Fish in urban environments

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ABSTRACT

In the urban environment the impact of human activity often results in the construction of tidal barriers to estuarine fish passage and/or highly modified fish habitats. The modified, shallow estuarine habitat of the urban Rockdale wetland corridor, Botany Bay, is used by estuarine fish and its functional equivalency compared with similar non urban habitats is demonstrated. The argument is presented that estuarine fish are part of the urban wildlife fauna and they should be included in education and advisory programs developed and coordinated by various groups to protect, enhance and maintain wildlife populations in the urban environment.

Key Words: estuarine fish, urban wildlife, modified habitats, urban wetlands, tidal barriers

Introduction

In Australia the human population density is greatest on the coast, in the major towns and capital cities (Australian SoE 2001). This is especially evident on the eastern seaboard (Yapp 1986; Fairweather 1990; Zann 2000). Historically, the consideration and management of urban wildlife in Australia has not received a focus commensurate with this population density. When urban wildlife is considered the focus is on terrestrial systems and the issue of native birds, mammals and reptiles or the alternatives, which are companion animals (dogs and cats) in the urban environment. In both these situations there is a mixture of positive and negative reactions to the interaction between the animals, humans and the environment.

Fish are rarely if ever considered as urban wildlife. In the rare instances where fish are mentioned, freshwater native fish, or more likely introduced fish such as carp *Cyprinus carpio*, goldfish *Carassius auratus*, mosquito fish *Gambusia holbrooki* and their impacts on native freshwater fish are the focus (Arthington and Milton 1983; Wagner and Jackson 1993). One notable exception is the inclusion of intertidal zone fish with freshwater and exotic fish species in an identification field guide to the wildlife of the greater Brisbane region in Queensland (Ryan 1995).

In this paper I discuss not the freshwater fauna but rather the estuarine finfish fauna. These estuarine fish are considered cryptic by most as they are hidden from sight in the estuaries around which many coastal towns and cities are built. Yet, fish do form an important component of urban wildlife.

Estuaries

Estuaries are partially enclosed bodies of water connected to the ocean. They are characterised by brackish water derived from the mixing of oceanic and fresh waters and represent a 'mixing zone' between completely sheltered freshwaters and the open ocean (Pritchard 1955; Das *et al.* 2000; Roy *et al.* 2001). The forces driving this mixing include tides, wind, waves and river runoff (O' Loughlin *et al.* 1999), although the relative importance of each of these varies according to estuary type and the location within an estuary (Roy *et al.* 2001).

There are at least 950 water bodies joining the Tasman Sea along the New South Wales seaboard (Williams *et al.* 1998). However, the vast majority are very small and only intermittently opened to the sea. Only 130 have a water area greater than 0.05 km^2. Bell and Edwards (1980); West *et al.* (1985); Roy *et al.* (2001) have documented various attributes of the latter water bodies.

The NSW estuaries are generally complex systems comprising a number of inter-related habitats, including saltmarshes, mangroves, seagrasses, reedbeds, shallow sand and mud flats, rocky shores and reefs, and deeper zones of fine sediments (NSW Fisheries 1999). The composition of these estuarine habitats varies according to physical, biological and anthropogenic factors. Some habitats may show large variability in space and time and other habitats may be either relatively stable or particularly vulnerable to change (NSW Fisheries 1999).

Estuaries support a wide variety of fish and invertebrates that use the full range of key habitats especially those in shallow water (West *et al.* 1985; Bell and Pollard 1989; NSW Fisheries 1999). Estuaries provide abundant food and excellent shelter, and represent critical nursery areas for many of the fish species (Blaber and Blaber 1980; SPCC 1981a,b,c; Bell and Pollard 1989; McNeill *et al.* 1992; Gray *et al.* 1996), or are used as feeding areas by the adults (SPCC 1981c).

Estuaries and their immediate surrounds also support a wide variety of native wildlife. Associated habitats such as mud flats, mangroves, saltmarsh and she-oak forest provide food, shelter and breeding sites for a variety of terrestrial animals including insects, reptiles, mammals and, especially, birds. The specialized nature of these habitats ensures that estuaries make a significant contribution to terrestrial biodiversity.

Pp 82 - 92 in *Urban Wildlife: more than meets the eye,* edited by Daniel Lunney and Shelley Burgin 2004. Royal Zoological Society of New South Wales, Mosman, NSW.

Estuarine fish

There are many studies related to fish in NSW estuaries and the importance of shallow water habitats and wetlands (SPCC 1981 a,b,c; Burchmore *et al*. 1985; Middleton *et al*. 1984; Bell and Pollard 1989; Ferrell and Bell 1991; Bell and Worthington 1992; McNeill *et al*. 1992; Worthington *et al*. 1992; Ferrell *et al*. 1993; Pollard 1984, 1994; Gray *et al*. 1996; West and King 1996; Hannan and Williams 1998; Pease 1999; Gray *et al*. 2000; West and Jones 2001). The focus of these studies is normally the recreationally or commercially important harvested species and/or the recruitment of juveniles.

The above studies demonstrate the density of fish in estuaries is greater in the seagrass habitats than bare sand or mud habitats. Fish community structure within and between estuaries is similar with differences observed related to estuary morphology rather than latitudinal differences. This latter finding is however, partially confounded due to differences associated with water quality and habitat quality. One of the prime drivers of juvenile fish distribution is the availability of shelter, calm water, food, and also predator interactions. Most of the studies show that the fish fauna is diverse within both the urbanised and non-urbanised estuaries. There are large commercial and recreational catches of fish in both groups of estuaries.

There is considerable movement of fish between habitats in estuarine systems. This occurs at different life stages or on a seasonal basis. For example the general life cycle pattern for sea mullet *Mugil cephalus*, a common species in NSW estuaries, is for the adults to spawn in the open ocean, during autumn to early winter. The planktonic larvae then recruit to shallow mangrove/seagrass areas when they are about 30 millimetres long in late autumn and winter. The fish then move as subadults to river channel, mud and sand flat areas in late spring, and by that stage, they are about 125 millimetres long.

In comparison yellowfin bream *Acanthopagrus australis* adults spawn in the surf zones near the entrances to estuaries in winter, and the larvae recruit at about 15-20 millimetres in spring/summer to the seagrass meadows. This is when the mullet are leaving the shallow seagrass habitats. Then the juvenile bream move to deeper waters at about 120 millimetres long, this occurs in autumn/winter, which is when the mullet are recruiting.

There are many other examples of habitat use by fish at different life stages in the above literature. However, none of the studies focussed specifically on assessing the impact of urbanisation on estuarine fauna. Rather, they investigated the differences in the fish fauna in estuarine habitats.

Urbanization

The question becomes 'What happens when we have human settlement and consequent urbanisation around estuaries?' The major environmental changes affecting fish are habitat changes from anthropogenic activities such as reclamation, dredging, engineering works (construction of marinas, wharves, causeways, dams, weirs) and changes in water quality associated with pollution and various other activities.

In many cases these activities impact on fish by creating tidal barriers and alienation of the important, shallow-water protected habitats and wetlands, which are especially important for juvenile fish. The tidal barriers impact upon estuarine fish in terms of fish passage, the change of many areas from estuarine to freshwater and the overall loss of habitat area with the consequent loss of biological diversity.

Estuarine fish and tidal barriers

The often negative effects on the freshwater fish fauna of river modification, channelisation, flow regulation and barriers to passage are well documented (Swales 1982; Ward and Stanford 1989; Harris and Mallen-Cooper 1994; Jurajda 1995; Gehrke *et al.* 1995; Marsden and Gehrke 1996; Pethebridge *et al.* 1998). The impacts of reduced freshwater flow due to such river regulation and diversion on estuarine and marine fish and invertebrates have been reviewed by Drinkwater and Frank (1994). These impacts on estuarine fish include effects on migration patterns, spawning habitat, species diversity, water quality and distribution, and production of lower trophic levels.

The impact of tidal floodgate structures on the marine and estuarine fish fauna of rivers is less well understood (Rey *et al.* 1990; Pollard and Hannan 1994; Vose and Bell 1994; Williams and Watford 1996, 1997). All studies demonstrate degradation in the quality of fish habitat and a significant reduction in the abundance and species composition of the fish community above as compared to below barriers. The importance of tidal exchange as a key factor regulating fish in estuarine wetland studies has also been demonstrated (Gilmore 1986; Rey *et al.* 1990; Vose and Bell 1994).

Data from a two-year study on the utilization of restored shallow water estuarine habitats (wetlands) by fish and invertebrates (Gibbs *et al.* 1999) are summarized to illustrate the major impact on fish of tidal barriers, which result from urbanisation.

Juvenile fish and invertebrates were collected from six estuaries along the central coast of NSW on 9 sampling occasions during 1996 and 1997. Three of the estuaries had tributaries with restricted tidal flow due to floodgates or some other barrier and have either been restored, partially restored or proposed for future restoration. They are the Rockdale Wetland in Botany Bay (a restored wetland with a modified channel for tidal flow), Ironbark Creek on the Hunter River (a partially restored wetland with floodgates) and the Yarrahapinni Broadwater on the Macleay River (proposed for future restoration by removal of the floodgates). The tributaries in the remaining three estuaries (Nambucca River, Manning River and Wallamba River in Wallis Lake) are the reference estuaries. In these reference estuaries the study locations were not near any floodgates or tidal barriers and are similar in spatial location in the estuary, substrate and seagrass cover to the floodgate sites in the other estuaries.

Twelve locations were selected for sampling, three locations (impacted wetland area, near reference and far reference) in each of the three estuaries with barriers and one location in each of the three reference estuaries.

At each location three sites were selected for sampling (a total of 36 sites Figure 1). Three replicate samples were collected from each site yielding 108 seine hauls at each sampling time. All sites were within 7 to 13 km of the estuary mouth.

Samples were collected using a 20m headline *x* 2m drop *x* 6mm stretched mesh seine net with a cod-end. The net was set from the shore forming a U-shape and covering an approximate area of 100m^2. The net was then pursed up onto the shore. Three replicate hauls were done at each

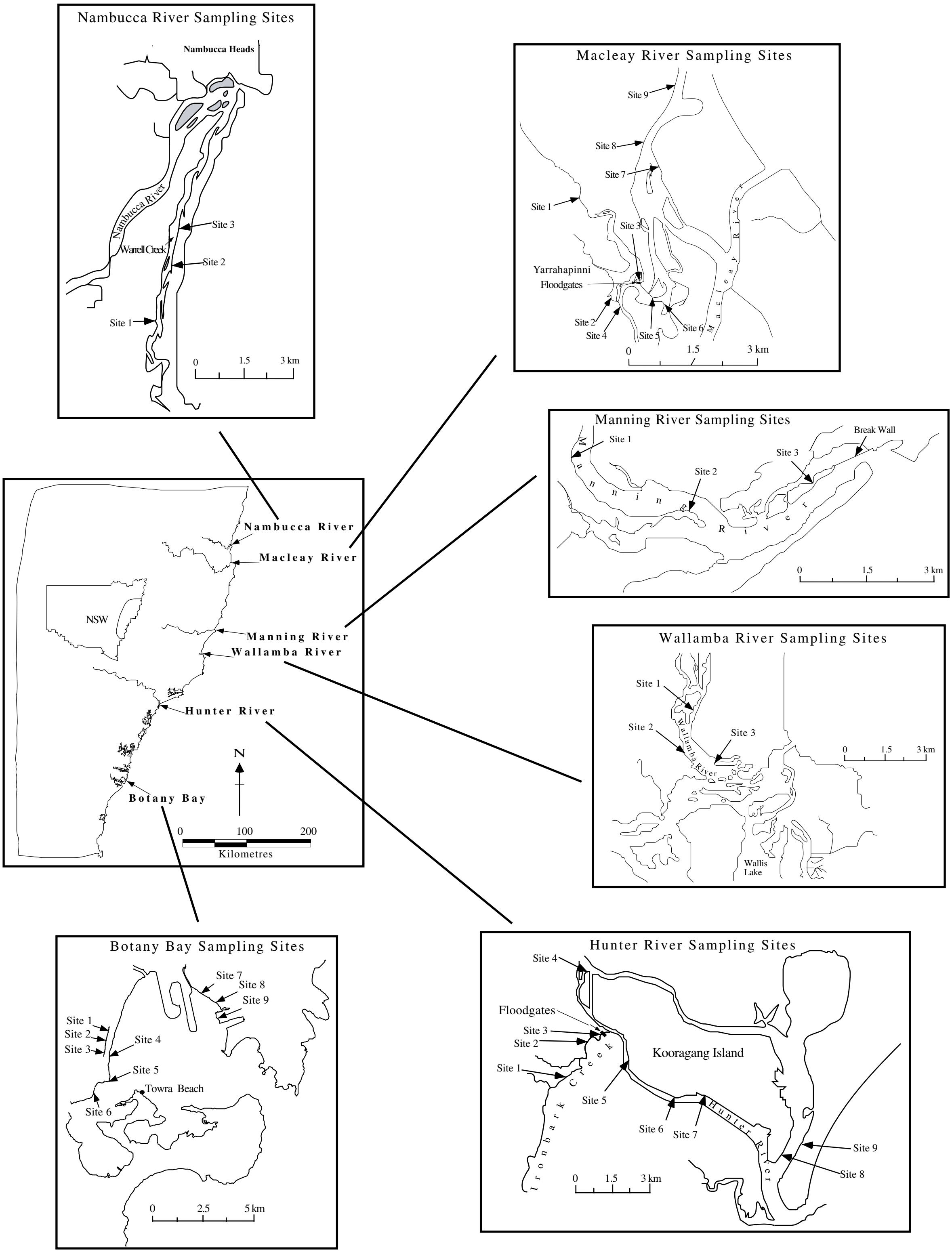

Figure 1. Map of the study area showing the three wetland estuaries (Botany Bay, Hunter River and Macleay River) and the three external reference estuaries (Wallamba River, Manning River and Nambucca River).

site and on each sampling occasion. The replicates were positioned to cover the available habitat without overlapping at any point. All sampling was done in daylight hours. The physical aspects of water quality; temperature, salinity, pH and chemical aspects; nutrients both phosphorous and nitrogen was measured at each sampling site.

The analysis of the data was based on assessing the community structure that existed within the fish and invertebrate fauna. This was achieved by multivariate analysis based on non-metric multidimensional scaling complemented with analysis of species, the abundance of individual species and biomass using univariate analysis of variance. The population structure of selected fish species was assessed based on length frequencies of recruiting fish.

The full analysis of the data is presented in Gibbs *et al.* (1999). The study showed the fish community structure above and below the tidal barriers to estuarine wetlands varied considerably dependent upon the degree of tidal exchange. Where floodgates were completely closed (Yarrahapinni wetlands Macleay River), the upstream community was dominated by freshwater species such as gudgeons *Philypnodon* sp., *Philypnodon grandiceps* and *Gobiomorphus* spp., the goby *Pseudogobius* sp., the southern blue-eye *Pseudomugil signifer*, the mosquitofish *Gambusia holbrookii* and aquatic insects such as dragonfly nymphs, damselfly nymphs and water boatman. There were very few commercially or recreationally important fish and invertebrate species collected from this area. The below floodgate community was diverse and dominated by flat tailed mullet *Liza argentea*, sea mullet *Mugil cephalus*, yellowfin bream *Acanthopagrus australis*, tarwhine *Rhabdosargus sarba*, striped trumpeter *Pelates sexlineatus*, glass perch *Ambassis jacksoniensis*, school prawns *Metapenaeus macleayi*, king prawns *Penaeus plebejus* and a variety of gobies and non commercial shrimps.

In comparison, the community above the partially open floodgates at Ironbark Creek in the Hunter River was very diverse and included juveniles of several species of economic importance and few of the freshwater species found in the Yarrahapinni wetlands. Overall, the community structure in Ironbark Creek was comparable to the main channel of the Hunter River but actually supported a greater number of juvenile sea mullet, yellowfin bream and school prawns than the main channel of the river.

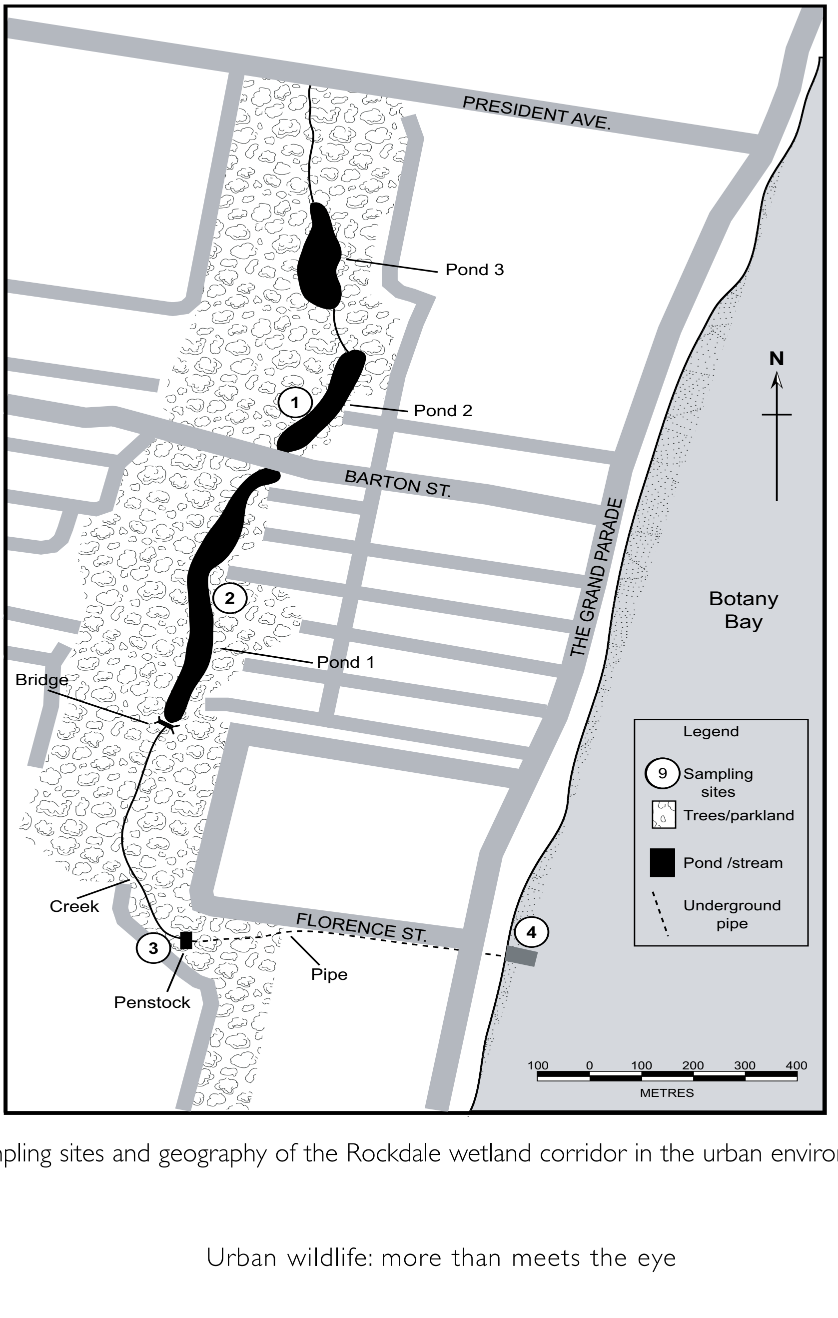

Figure 2. The sampling sites and geography of the Rockdale wetland corridor in the urban environment.

Table 1. Fish and invertebrate species collected from the Rockdale Wetland Corridor on eight sampling occasions during 1996 and 1997.

Family Name	Scientific Name	Common Name	Commercial Status	Total Number Collected
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	N	22059
Sparidae	*Acanthopagrus australis*	Yellowfin bream	C	3623
Mugilidae	*Myxus elongatus*	Sand mullet	C	2647
Mugilidae	*Mugil cephalus*	Sea mullet	C	1868
Gobiidae	*Pseudogobius* sp.	Blue-spot goby	N	640
Mugilidae	*Liza argentea*	Flat-tail mullet	C	330
Poeciliidae	*Gambusia holbrooki*	Mosquitofish	N	134
Eleotridae	*Philypnodon* sp.	Dwarf flathead gudgeon	N	121
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	N	84
Gobiidae	*Favonigobius tamarensis*	Tamar river goby	N	7
Gobiidae	*Arenigobius bifrenatus*	Bridled goby	N	6
Scorpaenidae	*Centropogon australis*	Fortescue	N	6
Gobiidae	*Favonigobius lateralis*	Long finned goby	N	5
Chandidae	*Ambassis marianus*	Ramsey's glassfish	N	4
Galaxiidae	*Galaxias maculatus*	Common jollytail	C	3
Anguillidae	*Anguilla reinhardtii*	Long-fin eel	C	3
Gobiidae	*Gobiopterus semivestitus*	Glass goby	N	2
Terapontidae	*Terapon jarbua*	Crescent perch	N	2
Anguillidae	*Anguilla australis*	Short-fin eel	C	1
Gobiidae	*Redigobius macrostoma*	Largemouth goby	N	1
Tetraodontidae	*Torquigener squamicauda*	Brush-tail toadfish	N	1
Clupeidae	*Hyperlophus vittatus*	Sandy sprat	N	1
Mysidae	*Unknown*	Opossum shrimp	N	Present
Sergestidae	*Acetes sibogae australis*	Shrimp	N	Present
Penaeidae	*Penaeus plebejus*	King prawn	C	Present
Hymenosomatidae	*Amarinus laevis*	Spider crab	N	Present
Hymenosomatidae	*Amarinus* sp.	Spider crab	N	Present
Hymenosomatidae	*Hymenosoma hodgkini*	Spider crab	N	Present
Palaemonidae	*Palaemon debilis*	Shrimp	N	Present
Palaemonidae	*Macrobrachium intermedium*	Shrimp	N	Present
Idiosepiidae	*Idiosepius notoides*	Dumpling squid	N	Present

The Rockdale wetland area in Botany Bay (Figure 2) is used by 22 fish and 9 epibenthic mobile invertebrates (Table 1). The main species that are using this highly modified habitat within the urban area are yellowfin bream, various mullet species and a number of gobies and gudgeons.

The recruitment of yellowfin bream and sand mullet to the urban wetlands is shown in the length frequency distribution of fish sampled during the study.

Two separate year classes of yellowfin bream occurred in the Rockdale wetlands area in Botany Bay throughout the study period. The smaller age class was always the most abundant. The recruitment of juveniles with a caudal fork length less than 50 mm occurred in the December of both sampling years with evidence that larger sub adults leave the system (Figure 3).

Until March 1997 there was one dominant year class of sand mullet *Myxus elongatus* in the wetland, which grew from an average of 50 mm total length to an average total length of approximately 125 mm. The recruitment of sand mullet in the Rockdale urbanised wetland area occurred in autumn. There was a distinct small age class in March 1997 with most individuals measuring less than 50 mm total length (Figure 4). The number of individuals of sand mullet collected from the Rockdale urbanised wetland varied from between 690 animals in March 1997 to only 15 individuals in December 1997 suggesting that there was movement of these animals out of the wetland. McDowall (1996) suggests that often juvenile sand mullet in their first year enter fresh water but rarely after this.

The water quality in the Rockdale habitat had as expected a seasonal temperature pattern from 18.3°C to 27.5°C.

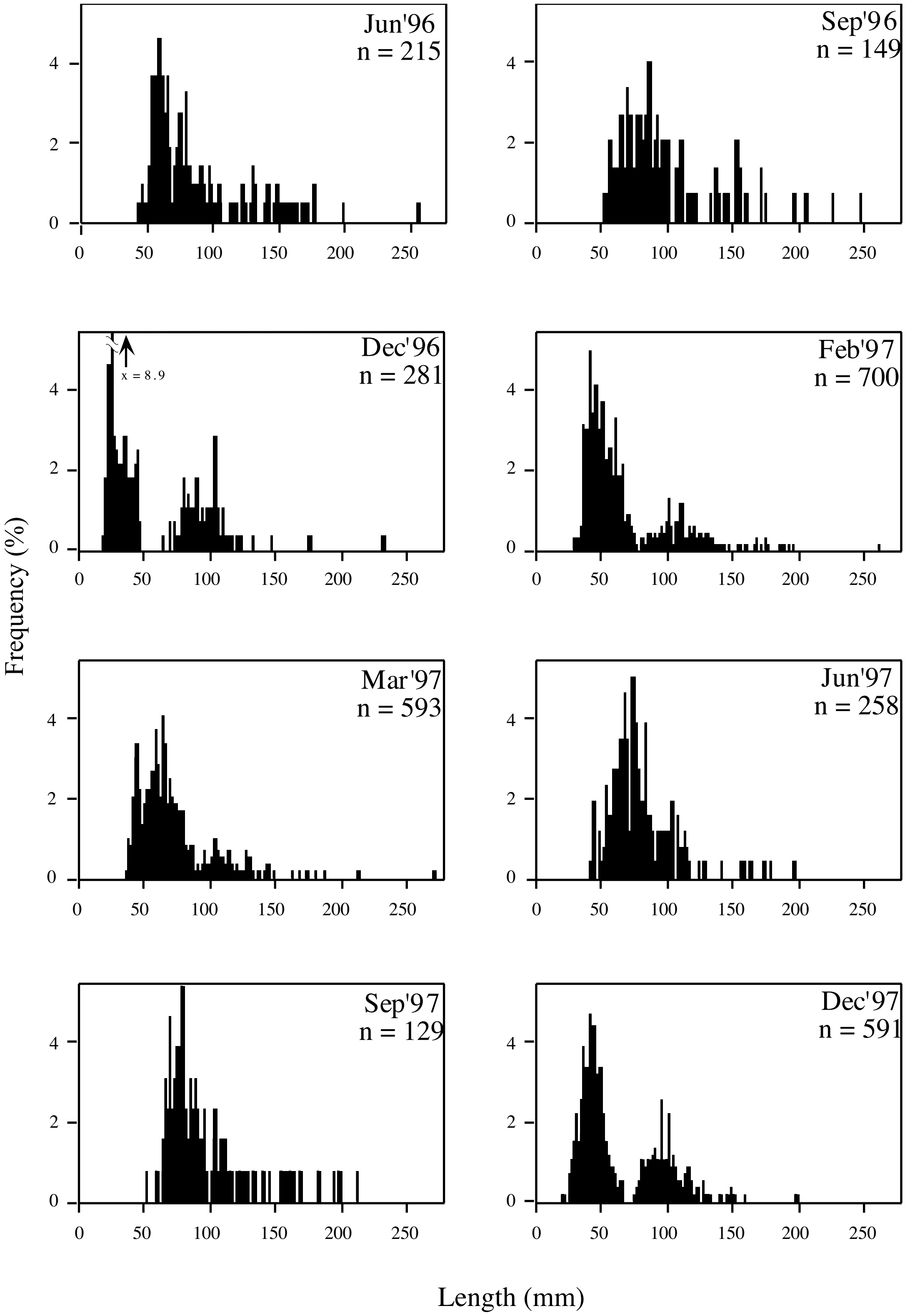

Figure 3. Length frequency histograms for yellowfin bream *Acanthopagrus australis* collected from the Rockdale urban wetland area for each of the sampling periods.

Salinity was variable and dependent on rainfall and distance from the salt-water input varying from 6.6ppt to 21.5ppt at the upper site 1, 13.4ppt to 35.1ppt at the lower sites 2 and 3 and 30.1ppt to 35.7ppt in Botany Bay (site 4). There was considerable elevation of nutrient levels (total phosphorous, total Kjeldahl nitrogen, ammoniacal nitrogen and nitrate/nitrite ratio) within the urban habitat compared to sites in Botany Bay and the reference estuaries (all data are in Gibbs *et al.* 1999).

Species absent or in very low densities inside the three restored wetlands compared to other locations in the parent estuary or the reference estuaries were silver biddies *Gerres subfasciatus*, tarwhine, blackfish *Girella tricuspidata*, striped trumpeter and king prawns.

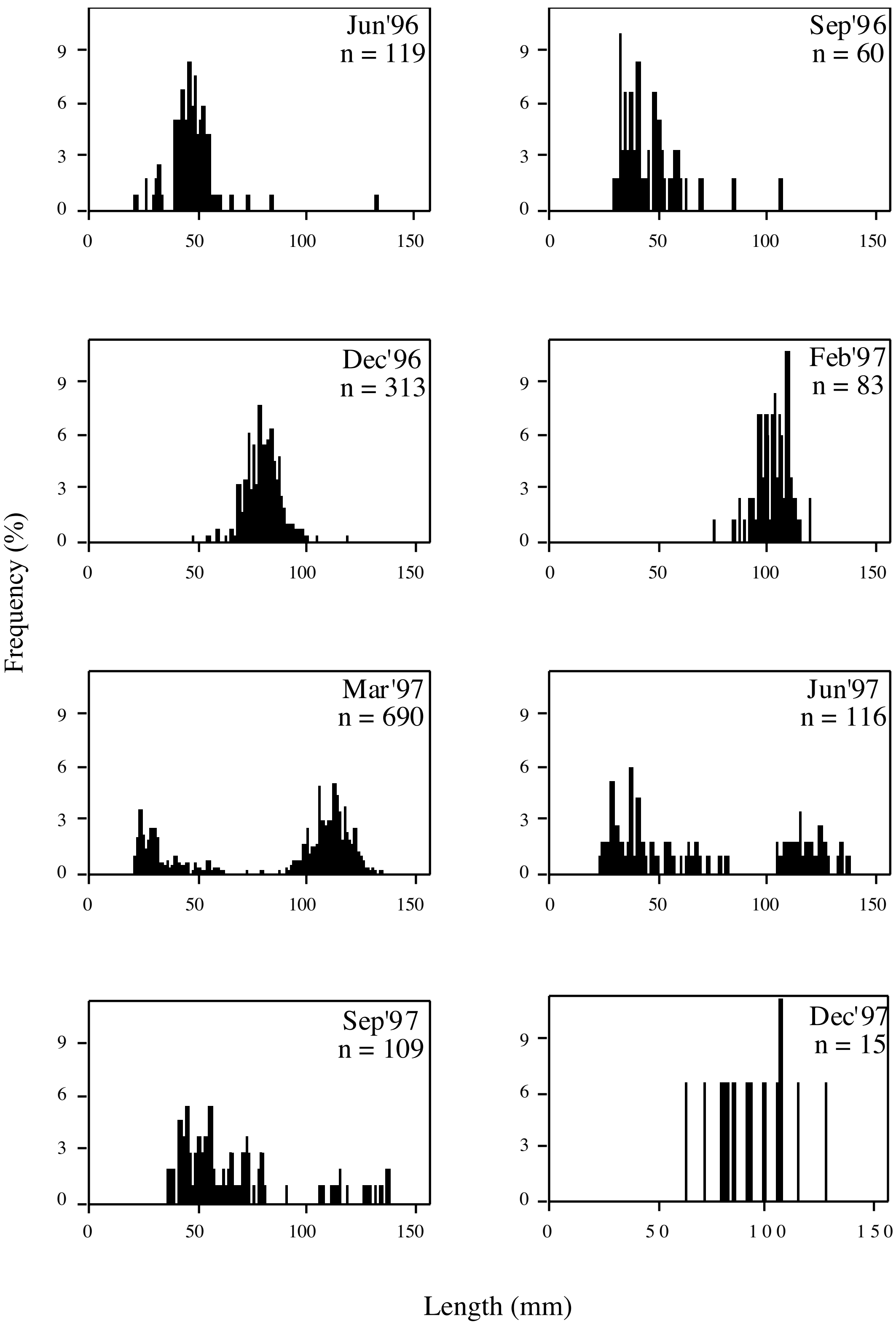

Figure 4. Length frequency histograms for sand mullet *Myxus elongatus* collected from the Rockdale urban wetland area for each of the sampling periods.

Urban environments: the new habitat

The Rockdale wetland area illustrates the degree of modification in fish habitat within the urban environment. Water flow into the fish habitat is via three approximately 700-metre long pipes from Botany Bay to the regulating penstock structure (Figure 5), which is in the middle of a recreational park surrounded by residential buildings. The system then constitutes a small shallow creek lined by trees on one side and grassed parkland and walking track on the other (Figure 6). The creek flows into a number of ponds restricted at each end by crossings including a major road. The ponds are surrounded by parkland and playing fields with stormwater drain inputs and backed by residential houses (Figure 7).

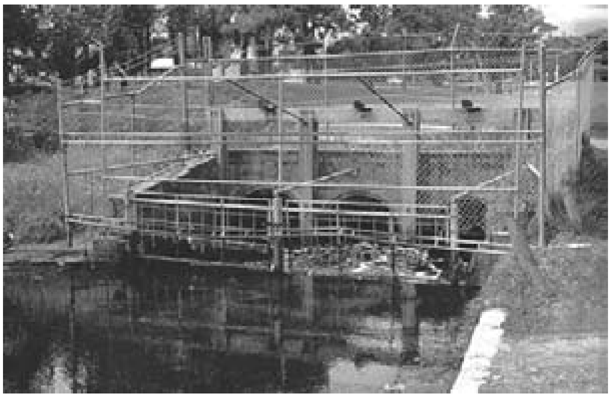

Figure 5. The pipes and penstock structure where the tidal flow to and from Botany Bay enters the Rockdale wetland area.

Figure 7. The view from pond 1 to pond 2 at Barton Street in the Rockdale wetland area shows the water constriction due to the causeway. The stormwater drain on the left is visible with residential house roofs and backyard trees in the background.

Estuarine fish are part of this urban habitat and the urban wildlife fauna. The above summary from Gibbs *et al.* (1999) on estuarine fish and tidal barriers and the Rockdale wetland corridor site description shows the urban environment provides highly modified habitat for estuarine fish. It provides an important nursery area, especially for yellowfin bream and sand mullet, which were able to move through the permanently open 700 m long pipes into the modified wetland.

A critical issue is: 'are these modified urban habitats functionally equivalent to natural habitats'? The ecological issues associated with aquatic habitats, which become highly modified, can be summarised into the broad categories of predicability, structure and function, limiting factors and landscape issues (Zedler 1996) and these factors apply to the urban situation. The functional or process attributes of the modified habitat compared with the natural habitats are difficult to measure and define. However, no environmental factor operates in isolation and the quality of the habitat is the summation of a range of factors, processes and conditions.

If the habitat is highly modified, restored, created or enhanced, the functional equivalence of the habitat must be considered (Simenstad and Thom 1996). In the case of most modified freshwater habitats functional equivalency has not been documented. On the contrary

Figure 6. View of the shallow creek (0.5m water depth) in the Rockdale wetland area from the penstock to the ponds, the residential development and parkland are visible in the background while the trees and vegetation on the left creek bank and the grassed track on the right bank are in the foreground.

habitat modification combined with the introduction of alien species is responsible for changes in the composition of fish communities, the decline in many native freshwater fish species and the declaration of many freshwater fish as endangered or vulnerable under either National or State threatened species legislation (Arthington and Milton 1983; Wager and Jackson 1993; Gehrke and Harris 2001; Morris *et al.* 2001).

The distribution of juvenile fish in estuaries has been partially explained in relation to shelter, calm water, suitable food, predators and turbidity (Blaber and Blaber 1980). Many studies have demonstrated the high proportion of temporary resident fish occurring as juveniles in shallow tidal wetlands containing seagrass, mangroves or salt marsh (Morton *et al.* 1987; Bell and Pollard 1989; Ferrell and Bell 1991; Bell and Worthington 1992; West and King 1996; Gray *et al.* 1996, 1998; Hannan and Williams 1998). Many of these estuarine fishes move between habitats on seasonal and/or inter annual cycles and an appropriate surrogate for the functional equivalence and sustainability of the modified habitat is the utilisation of the area by fish and invertebrates in a similar way to external reference sites and estuaries.

From previous studies in Botany Bay (Bell *et al.* 1984) we know that many juvenile estuarine fish use the Towra Point Reserve on the southern shore of Botany Bay as a nursery ground. The study by Gibbs *et al.* (1999) has identified the highly modified Rockdale wetland area, with its significant tidal exchange, as another important nursery ground for juvenile bream and mullet, which appears to be functioning in a sustainable manner. Repeated recruitment of juvenile estuarine fish, based on length frequency data, is occurring. The development of Botany Bay as a major shipping and industrial port including significant reclamation of the natural habitats has limited the available juvenile fish habitat in the Bay especially on the northern and western shores and this may have accentuated the importance and utilisation of the Rockdale wetland.

A further indicator of the functional equivalency of the 'modified urban' estuarine wetland at Rockdale, Botany Bay is the presence of small numbers of glass eels *Anguilla* sp. collected in winter through to summer in both years and common jollytails *Galaxias maculatus* collected in the spring of both years. Tidal barriers due to both the physical barrier and the habitat and water quality alterations above the barrier normally exclude these migratory species.

Anguilla australis occurs in a wide variety of wetland habitats including rivers, creeks, lakes and swamps while *A. reinhardtii* tends to occur more often in rivers rather than lakes. Eels migrate downstream to spawn in the sea when sexually mature. Larval eels (leptocephali) are carried back from the spawning grounds by the East Australian Current. When near the coast they metamorphose into glass eels. Young eels enter the estuaries often in winter and spring and migrate to freshwater during spring and summer. They may take 10-20 years to reach maturity and then begin their downstream migration to the sea to spawn (McDowall 1996).

Galaxias maculatus tolerates a wide range of habitat conditions including salinities well in excess of full seawater. Adults migrate downstream on new or full moons, mostly during autumn. They spawn among the terrestrial vegetation on the margins of river estuaries when inundated at high spring tides. The larvae (~7mm long) go to sea, spend the winter there and migrate back to the estuaries as slender, transparent juveniles (45-50mm long after ~5-6 months). They enter estuaries often in shoals on the rising tide and move upstream into adult habitats to feed and grow. Their usual adult size is ~100mm but they can reach up to 190mm (McDowall 1996).

Conclusions

In urbanised environments anthropogenic activities have significantly affected fish habitat. Generally there is a reduction in habitat area and a loss in habitat quality (Zann 1996, 2000). However, fish can still use highly modified urban habitats as juvenile nursery areas in the absence of the accepted preferred habitats provided the habitats are accessable without barriers to fish passage and there is some tidal flow to the habitat.

The remaining estuarine fish habitat areas in urban environments have become increasingly important due to the total reduction in habitat, which has resulted from urbanisation. Therefore, inclusion of estuarine fish as urban wildlife is important in the education and advisory programs developed and coordinated by various groups to protect, enhance and maintain wildlife populations in the urban environment.

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