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Short note

Fish use of an inundated saltmarsh flat in a temperate Australian estuary

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Abstract Fish associated with Australian saltmarshes have previously been sampled from within creeks or semi-permanent pools on the marsh; this is the first record of fish use of marsh flats inundated on high tides but emergent on low tides. Buoyant pop nets ($9\,m^2$, 1 mm mesh) were used to collect fish from two areas of the marsh flat on Torrens Island in the Barker Inlet–Port River estuary, South Australia. Fyke nets of the same mesh size were used to collect fish from small creeks draining the marsh flat. Fish were caught in only four of 48 pop net releases, for a total of 19 fish of two species (families Gobiidae and Atherinidae). A total of 1109 fish from six species were caught in creeks draining the same areas, and the two species caught on the flats were the most common species in the creeks. Economically important species were poorly represented, with just four specimens of the mugilid *Aldrichetta forsteri* (Valenciennes).

Key words: Atherinidae, coastal wetland, Gobiidae, pop and fyke nets, *Spartina*.

INTRODUCTION

Saltmarshes are considered to be valuable coastal habitat, important both in terms of their role in filtering surface overflow prior to it entering the sea and in their contribution to nearshore coastal productivity (Morrisey 1995). Part of the rationale for encouraging the conservation of saltmarshes has been their assumed importance as fish habitat, especially for juveniles of economically important species (Hyland & Butler 1989). Most ecological knowledge of saltmarshes comes from studies in the USA and Europe. These studies have mostly been aimed at elucidating the energy flux within lower marshes, and between marshes and the open water of an estuary (Talbot & Able 1984). Fish are typically sampled in open water adjacent to the marsh (e.g. Rakocinski *et al.* 1992). Sampling of fish in higher marshes, which are inundated for short periods on high tides only, is extremely difficult. It has been shown, however, that fish use high marsh areas, and that, although fewer species occur there, the high marshes act as nursery areas for larval and juvenile fish (Talbot & Able 1984; Kneib & Wagner 1994).

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In Australia, saltmarshes occupy the zone landward of mangroves high in the intertidal part of estuaries. Therefore, results of ecological studies of low marshes in the northern hemisphere in stands of tall cordgrass (*Spartina* spp.), which are inundated more frequently and for longer than marshes in Australia, should not simply be applied to these marshes dominated by shorter vegetation; in temperate waters by bushes (mainly samphires: Chenopodiaceae) and in subtropical and tropical waters by grasses (e.g. *Sporobolus*; Adam 1990). Results of studies in high marshes in the northern hemisphere (e.g. Talbot & Able 1984; Kneib & Wagner 1994) are more likely to apply in Australia, although the presence of mangrove forests on the seaward side of many Australian marshes might still render results inapplicable.

There are very few studies of fish communities from saltmarshes in Australia. The only record of fish from saltmarshes in temperate waters is from Wallis Lake in central NSW, where poisoning of a small creek caught 11 species, including juveniles of seven commercially important species (Gibbs 1986). The dominant species numerically was Pacific blue-eye (*Pseudomugil signifer*, Pseudomugilidae), and by weight was sea mullet (*Mugil cephalus*, Mugilidae). Pacific blue-eye also dominated collections by dip net in semi-permanent pools on the marsh flat, but no commercial species were caught there (Gibbs 1986). In the subtropical region of southeast Queensland a tidal creek draining marsh flats was netted on receding tides (Morton *et al.* 1987). This showed that the creek was used by fish, including juveniles of economically important species such as mullet (Mugilidae), bream (Sparidae) and whiting (Sillaginidae). A distinctly different fish assemblage, dominated by the exotic mosquito fish (*Gambusia affinis*, Cyprinodontidae) and Pacific blue-eye and with only small numbers of commercial species, was sampled from semi-permanent pools remaining after the marsh drained, but it is not known whether this difference was due to the use of a different collection technique (Morton *et al.* 1988). Juveniles of economically important species such as barramundi (Centropomidae) were also caught entering a creek supplying tidal water to a saltmarsh near Darwin in tropical Australia (Davis 1988). Assemblages of fish caught in permanent pools on the marsh flat differed from those in the creek, with a relatively high number of juveniles of barramundi. Again, it is not known whether this difference might have been due to the different sampling method used. The studies cited above of fish associated with saltmarshes indicate the beginnings of an attempt during the mid-1980s to determine the importance of marsh habitat, large areas of which were being degraded and destroyed. Unfortunately no further work was done, even though degradation of saltmarshes continued.

Saltmarshes and saltflats constitute approximately 22% of estuarine areas in Australia (Bucher & Saenger 1991). There are no records of fish having been sampled, anywhere in Australia, from the marsh flats that are inundated during high tides but drain completely as the tide recedes, even though they constitute the greater area of most saltmarshes. The aim of this work was to determine whether fish use one such flat in temperate Australian waters, and to compare differences in assemblage composition between fish caught in creeks and any caught on the flat.

METHODS

Study site

The Barker Inlet–Port River region is a marine-dominated estuary in temperate South Australia (see Connolly 1994a for full description). The estuary has very high abundances of juveniles of commercially important fish species (Jones 1984) and so has been declared an aquatic reserve. The ecology of fish within seagrass beds adjacent to the marshes has been the subject of several surveys and experiments (Connolly 1994a,b; Jones *et al.* 1996). The present study centred on Torrens Island (138°30′E, 34°45′S), which contains a large proportion of the saltmarsh area within the estuary. Saltmarshes constitute approximately 376 ha, which is 13% of the estuary area (Bucher & Saenger 1989). The area of saltmarsh has been greatly reduced by a combination of industrial and urban development, including salt evaporation pans and waste disposal sites (Brock 1975; Smith 1979). More than 75% of the estuary catchment has been cleared of natural vegetation coincident with agricultural, industrial and residential development north of Adelaide (Bucher & Saenger 1989).

The vegetation is typical of temperate Australian saltmarshes (Adam 1990), being dominated by chenopod shrubs (*Sclerostegia arbuscula*) and turf (*Sarcocornia quinqueflora*). Mangroves (*Avicennia marina* var. *resinifera*) fringe the island seaward of the saltmarsh. Large numbers of striped perch (*Pelates octolineatus* (Quoy & Gaimard)) and King George whiting (*Sillaginodes punctata* (Cuvier & Valenciennes)) recruit into seagrass beds in the estuary early and late in the autumn–winter period, respectively (Connolly 1994a).

Fish collections

To catch fish on marsh flats we used a 3 × 3 m version of a buoyant pop net (Connolly 1994c), used successfully in seagrass meadows and on mudflats (Connolly 1994b). The pop net consists of four fine-mesh (1 mm) walls pegged to the seabed at the bottom and buoyant at the top. Mesh walls are carefully folded and held under the plastic piping that forms the top of the net. The whole structure is inconspicuous, lying well hidden beneath the top of the low turf of *S. quinqueflora*, which was the dominant vegetation. The net is held depressed to the sediment until released remotely, whereupon the top of the net surfaces. On saltmarshes, erect vegetation obstructs attempts to use a collecting net with a width the same as the pop net (used in seagrass habitat, Connolly 1994c), and we collected fish instead with a hand-held dipnet from the lowest point in the sampling area, revisiting the net regularly until the area was dry. The pop net differs from Rozas' (1992) lift net in having no structures above the water near the site prior to release.

Fish were sampled on 16 occasions selected to coincide with the highest tidal peaks spread over the autumn–winter period (April–July 1993). Tidal peaks were greater than the theoretical height of 2.95 m (Department of Marine & Harbours 1993), and all occurred at night, within 4 h of dusk. One of two locations separated by almost 1 km of marsh was used on each sampling occasion, with each location used alternately. Each location is supplied with seawater and drained by two small creeks. Three pop nets were used to sample fish from the inundated marsh flats on each occasion. Nets were placed haphazardly with the closest edge 2 m from the creek, and were released at the top of the tide, with water depths ranging from 10 to 30 cm.

On each occasion fish were also collected from within the creeks at the same location. One fyke net was set in each of the two creeks at slack high tide, seaward of pop net sites, aiming to catch all fish moving down the creek on the ebbing tide. Fyke nets consisted of an 8 m long funnel, with mouth width 2 m and height 0.84 m, and 1 m wide wings, all of 1 mm mesh. The bottom of the wings and mouth were pegged to the sediment surface, with no obvious gaps through which fish could escape. All fish were identified and measured against a ruler to the nearest millimetre (total length, tip of snout to tip of tail). Water depth (cm) in the creeks at high tide was as follows (measured at fyke net site, $n = 8$ for each creek): location A, creek 1 mean = 75 (SE = 5.4), creek 2 mean = 50 (3.3); location B, creek 3 mean = 79 (6.0), creek 4 mean = 76 (4.9).

A comparison between fish densities on the marsh flat and abundances in creeks can be made if the marsh area drained by the creeks is known. The area inundated on a given night differed with tidal height. We estimated what we consider to be the average area drained by each creek, based on site inspections and tracings from aerial photographs and orthophoto maps (scale 1:2500). The shape of each drainage area was simplified to a polygon, and was estimated to be: location A, creek 1, 7400 m^2, creek 2, 2470 m^2; location B, creek 3, 2700 m^2, creek 4, 6890 m^2.

Water temperatures across the inundated flats followed ambient air temperatures, and ranged from 23°C in April to 14°C in July.

RESULTS

Fish were caught in only four of the 48 pop net releases, for a total of 19 fish of two species: *Gobiopterus semivestitus* (Munro) and *Atherinosoma microstoma* Günther (Table 1).

A total of 1109 fish of six species were caught in 31 fyke net sets (one set failed; Table 2). The two species caught in pop nets were the most abundant species caught in fyke nets. However, one additional species, *Pseudogobius olorum*, was also present in relatively large numbers. One species of economic importance, *Aldrichetta forsteri*, was collected, but in only small numbers.

A higher total number of fish and greater abundance of the common species were caught at location A compared to location B, because of the higher abundances in creek 1 (Table 2). The total number of fish caught in creek 1 was higher than in creek 2 on every sampling occasion. Creek 2 had similar numbers to creeks 3 and 4 at location B, even though water depth in both these creeks was as deep as in creek 1.

Table 1. Abundances and lengths of fish caught in 48 pop net releases on marsh flat

Date	Location	Abundances (per net) *Atherinosoma microstoma*	Abundances (per net) *Gobiopterus semivestitus*	Lengths (mm) (range, median)
10 April 1993	A	2		25–56, 40.5
11 April 1993	B	1		56
9 May 1993	B		11	18–28, 24
23 May 1993	A	5		25–50, 30

Table 2. Summary of abundances (totals from eight occasions in each case except creek 1 where the net failed on one occasion) and lengths (mm, medians of all fish from a creek, incorporating all occasions, shown in parentheses) of fish caught in creeks

Species	Location A Creek 1	Location A Creek 2	Location A Total	Location B Creek 3	Location B Creek 4	Location B Total	Total of both locations
*Gobiopterus semivestitus (*glass goby)	466	32	498	34	2	36	534
	(23)	(24)		(23)	(21)		
Atherinosoma microstoma (small-mouthed hardyhead)	213	35	248	73	94	167	415
	(46)	(42)		(37)	(43)		
Pseudogobius olorum (blue-spotted goby)	44	69	113	8	25	33	146
	(43)	(33)		(30)	(29)		
Pseudaphritis urvilli (congolli)	5	0	5	1	2	3	8
	(81)			(95)	(105)		
Aldrichetta forsteri (yelloweye mullet)	1	1	2	1	1	2	4
	(106)	(133)		(117)	(135)		
Pelates octolineatus (striped perch)	2	0	2	0	0	0	2
	(51)						
All species	731	137	868	117	124	241	1109
No. species	6	4	6	5	5	5	6

Abundances of common species showed no obvious trend across the 3 months of sampling but all of the *A. forsteri* (total 4) were caught at the first sampling occasion at the two sampling locations.

In comparing fish densities on the marsh flat with abundances in creeks we have pooled data from both locations and all sampling occasions because of the infrequency with which fish were caught in pop nets. The 1109 fish caught in creeks came from a potential area of drained marsh of 148 240 m^2 (eight fyke sets in creeks 2–4, seven in creek 1). If all fish caught in creeks had been on the marsh flat prior to capture and had been evenly distributed across the marsh, marsh flat densities would be 1 fish per 134 m^2. In fact the 19 fish caught in pop nets came from a total of 432 m^2 (48 releases), giving 1 fish per 23 m^2, a density about six times higher than expected.

DISCUSSION

This is the first record in Australia of fish being captured on a saltmarsh flat inundated at high tide but emergent at low tide. Species richness was low on the marsh flat relative to that in the creeks, but this may be due simply to the relatively small area of marsh flat netted. Species taken commercially or recreationally were represented only by a very small number of *A. forsteri* caught in the creeks but not on the marsh flat. No early juveniles of the most economically important species in the estuary, *Sillaginodes punctata*, were caught during this study, even though they were being caught in seagrass beds adjacent to the marsh in June and July of 1993 (Connolly unpubl. data). Only two individuals of *Pelates octolineatus* were caught (and these in a creek), despite this species being abundant in adjacent estuarine waters in autumn (Connolly 1994a).

Although the total number of fish caught on the marsh flat was small, more fish were caught there than would be expected from the number caught in creeks. One or more of the following possibilities could account for this: (i) fish on the marsh flat at high tide were more abundant near creeks rather than being evenly distributed across the flat; (ii) fish in creeks escaped capture by fyke nets; or (iii) pop nets caught more fish than occur on the flat when no netting takes place (e.g. fish might be attracted to pop net locations because of disturbances to sediment while setting nets). The data do not point to pop net catches underestimating fish densities on the marsh flat, but the efficacy of the pop nets in the very shallow waters on marsh flats cannot be confirmed without further work. It has recently been demonstrated that saltmarsh fish are recaptured about 90% of the time once placed inside a released pop net (A. Moussalli, pers. comm. 1996).

Results of the present study are not necessarily applicable to other regions, especially those with less obvious anthropogenic influences. The abundance of species might fluctuate with seasonal changes because, for example, juveniles of several other commercial species are present in the estuary during the warmer months of the year. Given the limited temporal and spatial scope, results presented here should be seen as preliminary work for a more thorough sampling procedure.

The value of the present study lies in giving an indication of the density of fish found on the inundated marsh flat on Torrens Island, and in demonstrating the use of a buoyant pop net in marsh habitat. To understand the role of saltmarsh as fish habitat, future work should attempt to determine the relationship between fish abundances and different tidal heights, distances from creeks, levels of prey availability, vegetation types and climates. This information should be brought together with results from studies in adjacent mangrove forests and mud flats.

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REFERENCES

Adam P. (1990) *Saltmarsh Ecology*. Cambridge University Press, Cambridge, UK.

Brock B. J. (1975) The decline of the estuarine commons near Adelaide. *Operculum* **4**, 90–5.

Bucher D. & Saenger P. (1989) *An Inventory of Australian Estuaries and Enclosed Marine Waters. V – South Australia.* Centre for Coastal Management, Northern Rivers College of Advanced Education, Lismore, NSW.

Bucher D. & Saenger P. (1991) An inventory of Australian estuaries and enclosed marine waters: an overview. *Aust. Geog. Stud.* **29**, 370–81.

Connolly R. M. (1994a) A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary. *Aust. J. Mar. Freshwat. Res.* **45**, 1033–44.

Connolly R. M. (1994b) Removal of seagrass canopy: effects on small fish and their prey. *J. Exp. Mar. Biol. Ecol.* **184**, 99–110.

Connolly R. M. (1994c) Comparison of fish catches from a buoyant pop net and a beach seine net in a shallow seagrass habitat. *Mar. Ecol. Prog. Ser.* **109**, 305–9.

Davis T. L. O. (1988) Temporal changes in the fish fauna entering a tidal swamp system in tropical Australia. *Env. Biol. Fish.* **21**, 161–72.

Department of Marine & Harbors (1993) *Tide Tables for South Australian Ports*. Department of Marine & Harbors, Adelaide.

Gibbs P. J. (1986) The fauna and fishery of Wallis Lake. In: *Wallis Lake: Present and Future*, pp. 1–7. Australian Marine Science Association, Sydney, NSW.

Hyland S. J. & Butler C. T. (1989) The Distribution and Modification of Mangroves and Saltmarsh-claypans in Southern Queensland. Information Series no. Q189004, Department of Primary Industries, Brisbane, Queensland.

Jones G. K. (1984) The importance of Barker Inlet as an aquatic reserve; with special reference to fish species. *Safic* **8**, 8–13.

Jones G. K., Baker J. L., Edyvane K. & Wright G. J. (1996) Nearshore fish community of the Port River–Barker Inlet estuary, South Australia. 1. Effect of thermal effluent on the fish community structure, distribution and growth of economically important fish species. *J. Mar. Freshwat. Res.* **47**, 785–99.

Kneib R. T. & Wagner S. L. (1994) Nekton use of vegetated marsh habitats at different stages of tidal inundation. *Mar. Ecol. Prog. Ser.* **106**, 227–38.

Morrisey D. (1995) Saltmarshes. In: *Coastal Marine Ecology of Temperate Australia* (eds A. J. Underwood & M. G. Chapman) pp. 205–20. University of New South Wales Press, Sydney.

Morton R. M., Beumer J. P. & Pollock B. R. (1988) Fishes of a subtropical Australian saltmarsh and their predation upon mosquitoes. *Env. Biol. Fish.* **21**, 185–94.

Morton R. M., Pollock B. R. & Beumer J. P. (1987) The occurrence and diet of fishes in a tidal inlet to a saltmarsh in southern Moreton Bay, Queensland. *Aust. J. Ecol.* **12**, 217–37.

Rakocinski C. F., Baltz D. M. & Fleeger J. W. (1992) Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Mar. Ecol. Prog. Ser.* **80**, 135–48.

Rozas L. P. (1992) Bottomless lift net for quantitatively sampling nekton on intertidal marshes. *Mar. Ecol. Prog. Ser.* **89**, 287–92.

Smith D. L. (1979) *Landuse and Groundwater History of the Northern Adelaide Plains*. Department of Geography, University of Adelaide, for Engineering and Water Supply Department of South Australia, Adelaide.

Talbot C. W. & Able K. W. (1984) Composition and distribution of larval fishes in New Jersey high marshes. *Estuaries* **7**, 434–43.