esperance Fishery
<i>Panulirus cygnus</i>	Western Australia	Acceptable	Spawning biomass at Abrolhos Islands and coastal regions to remain above 22% of unfished level

buyout in 2007, together with economic drivers such as high fuel prices and a downturn in the export market are all thought to have contributed to reduced effort in the fishery. The stock is classified as “not overfished” by the Bureau of Rural Sciences (Bensley *et al.*, 2009). Economic drivers such as high fuel prices and a downturn in the market are thought to have contributed to reduced effort over the last three years.

In New South Wales, *S. verreauxi* is a good news story. It was heavily exploited in the past and the current management strategy is aimed at rebuilding the depleted stocks and early results suggest that this initiative has achieved success and the TAC has been easily achieved. Catch per Unit Effort (CPUE) has doubled between 2000-02 and 200-08 and exceeds the 1998-99 benchmark by nearly 50%. The market price for shares has almost tripled in the past four years and demand is strong to both purchase and lease quota/shares.

Jasus edwardsii is fished in four States and these are also subdivided into zones in Victoria and South Australia. In Tasmania, the last stock assessment (up to end of Feb 09) indicated some problems in the fishery. It has been found that the catch rate has fallen in the last two years, almost the level it was at the start of the Quota Management System in 1998, undoing much of the stock rebuilding that occurred over the last decade. This decline has been so rapid that it is unlikely to be the result of poor puerulus recruitment alone; either natural mortality has been higher than normal, or catchability is lower than normal.

The situation in South Australia is similar. In the northern zone the biomass of lobsters has declined to a historically low level and this fishery should be considered as an overfished resource. There are clear signs that the resource on which the southern fishery is based has also declined. CPUE in the northern zone has decreased over the last 8 seasons from 1.4 to 0.7 kg/potlift, despite catches being cut by half. In the southern zone catch rates have fallen in each of the last 6 years from 2.1 to 0.7 kg/potlift. This reflects a corresponding decline in biomass which in turn reflects low recruitment over this period. Pre-recruit indices in the southern zone

fishery in 2007 and 2008 were two of the lowest on record.

In Victoria catch rates reached new record lows in each of the last three years so that it's now below 0.4 kg potlift, this is despite the catch dropping by 58% since 2000.

The Fishery Status Report for the West Coast Rock Lobster Fishery for *P. cygnus* published by the Department of Fisheries in Western Australia clarifies both the stock level and the fishing level as “acceptable”. This comes from the annual performance for commercial fisheries subject to export approval under the Australian Governments Environmental Protection and Biodiversity Conservation Act 1999. In Table 4 are listed all the fisheries discussed in this paper and their scores under the ACT and the Performance Measure against which they are judged. Clearly sustainability is being assessed in a wide range of ways. It is not easy to define sustainability. Everyone has their own definition, and clearly all of the scientists, managers and fishers believe that their fishery is sustainable, even if they do not completely agree with all the measures that have been implemented to achieve sustainability.

Dramatic changes have occurred in the Western Australian *P. cygnus* over the last couple of years. Annual commercial catches since the mid-1980s have fluctuated between about 8000 and 14,400 t, but on average have yielded around 11,000 t. Currently (2009-10), 387 boats in the commercial fishery will operate some 31700 pots (traps) over the season. Catch levels have been set for 2009-10 to a target of 5500 t. Reductions to fishers incomes are certain and unpopular.

These changes reflect concern by the managers to maintain sustainability of in the West Coast Rock Lobster Fishery in the face of three years of extremely low levels of puerulus settlement, which will be reflected in low availability of animals in the catch in 3-4 years, and to ensure that sufficient lobsters avoid capture in the fishery and join the breeding stock, to maintain the population. New management arrangements have been introduced for the West Coast Rock Lobster Fishery and the sustainability

objective is to ensure that the breeding stock in each zone remains above the threshold level, and the probability of it still being above it still being above this level in five years time is 75%.

Achieving this objective will take careful stewardship, and additional restrictions may be necessary if the levels of pueruli settlement do not increase over the next few years to the levels historically seen in this fishery. Since the reason(s) for the current low levels of pueruli settlement is unknown, the future remains uncertain. Some misinformation has also been reported. In a Fishing News International article (2009) it was reported that the 5500 t total catch introduced for 2009-10 will apply for the next three seasons up to 2011-12. However, it has in fact only been set for the 2009-10 season, and depending on other developments, including future levels of annual pueruli settlement, these cuts may yet be inadequate as the recruitment failure has been so profound.

It is interesting to point out that had this paper been written five years earlier it is likely that the commercial fisheries for these lobster species would have been very different than what it is today. The low recruitments (and subsequent low catches) were totally unexpected and at this stage do not appear to be linked between species.

There are many concerned Australian rock lobster fishers, mainly in the southern and western rock lobster fisheries and in recent times there have been reports from disgruntled fishers in many articles in the media. In Western Australia, it was reported (Fishing News International, 2009) that up to one third of the fishers would be unlikely to go to sea in the 2009-10 season. However, over the same season, other fishers were doubling up their number of pots by buying or leasing from others to make fishing financially viable. Because the western rock lobster fishery is currently input, not output controlled, fishers all fished hard through the 2009-10 season, which led to all zones being closed before the official (30 June) end of the season. Zones A and C closed in April and Zone B in mid-June. The social effects to the fishers and the coastal fishing communities as a result of these early closures, has yet to be determined.

Although all of the four fisheries have a recreational component, catches of this section of the fishery generally do not appear to be influencing the sustainability of the total fishery. However, in Tasmania there are regions experiencing rapid ecological change where up to 50% of the total catch is taken by the recreation sector. Managers in this fishery are also concerned that increase in recreational catch can accelerate stock decline during this period of low recruitment.

The southern rock lobster fisheries and the western rock lobster fishery in Australia face an uncertain future but action is being taken to reduce the levels of effort in all sections of these fisheries to attempt to increase the long term community benefit from these fisheries. The spiny lobster fisheries in Australia remain its highest valued species worth A \$ 0.4 billion in 2007-08 but the real value of the fisheries has fallen from A \$ 0.7 billion in 1999-00 because the species is export oriented and the strength of the A \$ against the currencies of major partners, particularly the US dollar and Japanese yen, has reduced the competitiveness of the Australian fisheries in recent years (ABARE, 2009).

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