*Asian Fisheries Science* **21**(2008):469-481
https://doi.org/10.33997/j.afs.2008.21.4.010



Asian Fisheries Society, Manila, Philippines

# An Observer-based Assessment of the Estuarine Fishery for Eastern Sea Garfish (*Hyporhamphus australis*) in Australia

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## Abstract

The estuarine fishery for eastern sea garfish (*Hyporhamphus australis*) in New South Wales (NSW), Australia was assessed using observers to quantify retained and discarded catches and interactions with threatened species. The fishery uses seine nets that are designed to fish the surface layers. Observers recorded 40 taxa caught during two fishing seasons between April 2005 and March 2006. Eight taxa were retained and 39 were discarded. The target species, eastern sea garfish, represented ~90% of the total catch by weight and numbers. The majority of discarded fish were small individuals of non-commercially important species. Overall, ratios of retained to discarded catch were ~ 23:1 by numbers and weight. During the period of assessment, this beach-based estuarine fishery had limited by-catch, did not target juvenile or spawning aggregations of con-specifics, had no record of deleterious interactions with threatened species and was unlikely to have had any major ecological impacts. The relatively low levels of by-catch and juvenile-sized eastern sea garfish probably reflect regulations that: (i) prohibited fishing over beds of the seagrass *Posidonia australis*; and (ii) increased the minimum size of mesh in fishing nets.

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## Introduction

The eastern sea garfish *Hyporhamphus australis* (hereafter sea garfish), attains ~ 40 cm fork length (FL) and is a pelagic, schooling, inshore marine species targeted by commercial and recreational fishers in sheltered bays and in estuaries (Kailola et al. 1993). The fishery for sea garfish operates along the eastern coast of Australia, almost exclusively in the coastal waters of New South Wales (NSW). The commercial fishery is divided into two sectors, estuarine and ocean, which require separate endorsements. The garfish are captured using seine nets that have been designed to fish the surface layers. The regulated gear specifications are the same in the estuarine and ocean fisheries, with nets being limited to less than 300 m in length and having mesh sizes of not less than 28 mm nor more than 36 mm. Fishing generally involves two to six fishers and may either be beach-based, where small boats are used to encircle schools of fish and the nets are retrieved onto the shore, or boat-based, where lampara-style nets are deployed and retrieved to the boat (Stewart et al. 2004).

The estuarine fishery for sea garfish is relatively small averaging, since 1998, ~ 8 tonnes year$^{-1}$ which is valued at around AUD$ 40K at the point of first sale (New South Wales Department of Primary Industries - NSWDPI catch statistics). It is, however, a lucrative short-term fishery for some fishers. Sea garfish are highly sought for human consumption both domestically and overseas and smaller fish are considered excellent bait. Unfortunately, the stock of sea garfish has declined markedly since the mid 1990s and is currently listed as being overfished (Stewart et al. 2005). In response, a recovery program aimed at protecting juveniles and reducing fishing mortality on adults has been implemented by the governing fisheries agency (NSWDPI). As a part of this recovery program, the minimum allowable mesh in garfish seine nets was increased from 25 to 28 mm (Stewart et al. 2004) and the estuarine sector of the fishery was completely closed in August 2003.

Following indications of improved recruitment of sea garfish during 2004, and intense lobbying of the government minister by commercial fishers, the fishery was re-opened in 2005 under a permit system. Under the permit system: (i) the length of the net was limited to 300 m; (ii) mesh sizes (stretched length) could not be smaller than 28 mm nor greater than 36 mm; (iii) hauling of the net had to be done in a continuous manner and could not be towed by any vessel; (iv) fishing was not allowed on weekends or public holidays; (v) fishing was prohibited over beds of the sea-

grass *Posidonia australis*; and, (vi) fishers were required to complete a daily log of their fishing operations that included information on the number of hauls done on the day, the fishing locations, whether it was beach or boat-based and the total weight of sea garfish caught.

Despite the re-opening of the fishery, there remained major concerns that estuary fishing for sea garfish may not be ecologically sustainable. Concerns were: (i) because other species of the family Hemiramphidae spawn in vegetated estuarine habitats (Berkeley & Houde 1978; Jordan et al. 1998; Jones et al. 2002) that the estuarine fishery would catch too many juveniles and/or spawning adults; (ii) using small mesh nets (28 mm) in areas of known high abundance of juveniles of commercially and recreationally important species (Bell & Pollard 1989), would result in substantial levels of by-catch; and, (iii) the potential for interaction with threatened species such as dolphins and turtles (Ganassin & Gibbs 2005).

There have been few observer-type studies on fisheries that target hemiramphid fishes and any previous findings may not be applicable to this estuarine seine fishery. McBride & Styer (2002) used onboard observers to document the catch in the South Florida lampara net fishery for Hemiramphidae, and they concluded that the fishery was highly selective and that by-catch was insignificant because of the surface-oriented behaviour of the fish and the design of the net. The fishery in Florida is, however, a coastal boat-based fishery that uses much larger nets than the fishery for sea garfish in Australia (McBride et al. 1996). Observer studies that have documented the discarded and retained catches of estuarine seine-fisheries in NSW have targeted different species that are caught using larger nets (1000 m headline length), larger meshes ( >50 mm in the bunt) and in different estuaries (Gray et al. 2001; Gray & Kennelly 2003). Given the concerns outlined above, the aim of this study was to assess the estuarine fishery for sea garfish in terms of its retained and discarded catch and its potential impact on habitats and threatened species.

## Materials and Methods

The observer study was done in the Port Stephens estuary (32º43’S, 152º09’E), where more than 95% of the estuarine catch of sea garfish has been reported since 2002 (NSWDPI catch statistics). After the fishery was re-opened in 2005, all of the 13 permits issued to allow fishing for sea garfish were allocated to this estuary. The estuarine fishery for sea garfish

is seasonal, with 98% of the reported catch being taken between February and June (inclusive) since 1998 (NSWDPI catch statistics). Therefore, the observer study was done during March and April in 2005 and 2006.

Scientific observers accompanied commercial fishers during their fishing operations throughout the study period. During each sampling occasion, observers recorded information that included: (i) the names of the fishers; (ii) the date and time of hauling; (iii) exact locations; (iv) substrate type; (v) gear specifications; (vi) weather conditions; and, (vii) any interactions of the fishing operations with threatened species. After each haul the catch was sorted into the retained and discarded portions by the observer and commercial fishers. The condition of the by-catch and its probability of survival, if discarded immediately as part of the normal fishing operation, were also recorded. Data were collected on the weights, numbers and lengths (FL - rounded down to the nearest whole cm) of all species caught for both the retained and discarded portions of the catch. Weights of porcupine fish (*Dicotylichthys punctulatus*) were not recorded because of their habit of inflating themselves with water. When the catch of a species was too large to fully sample, sub-sampling was done by measuring approximately half of a standard fish box (~ 10 to 15 kgs) of that species and the total numbers estimated using simple proportions of the weight of fish measured and the total weight of the catch. There was one day when the total catches from two hauls were combined prior to sampling owing to logistic difficulties in handling the catch.

Total fishery catch and effort information was obtained from fishers' compulsory daily logbooks. These logbooks detailed the number of days targeting sea garfish and the number of hauls done each day. The sizes of sea garfish landed in the ocean fishery were also measured concurrently with this observer study as part of the NSWDPI fisheries monitoring program. The monitoring program takes routine sub-samples from commercial landings and records fish lengths as FL. The sizes of these ocean caught sea garfish were compared with those retained by estuarine fishers using Kolmogorov-Smirnov tests (Sokal & Rohlf 1981).

# Results

## *Catch, effort and observer coverage*

Commercial fishers reported a total of 24 hauls using garfish hauling nets in 2005 and 22 in 2006 (Table 1). All commercial fishing efforts were reported as beach-based. Observers sampled seven days and nine hauls in 2005 and five days and six hauls in 2006, which represented 38 and 28% of the total hauls done in the fishery during those years, respectively. The total observed landed catch was 2,736 kg of which 96% was retained and 4% was discarded. The overall ratios of retained to discarded catch were 23.1:1 by numbers and 22.8:1 by weight.

Table 1. Commercial fishing effort, sea garfish catch (kgs) and observer coverage during 2005 and 2006.

| | Commercial effort | | | Observer coverage | | | Percent coverage | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Days | Hauls | Sea garfish | Days | Hauls | Sea garfish | Days | Hauls | Sea garfish |
| 2005 | 21 | 24 | 5,791 | 7 | 9 | 923 | 33% | 38% | 16% |
| 2006 | 18 | 22 | 4,463 | 5 | 6 | 1,527 | 28% | 28% | 34% |
| Total | 39 | 46 | 10,254 | 12 | 15 | 2,450 | 31% | 33% | 24% |

During the observer coverage there was no correlation between the weight of fish discarded and the weight retained per day (Pearson's correlation coefficient $r = 0.57$, 10 d.f., $P > 0.01$), suggesting that the quantity of by-catch was independent of the quantity of target fish captured.

## *Retained catch composition*

Observers recorded eight species to be retained during the two years of the study. Sea garfish was present in every haul and represented 93% of the retained catch by weight and numbers (Table 2) and approximately 90% of the total landed catch by weight and numbers. No sea garfish were discarded, but some unmarketable individuals of the other retained species were observed to be discarded at various times (Table 3).

## *Discarded catch composition*

Observers recorded 39 species to be captured and discarded (Table 3). The majority were captured infrequently, with the most commonly caught being rough leatherjacket (*Scobinicthys granulatus*) and striped sea pike (*Sphyraena novaehollandiae*), both occurring in 43% of the days observed. The two most abundant species observed to be discarded, hardyheads (Atherinidae spp.) and flat-tail mullet (*Liza argentea*), are schooling fishes and were observed in 29 and 21% of the days, respectively.

Table 2. Summary of the total catch of retained species in terms of weight (kg), numbers and percent frequency of occurrence (%FO).

| Scientific name | Common name | Kg | Number | % FO |
|---|---|---|---|---|
| *Hyporhamphus australis* | Sea garfish | 2450 | 30932 | 100 |
| *Trachurus novaezelandiae* | Yellowtail scad | 75 | 968 | 7 |
| Atherinidae spp. | Hardyheads | 13 | 923 | 7 |
| *Sillago ciliata* | Sand whiting | 63.5 | 265 | 29 |
| *Sepioteuthis australis* | Southern calamari squid | 15.1 | 51 | 36 |
| *Sphyraena novaehollandiae* | Striped sea pike | 3.7 | 29 | 14 |
| *Sepia* spp. | Cuttlefish | 0.6 | 6 | 14 |
| *Acanthopagrus australis* | yellowfin bream | 0.3 | 1 | 7 |
| Grand total | 8 species | 2621 | 33174 | |

Table 3. Summary of the total catch of discard species in terms of weight (kg), numbers and percent frequency of occurrence (%FO). * denotes not weighed.

| Scientific name | Common name | Kg | Number | % FO |
|---|---|---|---|---|
| *Atherinidae* spp. | Hardyheads | 2.3 | 248 | 29 |
| *Liza argentea* | Flat-tail mullet | 12.8 | 117 | 21 |
| *Scobinicthys granulatus* | Rough leatherjacket | 5.75 | 103 | 43 |
| *Torquigener pleurogramma* | Banded toadfish | 0.55 | 96 | 21 |
| *Gerres subfasciatus* | Silver biddy | 6.4 | 90 | 14 |
| *Meuschenia freycineti* | Six-spined leatherjacket | 5.6 | 84 | 29 |
| *Enoplosus armatus* | Old wife | 1.5 | 75 | 7 |
| *Acanthaluteres spilomelanurus* | Bridled leatherjacket | 1.15 | 72 | 29 |
| *Sphyraena novaehollandiae* | Striped sea pike | 9.5 | 64 | 43 |
| *Upeneichthys* spp. | Red Mullet | 1.2 | 63 | 21 |
| *Monacanthus chinensis* | Fanbellied leatherjacket | 2.85 | 60 | 36 |
| *Parupeneus spilurus* | Blackspot goatfish | 1.2 | 51 | 21 |
| *Sepia* spp. | Cuttlefish | 3.25 | 50 | 29 |
| *Sillago ciliata* | Sand whiting | 8.2 | 45 | 29 |
| *Pelates quadrilineatus* | Trumpeter | 0.81 | 25 | 29 |
| *Pagrus auratus* | Snapper | 0.8 | 22 | 21 |
| *Aldrichetta forsteri* | Yelloweye mullet | 4.6 | 19 | 7 |
| *Rhabdosargus sarba* | Tarwhine | 2.6 | 18 | 36 |
| *Meuschenia trachylepis* | Yellowfinned leather-jacket | 0.8 | 18 | 14 |
| *Siganus fuscescens* | Black trevally | 0.75 | 16 | 21 |
| *Trygonorrhina sp.* | Eastern fiddler ray | 19.1 | 15 | 21 |
| *Sepioteuthis australis* | Southern calamari squid | 5.4 | 15 | 14 |
| *Trachurus novaezelandiae* | Yellowtail scad | 1.45 | 14 | 14 |
| *Platycephalus fuscus* | Dusky flathead | 6.55 | 9 | 29 |
| *Acanthopagrus australis* | Yellowfin bream | 2 | 9 | 21 |
| *Myxus elongatus* | Sand mullet | 0.4 | 7 | 7 |
| *Pomatomus saltatrix* | Tailor | 1.9 | 5 | 14 |

Table 3. Summary of the total catch of discard species in terms of weight (kg), numbers and percent frequency of occurrence (%FO). * denotes not weighed (continued).

| Scientific name | Common name | Kg | Number | % FO |
|---|---|---|---|---|
| *Tylosurus gavialoides* | Longtom - Stout | 1.1 | 5 | 14 |
| *Branchaluteres jacksonianus* | Pigmy leatherjacket | 0.15 | 5 | 14 |
| *Fistularia petimba* | Flutemouth - Rough | 0.35 | 3 | 14 |
| *Dicotylichthys punctulatus* | Porcupinefish - three-barred | * | 3 | 7 |
| *Pseudorhombus jenynsii* | Small-toothed flounder | 0.75 | 2 | 7 |
| *Strongylura leiura* | Longtom - slender | 0.1 | 2 | 7 |
| *Trygonoptera testacea* | Stingaree - common | 1.1 | 1 | 7 |
| *Myliobatis australis* | Eagle Ray | 0.8 | 1 | 7 |
| *Orectolobus ornatus* | Banded wobbegong | 0.7 | 1 | 7 |
| *Pseudocaranx dentex* | Silver trevally | 0.22 | 1 | 7 |
| *Tetractenos glaber* | Smooth toadfish | 0.1 | 1 | 7 |
| *Reicheltia halsteadi* | Halsteads toadfish | 0.1 | 1 | 7 |
| Grand total | 39 species | 114.9 | 1436 | |

### *Lengths of sea garfish captured*

The length distributions of sea garfish caught in the estuarine fishery in 2005 and 2006 were significantly different to those caught in the ocean fishery during the same years (Fig. 1, Kolmogorov-Smirnov tests, $D = 0.49$ and 0.36 respectively, $P < 0.01$ in each case). There were no differences between the sizes of sea garfish caught in the ocean fishery during 2005 and 2006 ($D = 0.05$, $P > 0.05$), however those caught in the estuary in 2005 were significantly larger than those caught during 2006 ($D = 0.28$, $P < 0.01$).

## Discussion

The findings and conclusions from this study are only relevant to the beach-based estuarine fishery for sea garfish as no boat-based fishing for sea garfish occurred during the study. The estuarine fishery for sea garfish during this study was highly selective; with the target species comprising ~ 90% of the total catch by weight and numbers. The predominance of the target species in catches was largely a result of their pelagic schooling behaviour and fishers only deploying their fishing nets when schools were detected from the beach. Non-target species that were retained in this fishery represented a small component of the total catch by weight (~ 6%) and contributed little to the income from this fishery. In this respect the

fishery is somewhat similar to the Hemiramphidae lampara net fishery in Florida where McBride & Styer (2002) reported an incidental by-catch rate of ~ 0.03 by weight (~ 1:30) slightly lower than the 1:23 ratio in the Australian sea garfish estuarine beach fishery. The capture of demersal dwelling species in the Australian beach-based fishery, such as eastern fiddler rays (*Trygonorrhina sp*.), dusky flathead (*Platycephalus fuscus*), common stingaree (*Trygonoptera testacea*) and eagle ray (*Myliobatis australis*), indicates that the net, at times, fishes the sea floor. This is likely to occur in shallow water when the net is being hauled onto the beach, rather than during the entire fishing operation.

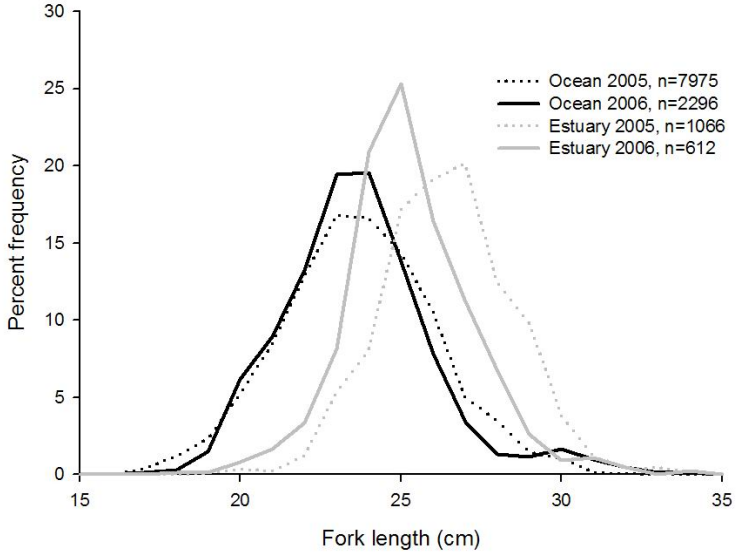


Figure 1. The lengths of sea garfish measured from the ocean and estuarine fisheries during 2005 and 2006.

Species discarded during the present study were done so for several reasons. Some were non-saleable species (e.g. banded toadfish (*Torquigener pleurogramma*), old wife (*Enoplosus armatus*), bridled leatherjacket (*Acanthaluteres spilomelanurus*)), some were individuals of saleable species below the legal minimum length (e.g. sand whiting (*Sillago ciliata*), snapper (*Pagrus auratus*), yellowfin bream (*Acanthopagrus australis*)), while others were captured in quantities that fishers considered too small to send to market on that day (e.g. sand whiting, hardyheads, southern calamari (*Sepioteuthis australis*)).

The by-catch in the estuarine fishery for sea garfish consisted mainly of small, commercially unimportant species. This is in contrast to the by-catch taken in other estuarine finfish seine fisheries in NSW, where the majority of the by-catch has been reported to be small individuals of commercially important target species (Gray et al. 2001; Gray & Kennelly 2003). Ratios of retained to discarded catch in these demersal estuarine seine fisheries were typically between 1:0.51 and 1:1.5, substantially lower than that observed during the present study.

During normal beach-based sea garfish fishing operations, obviously unwanted catch is sorted and released in shallow water. This practice is likely to promote the survival of discards. However during the observer study, all discarded fish were retained for sampling, making it impossible to gauge their chance of survival. The majority of by-catch had no obvious physical damage and larger sized species such as the common stingaree, banded wobbegong (*Orectolobus ornatus*) and eagle ray appeared to survive the fishing operation well. Some species, however, are likely to suffer from high rates of mortality. Leatherjackets (family Monacanthidae) were almost always caught by their dorsal spines in the netting and in general were badly damaged when removed. Likewise, small pelagic species (e.g. hardyheads) appeared delicate and unlikely to survive being hauled onto the beach prior to possible discarding.

The large number of species (40) and small sizes of many captured individuals indicated that the small mesh (28 mm) used in the estuarine sea garfish fishery has the potential to be largely non-selective for non-target species. A similar situation was reported by Cabral et al. (2003) who studied a beach seine fishery in Portugal that targeted small pelagic species. The 20 mm mesh used in that fishery resulted in unacceptably high levels of by-catch of juvenile fish because the fishery operated in known nursery areas.

It is well documented that seagrass (*Posidonia australis*) provides nursery habitat for a wide variety of fish (Jenkins et al. 1997; Rotherham & West 2002). Therefore, it is hypothesized that the banning of hauling nets over *P. australis* in the NSW fishery has removed a potentially significant by-catch problem. However, hauling of nets is still permitted over the seagrass *Zostera capricorni* which is also an important nursery habitat for many species (Worthington et al. 1992; Rotherham & West 2002). Preventing hauling over beds of *Z. capricorni* may decrease the by-catch in this fishery even further. Another benefit of the management restriction to hauling over *P. australis* is that it provides some protection to sea garfish

that may be feeding (Parsons 2002) or using the seagrass as a spawning habitat. Spawning over *P. australis* has not been demonstrated for sea garfish; however such habitats are important for the spawning of other species of Hemiramphidae (Berkeley & Houde 1978; Jordan et al. 1998; Jones et al. 2002).

The estuarine fishery for sea garfish does not currently target spawning aggregations. The fishery operates between February and June, because these are the times during which sea garfish are sufficiently abundant in estuaries to make them a viable commercial fishing target. The spawning season for sea garfish is from June to December inclusive (Hughes & Stewart 2006), hence sea garfish caught in estuaries between February and June are unlikely to be spawning. This observation lends weight to the model that, unlike many other hemiramphid fishes, sea garfish in NSW may not be reliant on seagrass as a spawning habitat. Rather, their observed spatial and temporal patterns of distribution suggest that near-shore algal habitats may be more important for spawning.

The sizes of sea garfish observed in estuarine catches, and also those in the ocean fishery (Fig. 1) suggest that the regulated change in permissible mesh size has been successful in minimising the catch of juvenile sea garfish (Stewart et al. 2004). In addition, the estuarine fishery caught almost no juvenile-sized sea garfish (< 21 cm FL; Hughes & Stewart 2006) during the two-year study period. This observation supports the model that the estuarine sea garfish fishery in NSW targets schools of adult fish that enter the estuaries between February and June, presumably to feed.

Observers recorded no interactions of the fishing operations with threatened species; however only a small number (15) of hauls were observed. There remains the potential for interactions with predators such as dolphins and birds that feed on sea garfish, but the severity and consequences of such interactions cannot be assessed here.

We cannot quantify the ecological impact of the catch taken in the estuarine sea garfish fishery. Nevertheless, the relatively low proportion of by-catch and the fact that it consisted mainly of juveniles, which are likely to suffer from high levels of natural mortality, suggests that the ecological impact may be negligible. Any physical damage to the substrate from hauling is unlikely given the net is designed to fish the surface layers and that hauling over seagrass has been shown not to have any detectable effects (Otway & Macbeth 1999). It is likely that any significant ecological impact from this fishery would be related to the removal of large numbers

of sea garfish that are known to be important prey for predatory fish, birds and dolphins (Kailola et al. 1993).

It is not known whether the presence of observers caused any change in the fisher's normal behaviour. It is possible that fishers did not fish in areas, or at times, where they expected to catch large quantities of by-catch. It is also possible that the quick sorting of discards at the waters edge (in order to demonstrate a high likelihood of survival of discards) was not a normal practice. This study, however, observed ~ 33% of all reported hauls during the two-year study period. Therefore, it is unlikely that fishers altered their operations significantly because of the potential losses in income by doing so.

## Conclusions

This observer-based assessment concludes that the beach-based estuarine fishery for sea garfish during 2005 and 2006: (i) had only limited by-catch; (ii) did not target juveniles or spawning aggregations; (iii) had no record of deleterious interactions with threatened species; (iv) was a minor component of the total sea garfish fishery; and, (v) was unlikely to have had any major ecological impact on the habitat. Nevertheless, fisheries managers must first assess a number of factors including societal approval of the fishing activity, fishers' compliance to regulations and the accuracy of their reports before any decisions on the future of this fishery can be made. If the fishery is allowed to continue, there should be a commitment to the continued monitoring of catches of sea garfish while this species remains under a recovery program.

## Acknowledgements

The author would like to thank the commercial fishers who co-operated during this study, Luke Ritchie and Dave Eggert for their observer work, Dr. Charles Gray, Dr. Douglas Rotherham and Mr. Ken Graham who provided useful comments during the preparation of the manuscript. This study was done under NSWDPI Animal Care & Ethics approval.

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*Received: 4 March 2007; Accepted: 11 February 2008*