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FISH DIVERSITY BEFORE AND AFTER CONSTRUCTION OF THE PUNGGOL AND SERANGOON RESERVOIRS, SINGAPORE

Pei Xin Ng and **Heok Hui Tan**[1*]
[1]*Raffles Museum of Biodiversity Research, National University of Singapore*
Block S6, Science Drive 2, #03-01, Singapore 117546, Republic of Singapore
(*[*]Corresponding author: dbsthh@nus.edu.sg*)

ABSTRACT. — The fish diversity in Punggol and Serangoon estuaries was documented before and after they were dammed to serve as reservoirs. A total of 119 species was recorded before the estuaries became landlocked. The fish community changed with the gradual conversion of the marine environment to freshwater. A year later, 32 species were recorded with seven additional freshwater species. This is a considerable drop in fish diversity as most species, unable to adapt to complete their life cycle in freshwater, disappeared. Their places were taken over by nine, largely alien, freshwater taxa.

KEY WORDS. — aquatic biodiversity, Punggol reservoir, Serangoon reservoir, estuary, Singapore

INTRODUCTION

The Punggol and Serangoon reservoirs are the 16th and 17th reservoirs in Singapore. These two reservoirs were formed by damming the estuaries of Sungei Punggol and Sungei Serangoon, which changed the aquatic environment. Originally marine, these water bodies gradually became freshwater when tidal influence ceased upon damming. In response to the decreasing salinity, there is an expected change in the fish species assemblages. This report provides a record of the changes in the fish community observed before and after the completion of the Punggol and Serangoon reservoirs.

MATERIAL AND METHODS

Baseline fish surveys were conducted before the barrage construction at Sungei Punggol and Sungei Serangoon from Dec.2003 to Feb.2004. During barrage construction, monthly surveys were conducted from Feb.2007 to Nov.2009. Construction at Sungei Punggol was completed in Dec.2009. Thereafter, the frequency of surveys decreased from monthly to quarterly in the year 2010, corresponding to the decrease in construction activity at the estuaries. Quarterly surveys were conducted in Jan., Apr., Jul., Oct., and Nov.2010. After the Serangoon Tidal Gates were completed and closed in Oct.2010, half-yearly surveys (in Apr. and Oct.) were conducted in 2011. Surveys sites are indicated in Fig. 1. Salinity was not measured, but records are maintained by the Public Utilities Board (PUB).

Fish species were sampled primarily by cast-netting (each net about 12 or 14 feet across, with 15 mm mesh) from a boat. The collection of fish was supplemented with gill-netting (gill net ~200 m, with ~8 cm mesh) and seining (seine net 30 m, with 1 cm mesh). However, seining was no longer used after sandy areas suitable for this method were dredged for barrage construction.

RESULTS AND DISCUSSION

A total of 129 fish species was recorded in Sungei Punggol/Punggol Reservoir and Sungei Serangoon/Serangoon Reservoir. From the last surveys, 32 species were found, but the diversity is expected to drop further. The fish diversity recorded before and during dam construction, as well as up to two months after the dam closure, was compared with that observed more than two months after the dam closure (Table 1). The change in the fish community follows the presumed change in water salinity before the dam closure and after gradual desalination had taken place for two months or more after the dam closure.

Prior to dam closure, during the period of construction, and immediately after dam closure, a wide range of estuarine and freshwater fish species was recorded. Most estuarine species were not observed several months after the tidal gates were closed. This is most likely due to the decreased salinity of the reservoir water. Although salinity data were not recorded, gradual desalination would have occurred when water was released into the sea at the barrage, and reservoirs

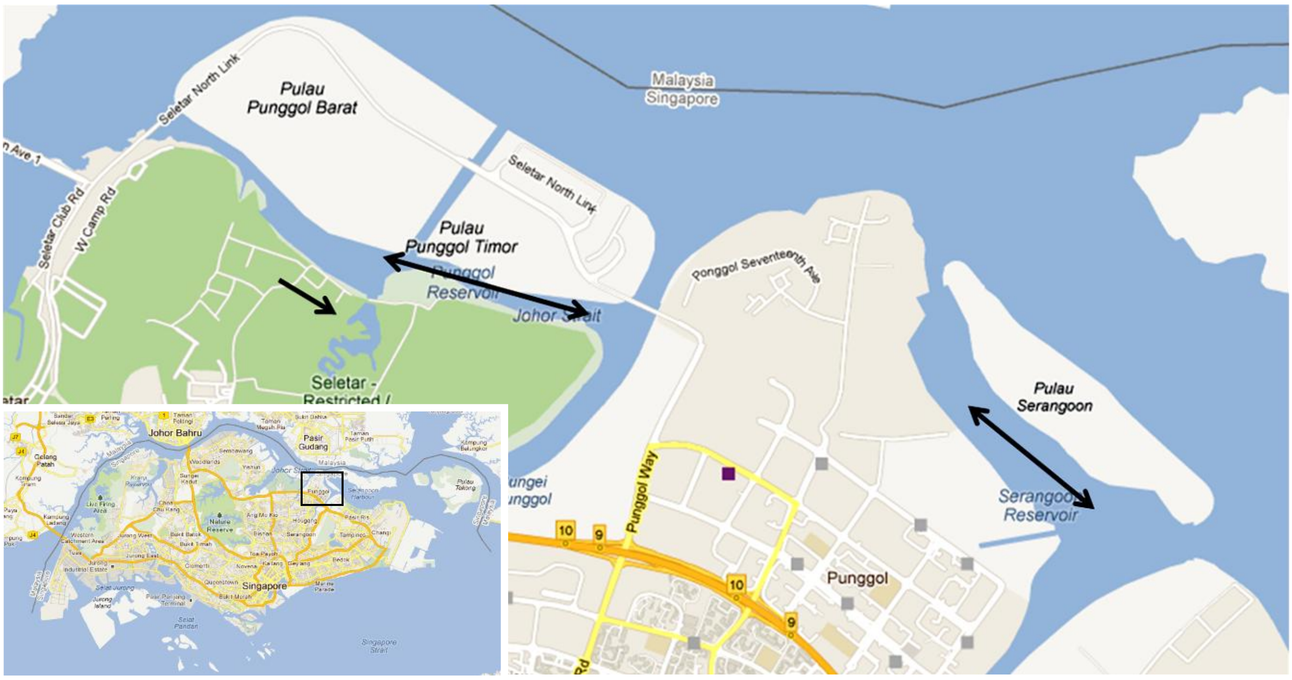

Fig. 1. Double-headed arrows indicate regions where sampling was conducted. Single-headed arrow points to survey site at the Wet-Gap within Seletar Camp (Google Maps, 2011).

were filled by rainwater. Many species of estuarine fish could have died when they were unable to cope with the reduced salinity. All together, 90 species were not recorded again one year after the water bodies were isolated from the sea.

Nevertheless, it is interesting to note that at least four estuarine species persisted in Punggol Reservoir one year after the closure of Punggol Tidal Gate, when the salinity level would have been very much reduced. These four species are *Glossogobius aureus* (Fig. 2), *Hyporhamphus limbatus* (Fig. 3), *Toxotes jaculator* (Fig. 4), and *Zenarchopterus buffonis* (Fig. 5). Although they appear to be surviving, they are probably unable to reproduce successfully in the altered environment. Their persistence indicates that they have higher tolerance to water of low salinity levels. These species are not present in the older estuarine reservoirs such as Kranji and Lower Seletar, so those in the Punggol Reservoir are likely to die off in due time.

Because of time and cost constraints, sampling was restricted to the mouth of the drainages. Interior reaches and deeper areas of the drainage system were not explored for fish diversity. It is possible that more estuarine species may persist in the deeper pockets where the water may remain brackish. The water salinity profiles of the Sungei Punggol and Sungei Serangoon drainages were not investigated, and it is not known how water chemistry and movement affect the fish community there.

A total of 54 non-native freshwater fish species were found in the other 15 reservoirs in Singapore (Ng & Tan, 2010). Out of these, 10 were observed in the Punggol and Serangoon reservoirs (Table 2). These non-native species could have been introduced via the release of pet fish from the ornamental fish trade (e.g., *Parambassis siamensis*), for angling purposes (e.g., *Cichla orinocensis*), and from the live food fish industry (e.g., *Oreochromis niloticus*). However, it is more likely that they were already present in the interior, freshwater reaches of the drainage system, and simply migrated to the sampling sites when the water salinity profile was altered. The status of *Mystus wolffii* has been clarified by Ng (2012) and it is likely to be a native species, especially in coastal drainages or dammed estuaries converted into reservoirs (e.g., Lower Seletar and Kranji reservoirs).

The species list in Table 1 is unlikely to be comprehensive, partly owing to limited sampling techniques (cast netting, seining, and gill netting), inadequate sampling, and limited access to survey sites. Records of certain freshwater species (e.g., *Rasbora borapetensis*) were based on specimens collected earlier in the area and deposited at the Zoological Reference Collection (ZRC), Raffles Museum of Biodiversity Research, National University of Singapore. A nationally and internationally vulnerable fish, the spotted seahorse or *Hippocampus kuda*, was recorded in 2007 from the then Sungei Serangoon. Hilomen-Garcia et al. (2003) has shown that this species will not survive in freshwater, so it is expected to become extirpated in the Serangoon Reservoir.

Table 1. Fish species recorded from Sungei Punggol/Punggol Reservoir, Sungei Serangoon/Serangoon Reservoir, and the Wet-Gap at Seletar Camp before, during, and immediately after dam construction/closure, and months after dam closure. Introduced species are indicated with an asterisk (*). Species that live and breed predominantly in freshwater are marked with a hash sign (#).

S/No.	Family	Species	Presence before and during Dam Construction, and Immediately after Dam Closure	Presence Months after Dam Closure
1.	Adrianichthyidae	*Oryzias javanicus*	Y	Y
2.	Ambassidae	*Ambassis interrupta*	Y	
3.	Ambassidae	*Ambassis kopsii*	Y	Y
4.	Ambassidae	*Ambassis nalua*	Y	
5.	Ambassidae	*Ambassis vachelli*	Y	
6.	Ambassidae	*Parambassis siamensis* *#		Y
7.	Apogonidae	*Apogon hyalosoma*	Y	
8.	Ariidae	*Arius oetik*	Y	
9.	Ariidae	*Hexanematichthys sagor*	Y	Y
10.	Ariidae	*Plicofollis nella*	Y	
11.	Atherinidae	*Atherinomorus duodecimalis*	Y	
12.	Bagridae	*Mystus gulio*	Y	
13.	Bagridae	*Mystus wolffii*		Y
14.	Batrachoididae	*Batrachomoeus trispinosus*	Y	
15.	Belonidae	*Strongylura strongylura*	Y	
16.	Blennidae	*Omobranchus ferox*	Y	
17.	Callionymidae	*Callionymus schaapi*	Y	
18.	Carangidae	*Alectis indicus*	Y	
19.	Carangidae	*Alepes djedaba*	Y	
20.	Carangidae	*Carangoides praestus*	Y	
21.	Carangidae	*Scomberoides commersonnianus*	Y	
22.	Chaetodontidae	*Parachaetodon ocellatus*	Y	
23.	Chanidae	*Chanos chanos*	Y	
24.	Channidae	*Channa striata* #		Y
25.	Cichlidae	*Cichla orinocensis* *#		Y
26.	Cichlidae	*Cichlasoma* sp. (Luohan) *#	Y	
27.	Cichlidae	*Cichlasoma urophthalmus* *	Y	Y
28.	Cichlidae	*Etroplus suratensis* *	Y	Y
29.	Cichlidae	*Oreochromis mossambicus* *	Y	Y
30.	Cichlidae	*Oreochromis niloticus* *#	Y	
31.	Cichlidae	*Oreochromis mossambicus* × *Oreochromis niloticus* hybrid *	Y	Y
32.	Clupeidae	*Anodontostoma chacunda*	Y	
33.	Clupeidae	*Escualosa thoracata*	Y	
34.	Clupeidae	*Herklotichthys dispinolotus*	Y	
35.	Clupeidae	*Hilsa keele*	Y	
36.	Clupeidae	*Nematolosa nasus*	Y	
37.	Clupeidae	*Sardinella albella*	Y	
38.	Cynoglossidae	*Cynoglossus puncticeps*	Y	
39.	Cyprinidae	*Rasbora borapetensis* *#	Y	
40.	Dasyatidae	*Neotrygon kuhlii*	Y	
41.	Dasyatidae	*Himantura walga*	Y	
42.	Dasyatidae	*Himantura zugei*	Y	
43.	Drepaneidae	*Drepane punctata*	Y	
44.	Eleotridae	*Butis humeralis*	Y	
45.	Eleotridae	*Butis butis*	Y	
46.	Eleotridae	*Oxyeleotris marmorata* #		Y
47.	Elopidae	*Elops hawaiiensis*	Y	
48.	Engraulididae	*Stolephorus indicus*	Y	
49.	Engraulididae	*Thryssa hamiltonii*	Y	
50.	Gerreidae	*Gerres abbreviatus*	Y	
51.	Gerreidae	*Gerres filamentosus*	Y	
52.	Gerreidae	*Gerres kappas*	Y	
53.	Gerreidae	*Gerres longispinis*	Y	
54.	Gerreidae	*Gerres macracanthus*	Y	
55.	Gerreidae	*Gerres oyena*	Y	
56.	Gobiidae	*Acentrogobius caninus*	Y	
57.	Gobiidae	*Acentrogobius janthinopterus*	Y	
58.	Gobiidae	*Acentrogobius nebulosus*	Y	
59.	Gobiidae	*Acentrogobius viridipunctatus*	Y	Y
60.	Gobiidae	*Brachygobius kabiliensis*	Y	
61.	Gobiidae	*Calamiana variegata*	Y	
62.	Gobiidae	*Drombus globiceps*	Y	

S/No.	Family	Species	Presence before and during Dam Construction, and Immediately after Dam Closure	Presence Months after Dam Closure
63.	Gobiidae	*Exyrias puntang*	Y	Y
64.	Gobiidae	*Glossogobius aureus*	Y	Y
65.	Gobiidae	*Glossogobius circumspectus*	Y	
66.	Gobiidae	*Glossogobius giurus*	Y	
67.	Gobiidae	*Glossogobius sparsipapillus*	Y	Y
68.	Gobiidae	*Gobiopterus birtwistlei*	Y	
69.	Gobiidae	*Gobiopterus brachypterus*		Y
70.	Gobiidae	*Hemigobius hoeveni*	Y	
71.	Gobiidae	*Pandaka pygmaea*	Y	
72.	Gobiidae	*Periophthalmus argentilineatus*	Y	
73.	Gobiidae	*Periophthalmodon schlosseri*	Y	Y
74.	Gobiidae	*Periophthalmus walalaikae*	Y	
75.	Gobiidae	*Pseudogobius javanicus*	Y	Y
76.	Gobiidae	*Stigmatogobius sadanundio*	Y	
77.	Haemulidae	*Plectorhinchus gibbosus*	Y	
78.	Haemulidae	*Pomadasys kaakan*	Y	
79.	Haemulidae	*Pomadasys maculatum*	Y	
80.	Hemiramphidae	*Hyporhamphus quoyi*	Y	
81.	Hemiramphidae	*Zenarchopterus buffonis*	Y	Y
82.	Hemiramphidae	*Zenarchopterus gilli*	Y	
83.	Hemiramphidae	*Hyporhamphus limbatus*		Y
84.	Latidae	*Lates calcarifer*	Y	
85.	Leiognathidae	*Aurigequula longispina*	Y	
86.	Leiognathidae	*Karalla daura*	Y	
87.	Leiognathidae	*Leiognathus equulus*	Y	
88.	Leiognathidae	*Nuchequula blochii*	Y	Y
89.	Leiognathidae	*Secutor hanedai*	Y	
90.	Monacanthidae	*Acreichthys tomentosum*	Y	
91.	Monodactylidae	*Monodactylus argenteus*	Y	
92.	Mugilidae	*Ellochelon vaigiensis*	Y	Y
93.	Mugilidae	*Liza oligolepis*	Y	Y
94.	Mugilidae	*Liza tade*	Y	
95.	Mugilidae	*Valamugil buchanani*	Y	Y
96.	Mugilidae	*Valamugil speigleri*		Y
97.	Mugilidae	*Upeneus sulphurous*	Y	
98.	Osphronemidae	*Trichopodus trichopterus #*		Y
99.	Paralichthyidae	*Pseudorhombus malayanus*	Y	
100.	Phallostethidae	*Neostethus lankesteri*	Y	
101.	Platycephalidae	*Platycephalus indicus*	Y	
102.	Platycephalidae	*Thysanophrys carbunculus*	Y	
103.	Plotosidae	*Plotosus canius*	Y	
104.	Plotosidae	*Plotosus lineatus*	Y	
105.	Poeciliidae	*Gambusia affinis *#*		Y
106.	Poeciliidae	*Poecilia reticulata *#*	Y	
107.	Poeciliidae	*Poecilia sphenops **	Y	Y
108.	Pristigasteridae	*Ilisha* sp.	Y	
109.	Scatophagidae	*Scatophagus argus*	Y	
110.	Sciaenidae	*Dendrophysa russelli*	Y	
111.	Sciaenidae	*Sciaenops ocellata **	Y	
112.	Serranidae	*Epinephalus coioides*	Y	
113.	Siganidae	*Siganus guttatus*	Y	
114.	Siganidae	*Siganus javus*	Y	
115.	Sillaginidae	*Sillago sihama*	Y	Y
116.	Soleidae	*Brachirus orientalis*	Y	
117.	Sphyraenidae	*Sphyraena jello*	Y	
118.	Stromateidae	*Pampus chinensis*	Y	
119.	Syngnathidae	*Hippichthys cyanospilus*	Y	
120.	Syngnathidae	*Hippocampus kuda*	Y	
121.	Terapontidae	*Terapon jarbua*	Y	
122.	Tetraodontidae	*Lagocephalus lunaris*	Y	
123.	Tetraodontidae	*Takifugu oblongus*	Y	
124.	Tetraodontidae	*Tetraodon nigroviridis*	Y	
125.	Toxotidae	*Toxotes chatareus*	Y	Y
126.	Toxotidae	*Toxotes jaculator*	Y	Y
127.	Triacanthidae	*Triacanthus biaculeatus*	Y	
128.	Triacanthidae	*Tripodichthys blochii*	Y	
129.	Trichiuridae	*Eupleurogrammus glossodon*	Y	

Fig. 2. *Glossogobius aureus*, ca. 120 mm SL, an estuarine species that was recorded in Punggol Reservoir one year after the tidal gates were closed (Photograph by: Tan Heok Hui).

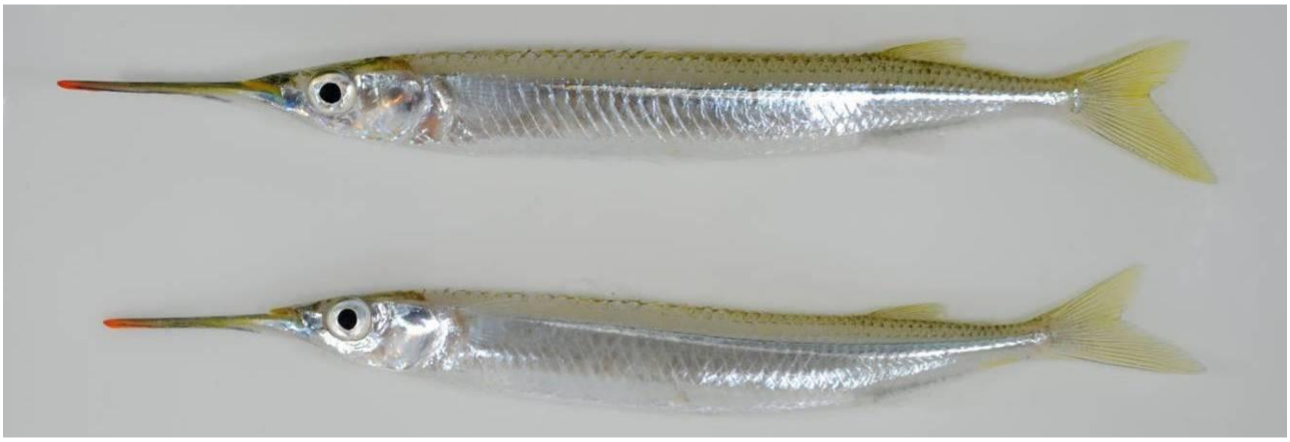

Fig. 3. *Hyporhamphus limbatus*, 104.8 mm SL (top) and 100.4 mm SL (bottom), an estuarine species that was recorded in Punggol Reservoir one year after the tidal gates were closed (Photograph by: Tan Heok Hui).

Fig. 4. *Toxotes jaculator*, ca. 150 mm SL, an estuarine species that was recorded in Punggol Reservoir one year after the tidal gates were closed (Photograph by: Tan Heok Hui).

Fig. 5. *Zenarchopterus buffonis*, 114.7 mm SL, an estuarine species that was recorded in Punggol Reservoir one year after the tidal gates were closed (Photograph by: Tan Heok Hui).

Table 2. Non-native freshwater fish species of Punggol and Serangoon reservoirs, and their occurrences in other reservoirs in Singapore (based on Ng & Tan, 2010).

S/No.	Species	Reservoirs
1.	*Rasbora borapetensis*	Lower Seletar, MacRitchie
2.	*Mystus wolffii*	Murai, Lower Peirce, Lower Seletar, Upper Seletar
3.	*Gambusia affinis*	Bedok, Jurong Lake, Kranji, Lower Pierce, Lower Seletar, Murai, Tengeh, Upper Peirce, Upper Seletar
4.	*Poecilia sphenops*	Bedok, Lower Seletar
5.	*Parambassis siamensis*	Jurong Lake, Kranji, Lower Pierce, Lower Seletar, MacRitchie, Murai, Upper Peirce, Upper Seletar
6.	*Cichla orinocensis*	Bedok, Jurong Lake, Kranji, Lower Peirce, Lower Seletar, MacRitchie, Pandan
7.	*Cichlasoma urophthalmus*	Bedok, Sarimbun, Upper Peirce
8.	*Etroplus suratensis*	Kranji, Lower Seletar
9.	*Oreochromis mossambicus*	Bedok, Pulau Tekong
10.	*Oreochromis niloticus*	Jurong Lake, Murai, Sarimbun, Tengeh, Upper Peirce

CONCLUSIONS

The building of barrages to construct the Punggol and Serangoon reservoirs led to drastic changes in the water salinity, which affected the fish species composition in these two water bodies. It expectedly resulted in the disappearance of estuarine species that require waters with high salinity, and the colonisation of predominantly freshwater taxa. As all of the fish species recorded from the Sungei Punggol and Sungei Serangoon estuaries are also found in other coastal areas of Singapore, the construction of the two reservoirs is believed to have relatively low impact on the fish diversity of Singapore.

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