4 Estuarine fish

(RJ Williams and B Louden)

In the late 1970s a major environmental study of Botany Bay was commissioned by the then Maritime Services Board. The study was coordinated by the then State Pollution Control Commission (SPCC) and a number of reports were produced that related directly (SPCC 1978a, 1978b, 1979a, 1979b) or indirectly (SPCC 1979c, 1979d, 1979e, 1979f) to fish habitat, or to fish (SPCC 1979g, 1981a, 1981b, 1981c, 1981d). The studies of fish were confined to the bay, leaving a large gap in knowledge of the fishes of the Georges River. In July 1999 a Natural Heritage Trust (NHT) project enabled the sampling of fishes in a portion of the estuarine part of the river by NSW Fisheries (Williams, unpublished data). To our best knowledge, the present study is the first attempt at systematic fish sampling across the length of the estuary.

There is a common perception that the health of an estuary is closely related to its fish community, and that as some types of land use have the potential to reduce the number of species of fish or their overall abundance, land use needs to be appropriately managed. Catchment modifications of significance are thought to be those that modify water quality or have direct impact on fish habitat. Collection of data on the fish community of the Georges River help will help to define the ecosystem, draw some inferences about the impact of land use, and set out guidelines for its conservation.

4.1 Methods

4.1.1 Qualitative field sampling

Sampling was done in April 2000. Field staff examined each sampling site visually for approximately fifteen minutes, identifying macro-flora and macro-fauna, and entered the data on a standardised checklist (Appendix I). Any unknown species of intertidal animal were preserved in 10% formalin/seawater and identified at the laboratory of the Port Stephens Fishery Centre of NSW Fisheries.

4.1.2 Quantitative field sampling

Nets, traps, poison and electrofishing are common methods used to sample fish and invertebrate populations in the aquatic environment. Poisoning is not a favoured technique as water currents can spread its impact to non-target areas. Electrofishing is not feasible in saline waters.

The most effective way to sample for a range of species in estuaries is with nets. Several net types are available, including traps, fyke nets, gill nets, beam trawls and seine nets. Traps, fyke nets and gill nets are passive collecting techniques fixed in place usually over some hours. As fish traps used in estuaries are usually small in size, they catch small individuals and therefore do not assess the whole community, but can be useful for sampling shallow waters such as sheltered creek edges where other

methods cannot be used. Fyke nets can also be useful in shallow areas. Gill nets can bias a catch depending on mesh size and generally do not collect small individuals. Beam trawling and seining are active netting techniques, and the former is difficult to use where snags or other obstructions are present. A seine net pulled onto a beach has the advantage of being a quick and efficient way to sample small fishes and invertebrates that inhabit shallow foreshores.

Samples were collected with a seine net (20 m headline *x* 2 m drop *x* 12 mm stretched mesh with cod-end). With one end set at the water's edge, the net was progressively unloaded from a box in a shore-perpendicular direction, then shore-parallel in a L-shape, and then dragged back to shore (covering an approximate area of 100 m^2). All sampling was done in daylight hours. Fish larger than 150 mm were measured, weighed and released alive. All remaining animals were euthanased with ethyl p-amino-Benzoate (Benzocaine) and then preserved in 10% formalin/seawater before transportation to the laboratory for identification. Fish, crustaceans and molluscs were identified to species level and the total number recorded.

Figure 18 is a location diagram of the sites sampled in the Georges River. Samples were taken from each of the four estuarine zones (after Roy 1984) identified in Part 2:

- Marine Tidal Delta
- Central Mud Basin
- Fluvial Delta
- Riverine Channel.

Site locations are shown at a larger scale in Figures 18–22. Two locations were identified in each zone. At each location, five hauls of the seine net were made on each of bare and vegetated (seagrass) substrates.

4.2 Results

4.2.1 Overview

Seventy-one sites were sampled: ten bare and ten vegetated sites were seined at each of the zones except the Riverine Channel, where only eleven sites were sampled (ten on bare substrata and only one on seagrass as only one site with seagrass was found in this zone). Appendix J contains the raw data. Table 22 sets out an overview of the sampling results. In excess of 5300 individuals were taken of which nearly 2700 were of commercial or recreational significance. No threatened species were captured. The bulk of the catch was made up of fish (3976 individuals) and decapods (1346 individuals) (Table 22). Molluscs (11 individuals) were poorly represented. Of the fish, a relatively large proportion (2539 individuals; 64%) were of commercial/recreational significance compared to the decapods (157 individuals; 12%).

Multivariate assessment of the fish community neatly divided it into two groups, distinguishing between vegetated sites and non-vegetated sites (Figure 23; Appendix K

provides a display of zones, substrata and locations). The bare sites labelled in Figure 23 sit in the top centre-right of the figure and are readily differentiated from the vegetated sites. Furthermore, estuarine zones track across the figure sequentially from upstream to downstream locations. The low stress value (0.05) indicates that the plot is a reliable indicator of the relationships among sites. Distances between points do not fully reflect the similarity between fish communities at each site because the information has been compressed from three into two dimensions. The vegetated sites stand out largely due to greater number of individuals found there. Of the total catch of 5333 individuals, two thirds (3561 individuals) were taken from seagrass, even though fewer hauls (31 vs 40) were made on this substratum.

THIS PAGE HAS INTENTIONALLY BEEN LEFT BLANK FOR INSERTION OF FIGURE 4.1

Figure 18 Estuarine fish sampling sites

THIS PAGE HAS INTENTIONALLY BEEN LEFT BLANK FOR THE INCLUSION OF FIGURE 19

Figure 19 Estuarine fish sampling sites: Marine Tidal Delta

THIS PAGE HAS INTENTIONALLY BEEN LEFT BLANK FOR THE INCLUSION OF FIGURE 20

Figure 20 Estuarine fish sampling sites: Central Mud Basin

THIS PAGE HAS INTENTIONALLY BEEN LEFT BLANK FOR THE INCLUSION OF FIGURE 21

Figure 21 Estuarine fish sampling sites: Fluvial Delta

THIS PAGE HAS INTENTIONALLY BEEN LEFT BLANK FOR THE INCLUSION OF FIGURE 22

Figure 22 Estuarine fish sampling sites: Riverine Channel

Table 22 Taxonomic list and total number of fish, decapods and molluscs collected from the estuarine portion of the Georges River in April 2000

Class/Order/Infraorder/Family/Species		Common Name	Marine Tidal Delta	Central Mud Basin	Fluvial Delta	Riverine Channel	Total number caught
FISH							
CLASS CHONDRICHTHYES							
Order Rhinobatiformes							
Rhinobatidae	*Trygonorrhina fasciata**	Fiddler ray	1				1
CLASS ACTINOPTERYGII							
Order Myliobatiformes							
Dasyatididae	*Dasyatis fluviorum*	Stingray		1			1
Order Anguilliformes							
Anguillidae	*Anguilla australis**	Short-fin eel			2		2
Order Clupeiformes							
Clupeidae	*Hyperlophus vittatus**	Sandy sprat		25	103	256	384
Engraulidae	*Engraulis australis**	Australian anchovy		87			87
Order Lophiiformes							
Antennariidae	*Antennarius striatus*	Striped anglerfish	1				1
Order Atheriniformes							
Atherinidae	*Atherinomorus ogilbyi**	Ogilby's hardyhead	43	2			45
	Pseudomugil signifer	Southern blue-eye				8	8
Order Gasterosteiformes							
Syngnathidae	*Hippocampus whitei*	White's seahorse		1			1
	Stigmatopora nigra	Wide-body pipefish	7				7
	Urocampus carinirostrus	Hairy pipefish	3				3
Order Scorpaeniformes							
Scorpaenidae	*Centropogon australis*	Fortescue	220	48	18		286
Platycephalidae	*Platycephalus arenarius**	Flag-tail flathead	3				3
	*Platycephalus fuscus**	Dusky flathead		3	7		10
	*Platycephalus speculator**	Yank flathead	3				3
Order Gonorynchiformes							
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	119	280	5	41	445
	Ambassis marianus	Ramsey's glassfish		1	5	25	31
Order Perciformes							
Terapontidae	*Pelates sexlineatus**	Eastern striped trumpeter	627	131	70		828
Apogonidae	*Siphamia roseigaster*	Silver siphonfish	3				3
Sillaginidae	*Sillago ciliata**	Sand whiting	221	83	24	16	344
	*Sillago maculata**	Trumpeter whiting	3	35	21		59
Pomatomidae	*Pomatomus saltatrix**	Tailor	55	52	12		119
Carangidae	*Trachurus novaezelandiae**	Yellow-tail scad			1		1
Gerreidae	*Gerres subfasciatus**	Common silver belly	1	77	30	25	133
Sparidae	*Acanthopagrus australis**	Yellow-finned bream	2	40	50	11	103
	*Rhabdosargus sarba**	Tarwhine	12	42	8		62
Mullidae^	*Mullidae* unknown 1^	Goatfish	3				3
	Mullidae unknown 2^	Goatfish	9				9
	Upeneus tragula	Bar-tail goatfish	4				4
Monodactylidae	*Monodactylus argenteus*	Silver batfish				7	7
Girellidae	*Girella tricuspidata**	Blackfish	3	12	5	2	22
Enoplosidae	*Enoplosus armatus**	Old wife	2				2
Mugilidae	*Liza argentea**	Flat-tail mullet		13	25	88	126
	*Mugil cephalus**	Sea mullet			3	7	10
	*Myxus elongatus**	Sand mullet	10	31	5		46
Sphyraenidae	*Sphyraena obtusata**	Striped sea pike		3	2		5
Blenniidae	*Petroscirtes lupus*	Brown sabretooth blenny	29	4	1		34
Clinidae	*Heteroclinus* spp.	Weedfish	5				5
Gobiidae	*Acanthigobius flaviomonius*	Oriental goby			3	3	6
	Afurcagobius tamarensis	Tamar River goby		19	3	28	50
	Arenigobius bifrenatus	Bridled goby		3	3	1	7
	Arenigobius frenatus	Half bridled goby	4	163	48		215
	Bathygobius kreffti	Frayed-fin goby	20	1	1		22
	Cryptocentrus critatus	Oyster goby			1		1
	Favonigobius exquisites	Exquisite sand goby	3	18	47	4	72
	Favonigobius lateralis	Long finned goby	39	1	2		42
	Gobiopterus semivestitus	Glass goby				1	1
	Mugilogobius stigamaticus	Checkered mangrove goby	2				2
	Pseudogobius olorum	Blue-spot goby			1	5	6
	Redigobius macrostoma	Largemouth goby			2	1	3
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon				22	22
Siganidae	*Siganus nebulosus*	Happy moments	17				17
Order Pleuronectiformes							
Paralichthyidae	*Pseudorhombus arsius**	Large-tooth flounder	1	4	13		18
	*Pseudorhombus jenynsii**	Small-tooth flounder	1	15	9		25
Pleuronectidae	*Ammotretis rostratus**	Long-snout flounder	1	1			2
Cynoglossidae	*Paraplagusia unicolor**	Lemon tongue sole	3				3

Table 22 (cont.) Taxonomic list and total number of fish, decapods and molluscs collected from the estuarine portion of the Georges River in April 2000

Class/Order/Infraorder/Family/Species		Common Name	Marine Tidal Delta	Central Mud Basin	Fluvial Delta	Riverine Channel	Total number caught
FISH							
CLASS CHONDRICHTHYES							
Order Rhinobatiformes							
Rhinobatidae	*Trygonorrhina fasciata**	Fiddler ray	1				1
CLASS ACTINOPTERYGII							
Order Myliobatiformes							
Dasyatididae	*Dasyatis fluviorum*	Stingray		1			1
Order Anguilliformes							
Anguillidae	*Anguilla australis**	Short-fin eel			2		2
Order Clupeiformes							
Clupeidae	*Hyperlophus vittatus**	Sandy sprat		25	103	256	384
Engraulidae	*Engraulis australis**	Australian anchovy		87			87
Order Lophiiformes							
Antennariidae	*Antennarius striatus*	Striped anglerfish	1				1
Order Atheriniformes							
Atherinidae	*Atherinomorus ogilbyi**	Ogilby's hardyhead	43	2			45
	Pseudomugil signifer	Southern blue-eye				8	8
Order Gasterosteiformes							
Syngnathidae	*Hippocampus whitei*	White's seahorse		1			1
	Stigmatopora nigra	Wide-body pipefish	7				7
	Urocampus carinirostrus	Hairy pipefish	3				3
Order Scorpaeniformes							
Scorpaenidae	*Centropogon australis*	Fortescue	220	48	18		286
Platycephalidae	*Platycephalus arenarius**	Flag-tail flathead	3				3
	*Platycephalus fuscus**	Dusky flathead		3	7		10
	*Platycephalus speculator**	Yank flathead	3				3
Order Gonorynchiformes							
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	119	280	5	41	445
	Ambassis marianus	Ramsey's glassfish		1	5	25	31
Order Perciformes							
Terapontidae	*Pelates sexlineatus**	Eastern striped trumpeter	627	131	70		828
Apogonidae	*Siphamia roseigaster*	Silver siphonfish	3				3
Sillaginidae	*Sillago ciliata**	Sand whiting	221	83	24	16	344
	*Sillago maculata**	Trumpeter whiting	3	35	21		59
Pomatomidae	*Pomatomus saltatrix**	Tailor	55	52	12		119
Carangidae	*Trachurus novaezelandiae**	Yellow-tail scad			1		1
Gerreidae	*Gerres subfasciatus**	Common silver belly	1	77	30	25	133
Sparidae	*Acanthopagrus australis**	Yellow-finned bream	2	40	50	11	103
	*Rhabdosargus sarba**	Tarwhine	12	42	8		62
Mullidae^	*Mullidae* unknown 1^	Goatfish	3				3
	Mullidae unknown 2^	Goatfish	9				9
	Upeneus tragula	Bar-tail goatfish	4				4
Monodactylidae	*Monodactylus argenteus*	Silver batfish				7	7
Girellidae	*Girella tricuspidata**	Blackfish	3	12	5	2	22
Enoplosidae	*Enoplosus armatus**	Old wife	2				2
Mugilidae	*Liza argentea**	Flat-tail mullet		13	25	88	126
	*Mugil cephalus**	Sea mullet			3	7	10
	*Myxus elongatus**	Sand mullet	10	31	5		46
Sphyraenidae	*Sphyraena obtusata**	Striped sea pike		3	2		5
Blenniidae	*Petroscirtes lupus*	Brown sabretooth blenny	29	4	1		34
Clinidae	*Heteroclinus* spp.	Weedfish	5				5
Gobiidae	*Acanthigobius flaviomonius*	Oriental goby			3	3	6
	Afurcagobius tamarensis	Tamar River goby		19	3	28	50
	Arenigobius bifrenatus	Bridled goby		3	3	1	7
	Arenigobius frenatus	Half bridled goby	4	163	48		215
	Bathygobius kreffti	Frayed-fin goby	20	1	1		22
	Cryptocentrus critatus	Oyster goby			1		1
	Favonigobius exquisites	Exquisite sand goby	3	18	47	4	72
	Favonigobius lateralis	Long finned goby	39	1	2		42
	Gobiopterus semivestitus	Glass goby				1	1
	Mugilogobius stigamaticus	Checkered mangrove goby	2				2
	Pseudogobius olorum	Blue-spot goby			1	5	6
	Redigobius macrostoma	Largemouth goby			2	1	3
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon				22	22
Siganidae	*Siganus nebulosus*	Happy moments	17				17
Order Pleuronectiformes							
Paralichthyidae	*Pseudorhombus arsius**	Large-tooth flounder	1	4	13		18
	*Pseudorhombus jenynsii**	Small-tooth flounder	1	15	9		25
Pleuronectidae	*Ammotretis rostratus**	Long-snout flounder	1	1			2
Cynoglossidae	*Paraplagusia unicolor**	Lemon tongue sole	3				3

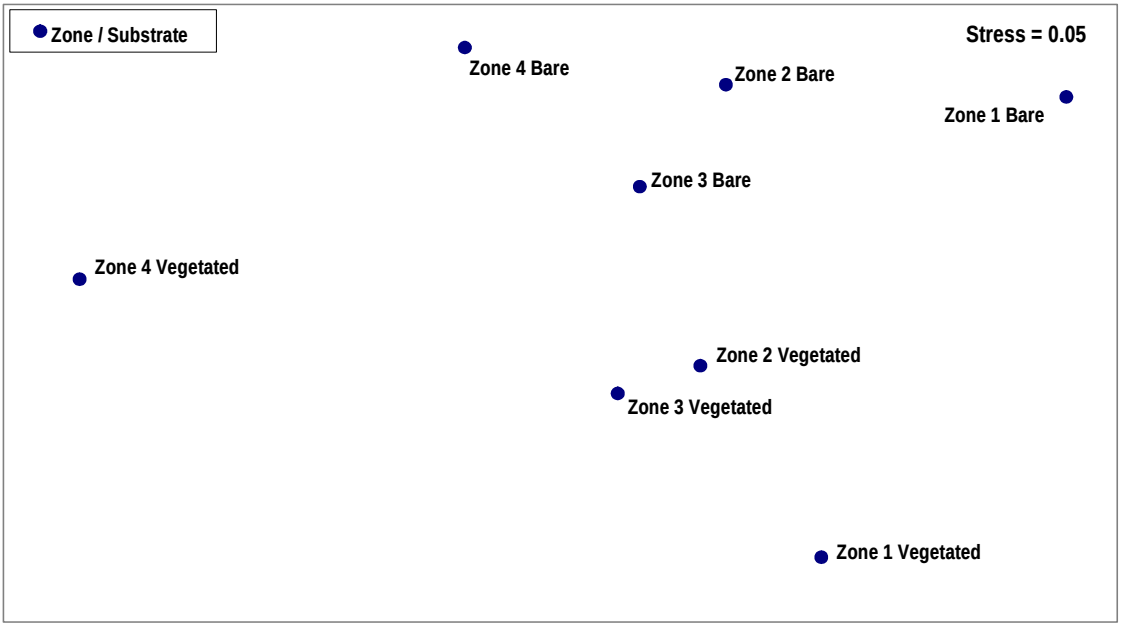

Figure 23 **Two-dimensional multidimensional scaling (MDS) ordination of fish communities in the four zones[1] and two substrata of the estuarine portion of the Georges River**

1. Marine Tidal Delta (Zone 1), Central Mud Basin (Zone 2), Fluvial Delta (Zone 3) and Riverine Channel (Zone 4).

4.2.2 Number of individuals

As indicated previously, the majority of individuals (67%) were captured in seagrass. Of these, 1521 came from the 10 seagrass sites in the Marine Tidal Delta, 1241 from the 10 sites in the Central Mud Basin, 742 from the 10 sites in the Fluvial Delta and 57 from the single seagrass station in the Riverine Channel (Table 23). In contrast, the bare substrata produced only 366 individuals from the Marine Tidal Delta, 552 from the Central Mud Basin, 354 from the Fluvial Delta and 500 from the Riverine Channel.

The abundance of individuals was greater in the lower portion of the estuary, but this was due in part to the fact that only one vegetated site was sampled in the Riverine Channel. If the number of fish (57 individuals) captured at the single vegetated site were assumed to be representative of catch at other parts of the Riverine Channel, then the total abundance of fish in the Riverine Channel (when standardised to a total of ten hauls) is approximately the same as the Fluvial Delta. Nevertheless, the catch at this part of the estuary is still considerably less than in either the Marine Tidal Delta or the Central Mud Basin.

Nearly 2700 individuals (~50% of the total catch) of the catch were of commercial/recreational value, 1416 from the vegetated sites and 1282 from the bare sites (Table 23). The Riverine Channel (408 individuals) and Fluvial Delta (440 individuals) had fewest commercial/ recreational individuals compared to the other two zones (731 and 1119 individuals in the Central Mud Basin and Marine Tidal Delta, respectively).

Table 23 Summary of the number of fish, decapod and mollusc individuals collected from four estuarine zones in the Georges River in April 2000

Taxa	Zone	Marine Tidal Delta			Central Mud Basin			Fluvial Delta			Riverine Channel			All zones		
	Substrate	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated[1]**	**All**	**Bare**	**Vegetated**	**All**
	No. of sites	**10**	**10**	**20**	**10**	**10**	**20**	**10**	**10**	**20**	**10**	**1**	**11**	**40**	**31**	**71**
Fish	**No. of individuals**	358	1217	1575	549	697	1246	272	331	603	499	53	552	1678	2298	3976
	No. of individuals of commercial/ recreational value	340	719	1059	324	350	674	218	183	401	390	15	405	1272	1267	2539
	No. threatened individuals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decapods	**No. of individuals**	8	293	301	3	544	547	82	411	493	1	4	5	94	1252	1346
	No. of individuals of commercial/ recreational value	2	56	58	2	55	57	5	34	39	1	2	3	10	147	157
	No. of threatened individuals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Molluscs	**No. of individuals**	0	11	11	0	0	0	0	0	0	0	0	0	0	11	11
	No. of individuals of commercial/ recreational value	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
	No. of threatened individuals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All	**No. of individuals**	366	1521	1887	552	1241	1793	354	742	1096	500	57	557	**1772**	**3561**	**5333**
	No. of individuals of commercial/ recreational value	342	777	1119	326	405	731	223	217	440	391	17	408	**1282**	**1416**	**2698**
	No. of threatened individual	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**

1. N=1—as only one small patch of vegetation was found in the Riverine Channel

Assessments based soley on the number of individuals taken at sites or within zones can be misleading due to the occasional capture of large numbers of schooling fish. For this reason the mean number of individuals taken at any zone or substrata is plotted (Figure 24). The Marine Tidal Delta and Central Mud Basin averaged approximately 90 individuals per haul, whereas the Fluvial Delta and Riverine Channel had of the order of 50 individuals per haul. These differences, as already indicated, were driven by the larger number of fish in the vegetated compared to the bare substrata (Figure 25).

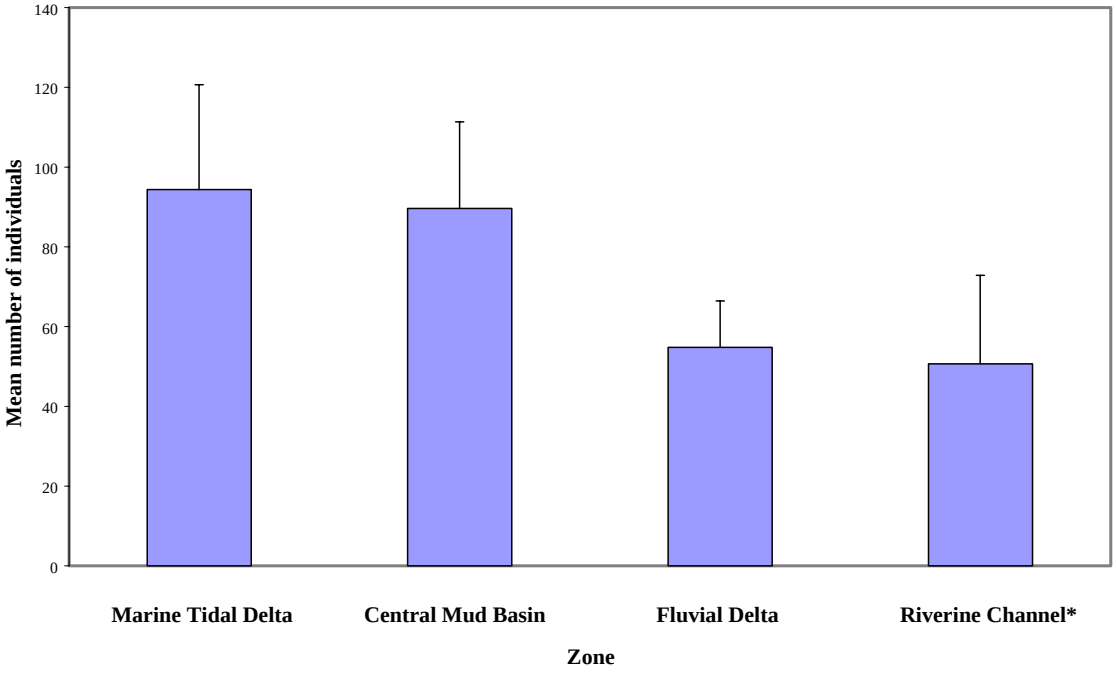

Figure 24 Mean number of individuals (± S.E.) caught in four zones of the Georges River, April 2000. n = 20 hauls for each zone except * where 11 hauls were done.

4.2.3 Number of species

The total number of species of fish present is also of significance. Eighty-seven species of fish, crustacean and mollusc were captured in the Georges River in April 2000 (Table 24). More species (76) were taken in vegetated habitats than in bare habitats (50). The Riverine Channel had half the number of species of the other zones (23 vs. 55, 46, 47 species for the Marine Tidal Delta, Central Mud Basin and Fluvial Delta, respectively).

Thirty-four species of commercial/recreational value were captured, 30 from the vegetated sites and 23 from the bare sites (Table 24). The Riverine Channel had relatively few commercial/ recreational species compared to the other zones (nine vs. 24, 24, 23 species in the Marine Tidal Delta, Central Mud Basin and Fluvial Delta, respectively).

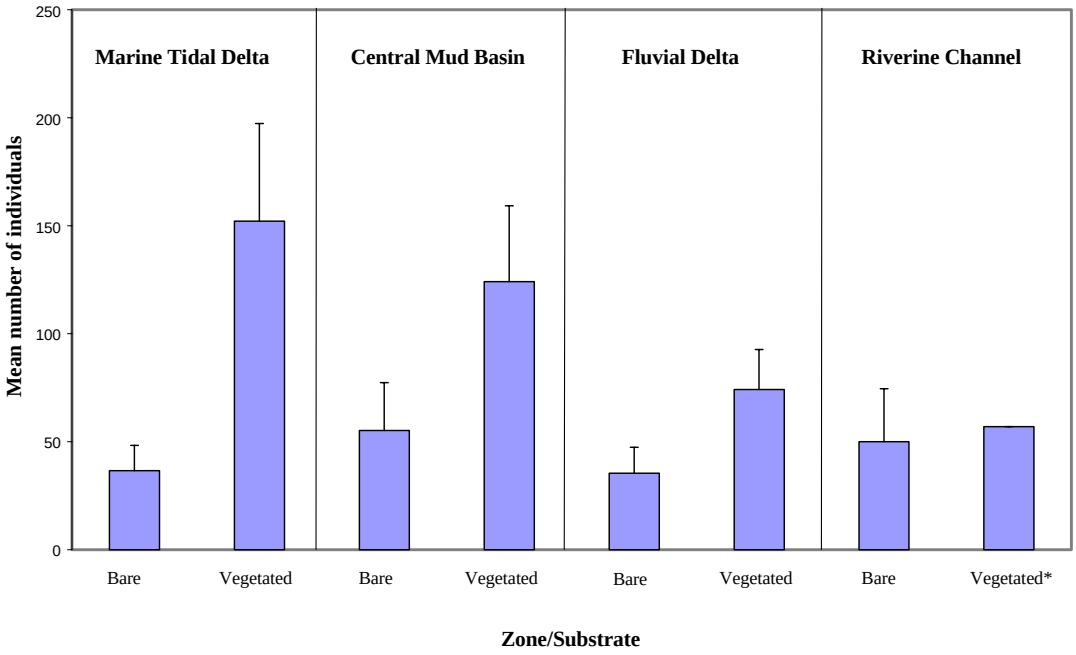

Figure 25 **Mean number of individuals (± S.E.) caught over vegetated and bare substrata in four zones of the Georges River, April 2000. n = 10 hauls for each substrata except * where one haul was done.**

The mean number of species in the Marine Tidal Delta, Central Mud Basin and Fluvial Delta was of the order of 9 to 11 species relative to the Riverine Channel with about five species (Figure 26). When the catch over the two substrata was averaged, thirteen to sixteen species were found in seagrass, except in Riverine Channel where the single sample was taken and eleven species were captured (Figure 27). An average of between four to eight species was found over bare sand.

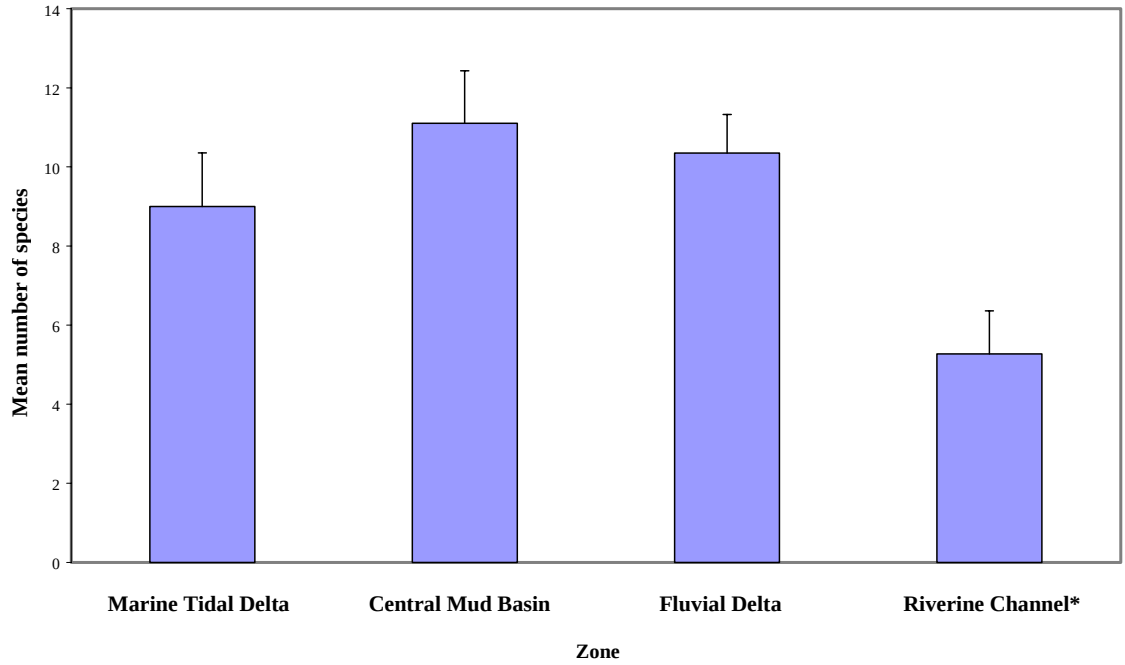

Figure 26 **Mean number of species (± S.E.) caught in four zones of the Georges River, April 2000. n = 20 hauls for each zone except * where 11 hauls were done.**

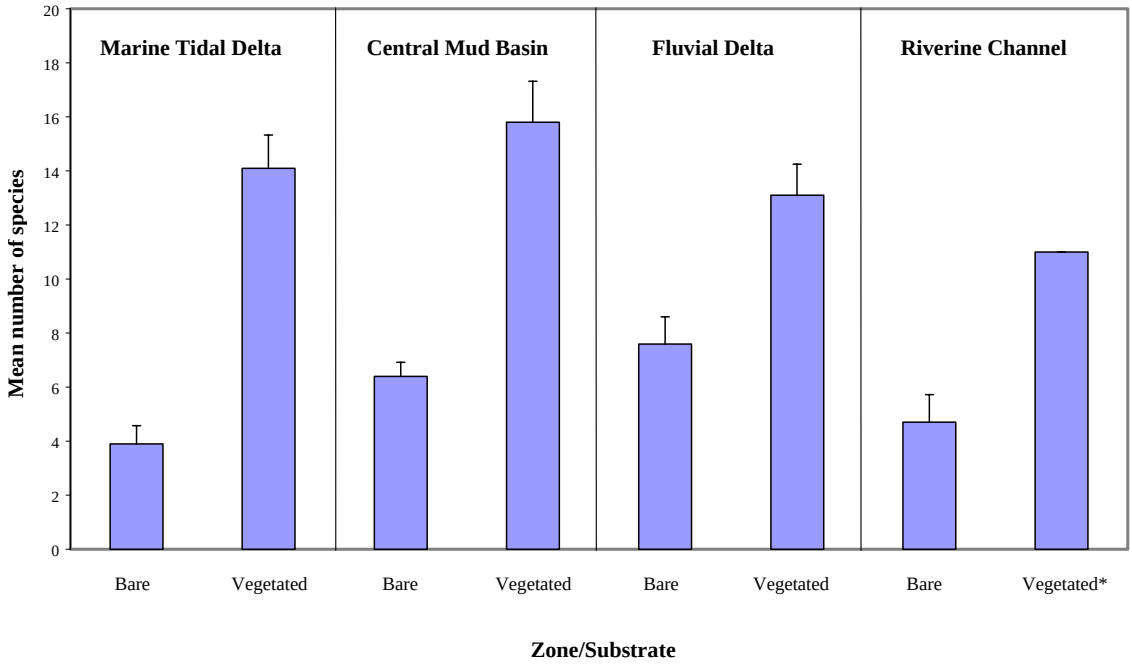

Figure 27 **Mean number of species (± S.E.) caught over vegetated and bare substrata in four zones of the Georges River, April 2000. n = 10 hauls for each substrata except * where one haul was done.**

Table 24 Summary of the number of fish, decapod and mollusc *species* collected from four estuarine zones in the Georges River in April 2000

Taxa	Zone	Marine Tidal Delta			Central Mud Basin			Fluvial Delta			Riverine Channel			All zones		
	Substrate	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated**	**All**	**Bare**	**Vegetated[1]**	**All**	**Bare**	**Vegetated**	**All**
	No. of sites	**10**	**10**	**20**	**10**	**10**	**20**	**10**	**10**	**20**	**10**	**1**	**11**	**40**	**31**	**71**
Fish	**No. of species**	16	35	42	17	31	35	22	34	36	17	9	20	39	58	65
	No. of species of commercial/recreational value	11	14	21	11	17	20	13	19	20	7	3	7	20	25	29
	No. of threatened species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decapods	**No. of species**	6	7	10	3	11	11	7	9	11	1	2	3	11	15	19
	No. of species of commercial/recreational value	1	2	2	2	4	4	2	3	3	1	1	2	3	4	4
	No. of threatened species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Molluscs	**No. of species**	0	3	3	0	0	0	0	0	0	0	0	0	0	3	3
	No. of species of commercial/recreational value	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	No. of threatened species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All	**No. of species**	22	45	55	20	42	46	29	43	47	18	11	23	**50**	**76**	**87**
	No. of species of commercial/recreational value	12	17	24	13	21	24	15	22	23	8	4	9	**23**	**30**	**34**
	No. of threatened species	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**

1. n=1 as only one small patch of vegetation was found in the Riverine Channel.

4.3 Discussion

The statistical outcome provided by multidimensional scaling (MDS) confirmed a general principle of estuarine ecology (e.g. Ferrell & Bell 1991): that communities of fish in seagrass are distinctly different to those found over bare substrata. More specifically, the number of species of fish taken from seagrass in the Georges River was greater than over bare substratum (Figure 27). Furthermore, there was a tendency for the number of individuals to also be greater (Figure 25). Hence, the conservation of seagrass is an important management consideration in relation to maintenance of fish biodiversity in the Georges River.

As well, the MDS defined four fish communities corresponding to the four estuarine zones. Unfortunately, the fish community in the vegetated substrata of the Riverine Channel (Zone 4) was based on data from only one haul of the seine net, as no other beds of Zostera were found in this zone at the time of sampling. Subsequently, during fieldwork to describe the river's estuarine vegetation, a number of similarly small beds were located (see Part C). To assess better the fishes in the seagrass beds and confirm the uniqueness of the Riverine Channel, sampling should be repeated in all zones over various time scales.

The two outcomes reported above lead to an important consideration—that there is a need to substantiate the presence of estuarine zones and if necessary establish and refine a concept of zone-based management of estuarine fish. That is to say, differing conservation strategies may need to be applied to different zones of the river. For example, because of its proximity to the ocean and the fact that the Marine Tidal Delta experiences full tidal flushing, the residence time of pollutants and hence their impact in this zone is considerably less than in the Riverine Channel. Retention time is of particular importance in the upper estuary where long-term increases in turbidity were once caused by sand mining. Now, stormwater runoff contributes to turbidity. Seagrass in the upper part of the estuary might be particularly susceptible to this type of impact.

Prior to this study, in the winter of 1999, parts of the Botany Bay system had been sampled by NSW Fisheries. The type of net and other sampling protocols used in that exercise were the same as used in this study. The winter sampling caught 1923 individuals, of which 521 were of commercial/recreational significance (Table 25). In contrast, the following summer (this project, April 2000), 5337 individuals including 2704 of economic significance were captured. The larger number of individuals caught during second sampling was due in part to the fact that sampling was conducted at four rather than at only two of the estuarine zones as well as seasonal or temperature factors. To examine this apparent difference, the two zones for which there were equivalent data (Marine Tidal Delta and Central Mud Basin) were compared. The greater number of individuals was taken in late summer (Table 25). Summer appears to be the best time to sample and enhance our understanding of biodiversity in the fish community of the Georges River–Botany Bay system. This point is referred to further below.

In the winter of 1999, 49 species of fish, crustaceans and molluscs were taken and of these, 23 were species of commercial or recreational significance (Table 26). The following summer, 89 species were captured of which 35 were of economic

significance. In comparison with 31 estuaries sampled by NSW Fisheries, some on two occasions (Table 26), the 89 species found in Georges River–Botany Bay in summer 2000 was the highest number of species present for any single sampling exercise (Table 27), and suggests that at the state-wide scale, Georges River–Botany Bay can function well as a fish habitat. The imbalance in the data sets and the lack of long-term sampling qualify this result.

It needs to be noted that some species occurred uniquely on one or other of the two sampling occasions: of the 49 species captured in winter of 1999, 10 were not found the following summer; of the 89 species taken in summer of 2000, 50 were not captured the previous winter. Consolidating these two data sets identifies 99 species in the system (77 species of fish, 19 species of crustacean, 3 species of mollusc), further substantiating the estuary's function, but also underlining the fact any single collection, even one in the summer, only identifies a subset of the species present.

In spite of the large number of species found in the estuary of the Georges River it can not be concluded that there are no conservation issues of significance. Problems, if present and as yet undetected, or likely to develop, will most likely manifest themselves in parts of the river where pollutants enter and there is a low degree of flushing. The Riverine Channel is the prime candidate for this situation. Only 20 of the 99 species so far found in the estuary were captured in this zone, but these species are not unique to the Riverine Channel as 16 of them were also found in the more downstream zones. Of the four remaining species, i.e. those found exclusively in the Riverine Channel (*Pseudomugil signifer*, *Monodactylus argenteus*, *Gobiopterus semivestitus* and *Philypnodon grandiceps*; Table 22), the first three are known from other studies to be widespread in estuaries. Even when fully grown, individuals of these species are small enough to escape through the size of mesh used in this study, but their capture may be because they were swept up with and kept within the net by the bodies of other fish. *P. grandiceps* can be considered the only species unique to the Riverine Channel. It occurs commonly in water of low salinity.

Table 25 Number of individuals of fish, crustaceans and molluscs taken from each zone in the Georges River in July 1999 and April 2000

		Marine Tidal Delta		Central Mud Basin		Fluvial Delta		Riverine Channel		All zones	
No. of samples	**1999**	N=20		N=20		NS		NS		N=40	
	2000	N=20		N=20		N=20		N=11		N=71	
		No. of individuals	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**
Fish	**1999**	377	168	478	273	NS	NS	NS	NS	855	441
	2000	1578	1064	1247	675	603	401	552	405	3980	2545
Crustaceans	**1999**	47	29	998	51	NS	NS	NS	NS	1045	80
	2000	301	58	547	57	493	39	5	3	1346	157
Molluscs	**1999**	5	0	18	0	NS	NS	NS	NS	23	0
	2000	11	2	0	0	0	0	0	0	11	2
All	**1999**	429	197	1494	324	NS	NS	NS	NS	1923	521
	2000	1890	1124	1794	732	1096	440	557	408	5337	2704

NS—Not sampled

Table 26 Number of species of fish, crustaceans and molluscs taken from each zone in the Georges River in July 1999 and April 2000

		Marine Tidal Delta		Central Mud Basin		Fluvial Delta		Riverine Channel		All zones	
No. of samples	**1999**	N=20		N=20		NS		NS		N=40	
	2000	N=20		N=20		N=20		N=11		N=71	
		No. of individuals	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**	**No. of individuals**	**No. of commercial/recreational individuals**
Fish	**1999**	23	11	32	18	NS	NS	NS	NS	41	22
	2000	45	22	36	21	36	20	20	7	68	30
Crustaceans	**1999**	4	1	5	1	NS	NS	NS	NS	7	1
	2000	10	2	11	4	10	4	3	2	18	4
Molluscs	**1999**	1	0	1	0	NS	NS	NS	NS	1	0
	2000	3	1	0	0	0	0	0	0	3	1
All	**1999**	28	12	38	19	NS	NS	NS	NS	49	23
	2000	58	25	47	25	46	24	23	11	89	35

NS—Not sampled

Table 27 NHT Estuarine Biodiversity Project: Maximum number of species per estuary. Estuaries are listed from north to south.

Bioregion[1]	Maximum number of species[2]						
	20–29	**30–39**	**40–49**	**50–59**	**60–69**	**70–79**	**80–89**
Tweed Moreton	*Moonee Creek # 1 (15) June 2000*	*Moonee Creek #2 (15) Aug. 2000*	Tweed River (25) Nov. 1999	Richmond River (40) Dec. 1999			
		Coffs Creek (15) June 2000	Brunswick River (33) Nov. 1999	Clarence River (40) Dec. 1999			
		Deep Creek 1 (15) June 2000	*Sandon River (40) June 2000*	*Wooli Wooli River (30) June 2000*			
		Deep Creek 2 (15) Aug. 2000	*Corindi River (30) June 2000*	Bellinger/Kalang Rivers (40) Mar. 2000			
Manning Shelf	Smiths Lake (30) Nov. 2000		Macleay River (31) Dec. 1999	Nambucca River (25) Mar. 2000	Hastings River (40) Feb. 2000	Karuah River/ Port Stephens (55) Jan. 2000	
				Wallis Lake (40) Feb. 2000	Manning River (40) Mar. 2000		
Hawkesbury Shelf		Hunter River (15) Jan. 2000	***Georges River–Botany Bay #1 (40) July 1999***	*Hawkesbury River (40) Sept. 1999*	Lake Macquarie (40) Jan.–Feb. 2000	Tuggerah Lakes (40) Mar. 2000	**Georges River–Botany Bay #2 (71) Apr. 2000**
				Lake Illawarra (40) Mar. 2000	Brisbane Water (40) Feb. 2000	Hacking River #2 (60) Apr. 2000	
					Pittwater (40) Sept. 1999		

					Parramatta River (40) Aug.–Sept. 1999		
					Hacking River #1 (40) Aug. 1999		
Batemans Shelf			Conjola Lake #1 (40) Apr. 2000	Shoalhaven/ Crookhaven Rivers (40) Mar. 2000			
				St. Georges Basin (40) Apr. 2000			
				Conjola Lake #2 (40) Nov. 2000			

1. Bioregions and estuaries are oriented from north to south. Italics show collections in winter months, (brackets) indicate number of seine hauls.

Therefore, the question of importance is: why do 79 species not inhabit the Riverine Channel? Are there natural, such as osmotic, constraints on their distribution, or are there artificial, human-induced impacts that have rendered this part of the estuary unusable by some fish? If the latter is the case, then the condition of at least part of the estuary needs further examination. Remembering that the deposition of sediments allows the Riverine Channel to slowly expand downstream at the expense of the Fluvial Delta, there is an implication that biodiversity may be being progressively reduced from the upper river through to the middle reaches. Does human activity quicken the infilling and speed up the reduction of biodiversity in the Riverine Channel?

The loads of epiphytes and sometimes patchy distribution of *Zostera* seagrass in Kogarah Bay (see Part 2 of this report) suggests this part of the Georges River catchment might also be under stress (Florence *et al.* 1999). If so, then the carrying capacity of this subcatchment for estuarine fishes may be compromised. Further investigations of the fish communities and habitats of Kogarah Bay are necessary.

4.4 Conclusions

The sampling method used in this project suggests that the estuarine fish community of the Georges River is as diverse and abundant as other NSW estuaries sampled in the same way. This finding is qualified by the lack of data on fish communities in the river as well as in NSW estuaries generally. No threatened species were found, but it can not be concluded that none are present. A wider array of sampling gear used over a range of seasons and years would be needed to confirm the lack of threatened species. Of concern, however, is the potential for increasing stress to be placed on fish communities via the modification of habitats as population pressure increases in the catchment. This is particularly true where sediments and particles washed into the estuary may change water quality and have an impact on the distribution of seagrass. Maintenance of the latter is of fundamental importance as, in keeping with the vast body of literature on estuarine fish communities, seagrass sites in the Georges River had a distinctly different suite of species compared to the bare substrata. Seagrass sites were characterised by more species of fish and more individuals (Figures 25 and 27).

As well, fish communities differed at various points along the river; specifically, each of the four estuarine zones had a distinct fish community (Figure 23). If this feature is real, rather than a function of limited sampling, separate management strategies may be needed to conserve and enhance the fish communities in each zone. For example, *Posidonia* seagrass is only found in the Marine Tidal Delta and Central Mud Basin environments (Part C), but its presence at the former is mediated by wave energy (Larkum & West 1990). Due to longer residence times of pollutants in upstream reaches, distribution and abundance of seagrass may be related to water quality. Kogarah Bay (a part of the Central Mud Basin) may indicate the latter circumstance, as some *Zostera* is patchy in distribution and/or covered with epiphytes, and the distribution of *Posidonia* is restricted (see Part C). In contrast, *Zostera* is found much further upriver than *Posidonia* and is apparently able to tolerate greater variation in salinity, turbidity and possibly other water quality variables. Maintenance of seagrass almost certainly requires different management considerations depending on location

in the river, water quality and pollutant residence times, and as indicated, the key to appropriate management of fishes appears to reside in the management of seagrass.

4.5 Recommendations

The following recommendations emerge from this phase of the study:

1. Planning instruments must support recovery plans for currently listed threatened species of fish such as black cod *Epinephelus daemelii* and green sawfish *Pristis zijsron*. Planning instruments must be flexible and able to contend with species that might be listed at some future time.

2. Planning instruments must support pest species management plans for fish identified as pests at some future time.

3. Separate management strategies need to be devised for the fish communities of each of the four estuarine zones of the Georges River.

4. The fish communities of Kogarah Bay need to be defined better, particularly those species associated with seagrasses.

5. The fish communities of the Riverine Channel, particularly those species associated with seagrass need to be defined better.

6. The potential benefits of restrictive land management practices (e.g. foreshore building restrictions) for the better conservation of estuarine fish at Biodiversity Core, Support and Enhancement sites needs to be assessed.

7. Where there is potential to enhance fish habitat, particularly in the Riverine Channel, foreshore rehabilitation programs should be initiated.

NOTE: NSW Fisheries is developing a series of documents designed to assist with the management of aquatic habitats, species and the threats to them. A list of the documents in this series that relate to the GRC is provided in Appendix N; however the most current list of such publications should be checked in the conservation section of the NSW Fisheries website (www.fisheries.nsw.gov.au).