FISH BIODIVERSITY IN LAKE ILLAWARRA: A REVIEW OF THREE RECENT SURVEYS

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ABSTRACT

Three surveys conducted in Lake Illawarra between 1997 and 2000 were designed to assess the abundance and number of species of small fish living in seagrass around the foreshore. The three studies were similar in using a small haul net, but differed in terms of net dimensions, and duration and frequency of sampling. A 12 m net was used in two of the surveys, but one survey was done at quarterly intervals over a three year period, while the other was at four to eight week intervals over one year. The third study used a 20 m net with a coarser mesh, and visited Lake Illawarra on only one occasion. In combination, 70 species of fish were found, of which 34 have economic significance. More species were found in the three-year survey even though the number of hauls was intermediate to the other two. Some species were found uniquely in each study. The species composition of small fishes in Lake Illawarra is placed in the context of recent sampling in over 100 other estuaries in NSW. Some of the management implications in relation to entrance condition and number of species of fish likely to be present are discussed.

INTRODUCTION

Many years ago it was recognised that increasing numbers of people would seek to retire or create a new lifestyle along the coast of New South Wales (Yapp, 1986). Subdivision of rural land, erection of mega-developments, and consolidation of housing schemes have subsequently catalysed this steady and continuing drift in population. In many circumstances the focal points of coastal development in NSW are the estuaries, of which there are about 140.

Beginning in the late 1980s there were several initiatives by which the NSW Government attempted to sustainably manage its estuaries. An Estuary Management Policy was promulgated in 1987, followed in 1992 by the Estuary Management Program. As part of the program, Estuary Management Committees were set up, and an Estuary Management Manual was prepared. The manual set out the need for Estuarine Process Studies, Estuarine Management Studies and Estuarine Management Plans. To further complicate matters, the Estuary Management Committees were expected to integrate their activities with relevant Catchment Management Committees. In the late 1990s, the Estuary Committees were subsumed within 19 Catchment Boards, and in 2004 all of the Boards, plus 20 Regional Vegetation Committees and 33 Water Management Committees were amalgamated into 13 Catchment Management Authorities. Underpinning and guiding these Authorities is the 1997 NSW Coastal Policy. Among the strategic actions the policy advocates is adherence to the principles of the Estuary Management

Manual. Hence, there will be a continuing need for process studies.

Independent of the various over-arching management strategies, public awareness of the need for estuarine conservation continued to rise. Slogans such as “No habitat = no fish” and “Habitat is where it’s at” appeared in the mid 1990s and referred to the need to manage seagrass, mangrove and saltmarsh appropriately. These plants are recognised as a source of detritus for estuarine and near-shore food chains (e.g., Bell and Pollard, 1989), and as places in which birds and fish shelter and forage. Public perception was that changes in land-use practices to cater for or stimulate population expansion would place increasing pressure on these plants and the animals that relied on them. For example, the clearing of terrestrial vegetation releases particulate that can smother seagrass and/or create new substrata for mangrove. Nutrient release from clearing, stormwater runoff or sewer overflow can also stimulate the process of eutrophication.

Even more recently, public interest has focused on aspects of estuarine “health”. Three themes commonly appear: Is the water clear? Are there smells or scums? Are fish and shellfish edible? These are important estuarine management questions but the framework from which they arise is the more familiar one of human health. (For a fuller discussion of the difference between human health and estuarine health see Coates et al. 2002). For estuaries where water quality is problematic, oftentimes a too simplistic and reactive approach has been taken in the form of a demand to treat the symptoms of degraded water quality with a permanent entrance. These demands persist in spite of studies that show the net effect on water quality of a permanent opening will be negligible. At other problematic estuaries, residents have attempted to modify water quality by using shovels to open the mouths of intermittently open estuaries.

Because estuaries are highly complex environments, their health has to be seen in a larger context and relate among other things to the number of species that live therein, or biodiversity. “Biodiversity (or biological diversity) is the variety of life forms, the different plants and animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity” (Commonwealth of Australia, 1996). While NSW has adopted the Commonwealth’s definition (NSW Government 1999), investigations of genetic and ecosystem diversity are highly sophisticated exercises, not readily carried out. The study of aquatic species diversity is more readily achieved and recognises varying scales of temporal and spatial change in habitats that influence the number of species, abundance of and distribution of birds, fish, crustaceans and molluscs.

Some local communities are dealing with habitat monitoring as a component of biodiversity assessments. For example, monitoring was initiated in Wallis Lake and led to a field guide for the identification and monitoring of seagrasses and macroalgae (Laedgsgaard, 2001). A second manual, to assist local communities that seek to monitor seagrass, was produced by the Central Coast Community Network (Dixon, 2004). These manuals focus community interest on the recognition of change in the distribution of estuarine habitats.

It is sometimes assumed that if large numbers of commercial and/or recreational fish are taken from an estuary then the latter's "health" is sound. The reality can be quite different. Due to different sizes, swimming speeds and other behavioural characteristics, many species of fish are not taken by commercial or recreational harvesters, and various capture methods need to be applied at a range of locations and over a range of time scales to comprehensively survey the fish that inhabit estuaries. Because some small species are cryptic and difficult to see, and because some large species have swimming speeds that make them difficult to catch, any one sampling method is inherently biased. Recognising this, Pease and Herbert (2002) attempted to determine the number of species in the Port Hacking estuary. They integrated 12 data sources, including records of the Australian Museum, published articles, grey literature and the observations of naturalists/anglers and naturalists/aquarium collectors. The data set ranged over 12 years, catering in part for rare occurrences of some species, and 252 species were recorded. In contrast, of the order of only 120 species of fish are harvested by commercial fishers in the estuaries of NSW, and of these, 20 species comprise 90% of the catch by weight (D. Makin, pers. comm. 2003). Anglers take of the order of 55 species of fish, but of these only 10-15 species (e.g., yellow-finned bream, dusky flathead) are common (A. Steffe, pers. comm. 2003). Therefore, any lists of fish produced for Estuarine Process Studies, if based solely on commercial or angling catch data, are estimate unsatisfactory if their intent is to biodiversity.

We assume the community is interested in broad questions than cannot be answered by short-term studies:

- What species of fish are in our estuary over long-term time scales?
- Are any species threatened?
- Are there fewer species now than there were some decades ago?
- What can be done to maintain or enhance the number of species or number of individuals present?

To assist in examining some of the issues associated with studies of estuarine fish biodiversity, and more specifically to review the fish community of Lake Illawarra, we:

- summarise the results of recent surveys of the fishes found in shallow seagrass of Lake Illawarra, specifically in terms of the numbers of species taken; and,
- relate the survey data from Lake Illawarra to a state-wide survey of the distribution of fish.

METHODS USED IN RECENT SEINE NET SURVEYS OF FISHES OF LAKE ILLAWARRA

Data from three surveys of the fish communities of seagrass along the foreshores of Lake Illawarra were amalgamated in this review. All surveys used seine nets, but differed in relation to dimensions of net and the duration of the study (Table 1). For Surveys #1 and #2, samples were collected with a net of 12 m headline and 2 m drop with 6 mm stretched mesh. For Survey #3, a longer net (20 m) albeit with the same drop, but with a 12 mm stretched mesh, was used. When set from the shore the

Table 1. Comparison of sampling features in three recent surveys of the fish communities of Lake Illawarra.

Survey features	Survey 1	Survey 2	Survey 3
Net features			
Net length	12 m	12 m	20 m
Net height	2 m	2 m	2 m
Mesh size - stretched	6 mm	6 mm	12 mm
Operational features			
Start date	Oct 1997	May 1999	Mar 2000
Finish date	July 2000	May 2000	Mar 2000
Duration	3 years	1 year	2 days
Frequency	quarterly	6-8 weekly	once only
Number of seine net hauls in the body of the lake	144	192	10
Number of seine net hauls along the entrance channel	0	0	10

shorter net encircled an area of the order of 25 m^2 while the larger net covered approximately 80 m^2. For each survey, the nets were hauled over *Zostera* seagrass beds. Operational details in terms of initiation of the respective surveys and their duration are also provided in Table 1.For Surveys #1 and #2, fish were identified to species level in the field. For Survey #3, large fish were measured and released alive, but small fish were euthanased with ethyl p-amino-Benzoate (Benzocaine) and then preserved in 10% formalin/seawater before transportation to the laboratory for processing. In each survey, fish were identified to species and a total number recorded. For the purpose of this review, fish were categorised in one of four ways:

- <u>Resident</u> - the entire life cycle is spent in the estuary. Few residents are of commercial or recreational significance, but may play important roles in the food chain.
- <u>Migrant</u> - the juvenile stage is spent in an estuary and after three or four years the fish exits to the ocean to spawn. Many of these are of economic importance.
- <u>Transient</u> - living offshore in oceanic waters, these species move in and out of open estuaries on apparently random frequencies but rarely venture into low salinity waters. Some are of commercial or recreational significance.
- <u>Tropical transient</u> - some subtropical species are carried south on the East Australian Current, but usually survive for only a few months in central and southern NSW during spring and summer. Other than as aquarium fish, few of these species are of economic importance.

Species of fish listed as Endangered Species under Schedule 4, or Vulnerable Species under Schedule 5, of Threatened Species Schedules of the Fisheries Management Act 1994 were noted. The order in which fish were listed in the tables follows the taxonomic sequence used by the Fish Department of the Australian Museum (Paxton *et al.* 1989).

One important aspect of our review was to determine if any one method caught species not taken by another method. Such a result would have design and budget implications for the conduct of estuarine process studies. The comparison of methods was hampered by the fact that differing scientific names are sometimes used for what may be the same species of fish. This situation appears to have occurred for the river garfish (identified in one survey as *Hypophamphus australis* and *Hyporhamphus regularis ardelio* in another), hardyhead (*Atherinosoma microstoma* vs. *Atherinomorus ogilbyi*) and toadfish (*Arothron firmamentum* vs. *Arothron hispidus*). Without specimens of the original fish, it was not possible to confirm these identities. We, therefore, made the assumption that these differences were due to assignment of scientific names rather than differences in taxa, i.e., we assumed that only three of the above listed were present.

A figure was prepared to show the number of species taken on the first visit of each survey and the number of new species taken on each subsequent visit.

To compare the number of species of fish in Lake Illawarra to other estuaries we created a matrix of number of species in relation to entrance condition. Data on number of species from other estuaries was obtained from West and Jones (2001) and Williams *et al.* (in prep.). Three numerical categories were set: 1-25, 26-50 and 51-75 species of fish. Entrance condition was derived from reports that identified the duration of opening (West *et al.* 1985, HRC 2002 and Haines 2003). The latter author has a substantive database of the opening and closing of 56 of the 85 NSW intermittently open lagoons. Confirmation of Haines' (2003) assessment of that Lake Illawarra was "mostly open" was provided by two professional habitat managers (Lugg, pers. comm. 2003; Yassini, pers. comm. 2003).

RESULTS

In combination, the three surveys caught of the order of 55,000 fish (Table 2). Not withstanding the difference in number of hauls, similar numbers of individuals were captured in Survey #1 (144 hauls, 27,000 individuals) and Survey #2 (192 hauls, 26,000 individuals). In marked contrast, Survey #3 took relatively few individuals (20 hauls, 1,621 individuals). The main reason for the large difference would appear to be mesh size: the smaller mesh used in Surveys #1 and #2 caught large numbers of fish that otherwise swam through the coarse mesh of the net used in Survey #3.

In combination, the three methods produced 70 species of fish. No species defined as Threatened under the Fisheries Management Act were encountered. Thirty four species were of economic significance, either to the commercial harvest, recreational harvest, as bait, or for the aquarium industry. In relation to life cycle, 37 species were regarded as resident in estuaries, 24 as migrants that spend their juvenile stages in estuaries but move off to spawn, six as transients, and three as tropical transients (Appendix 1).

Survey #2, the greatest number of species was taken in Survey #1 (56 species) (Table 2). Survey #2 produced 47 species and Survey #3 produced 34 species. Surprisingly, even though Survey #3 was a once-only visit to Lake Illawarra, six more species were taken than for the respective first visits of Surveys #1 and #2. Surveys #1 and #2 surpassed #3 at the second visit, and #1 passed #2 at the third visit. It would appear that the season in which sampling is initiated, the duration of the sampling exercise, and type of net used have ramifications in terms of assessing the numbers of species present. A plot of the cumulative number of new species collected on each visit to Lake Illawarra highlights the differences between surveys (Figure 1).

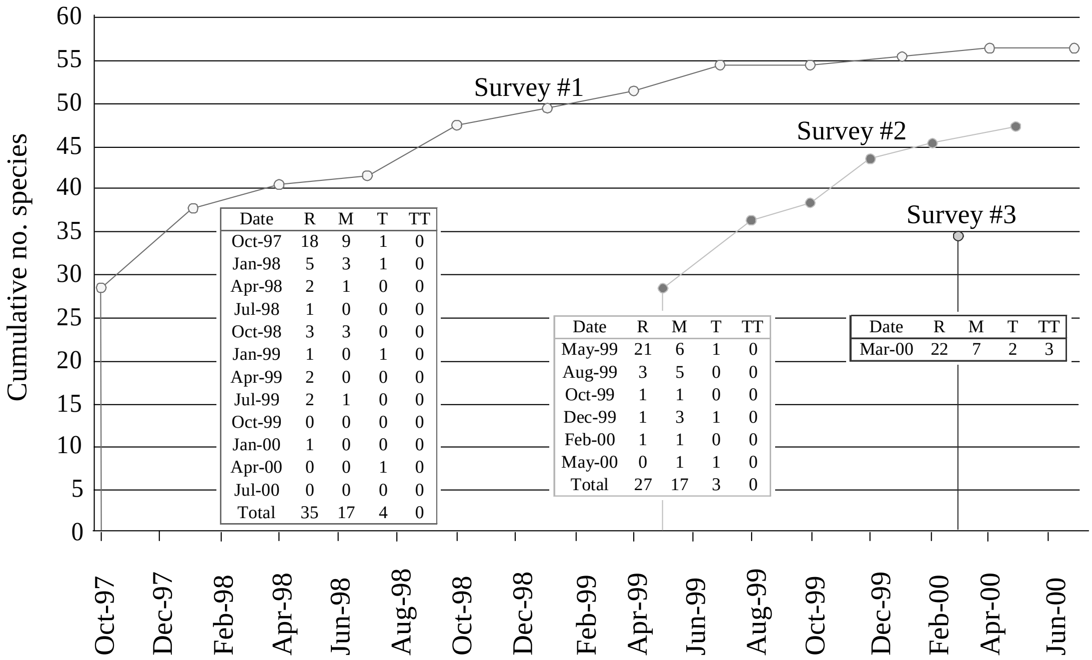
Resident, migratory and transient species were found in all three surveys, but tropical transients were only taken in Survey #3. This may be because Survey #3 was the only study to sample the entrance channel. Conversely, Survey #3 found the fewest number of resident or migratory species. Survey #1 found the greatest number of residents, migrants and transients.

Of particular note was the fact that some species were caught in one survey and not in others (Tables 2 and 3). For example, Survey #1 caught eight unique species: Sandy sprat, Smooth flutemouth, White trevally, Black-spot goatfish, Silver sweep, Yellowtail barracuda, Pygmy leatherjacket, and Fan-belly leatherjacket. Survey #3, even though

Table 2. Comparison of catch of fish in three recent fish surveys of Lake Illawarra.

Survey	**Survey #1**	**Survey #2**	**Survey #3**
No. of hauls	144	192	20
No. of individuals	27,037	25,976	1,621
Total no. of species	56	47	34
No. of Threatened Species	0	0	0
No. of resident species	35	27	22
No. of migrant species	17	17	7
No. of transient species	4	3	2
No. of tropical transient species	0	0	3
1st visit: no. of species taken	28 (Oct 1997)	28 (May 1999)	34 (March 2000)
2nd visit: cumulative number of species	36 (Jan 1998)	36 (Aug 1999)	NA
3rd visit: cumulative number of species	40 (April 1998)	38 (Oct 1999)	NA
6th visit: cumulative number of species	49 (Jan 1999)	47 (May 2000)	NA
12th visit: cumulative number of species	56 (July 2000)	NA	NA
Number of unique species	8	2	3

Figure 1. Cumulative number of species of fish taken in the shallow foreshore seagrass of Lake Illawarra in three recent surveys.



Date	R	M	T	TT
Oct-97	18	9	1	0
Jan-98	5	3	1	0
Apr-98	2	1	0	0
Jul-98	1	0	0	0
Oct-98	3	3	0	0
Jan-99	1	0	1	0
Apr-99	2	0	0	0
Jul-99	2	1	0	0
Oct-99	0	0	0	0
Jan-00	1	0	0	0
Apr-00	0	0	1	0
Jul-00	0	0	0	0
Total	35	17	4	0

Date	R	M	T	TT
May-99	21	6	1	0
Aug-99	3	5	0	0
Oct-99	1	1	0	0
Dec-99	1	3	1	0
Feb-00	1	1	0	0
May-00	0	1	1	0
Total	27	17	3	0

Date	R	M	T	TT
Mar-00	22	7	2	3

it had the fewest hauls (20), took juveniles of three unique species: Lancer, Australian mado, Damselfish. Survey #2, even though it involved the largest number of hauls (192), took juvenile fish of only two unique species: Long-fin eel and Stout longtom.

Fish survey and entrance condition data made it is possible to create a model of the number of species of foreshore seagrass fish in NSW estuaries. The model suggests there are up to three times as many species of seagrass fish present in estuaries that are always open compared to estuaries that are mostly closed (Table 4). The latter rarely have more than 25 species of small fish living in seagrass around their foreshores. Such findings were observed by Lenanton (1974) in Western Australia, and Pollard (1994) for Lakes Conjola, Swan and Wollumboola. It is therefore unreasonable to expect certain species of fish in estuaries that are mostly closed.

DISCUSSION

Depending on methodology, the number of individuals and number of species of fish taken from Lake Illawarra was seen to vary considerably. Assessment of fishes depends on the type of gear used, the places at which the gear is applied and the duration of study. Once-off surveys at few sites within an estuary give only a limited picture of the fish community. In order to be useful, studies of estuarine fish need to budget for repetitive collections with multiple techniques. The studies reported herein relied on haul nets, but other devices such as beam trawl, mesh net, fyke net and trap are available. Further, long-term surveys optimise the chance to capture transient and tropical transient species and hence establish better the biodiversity value of estuaries. It is to be expected that short-term studies underestimate the number of species present. For Lake Illawarra, on the basis of a three year study (Survey #1) the species count for Lake Illawarra was in the highest category (51-75 species). If only Survey #2, or only Survey #3, had been done, Lake Illawarra would have appeared to have considerably fewer species.

If subsequent studies show the model that relates number of fish species to entrance condition is valid, it follows that the placement of a permanent entrance could be used as a means by which to change the fish community. However, there are a number of reasons why modification should be approached with caution.

- The range of effects of an artificial entrance on the functioning of an estuarine ecosystem is difficult to predict.
- The cost of training walls is large, given the need for comprehensive engineering and environmental impact assessments as precursors to construction.
- The justification for training walls has changed over time. Their initial purpose was to facilitate shipping in the colony of NSW, but in the 20th century the rational changed to enable the operation of a coastal fishing fleet, and more recently there is an impression that they will address water quality.
- An understanding of the species of fish currently in an estuary, coupled with historical data on species, abundance and distribution is necessary before any conclusions can be drawn about the need to modify an entrance.

We estimate tidal flow regimes of at least 50 estuaries have been modified either by construction of entrance training walls or manual opening of the entrance. Training walls at some estuaries do not work as anticipated; the single wall on the north side of the entrance to the Manning River and the single wall on the south side of the entrance of Lake Illawarra are two notable examples as neither led to a permanently open entrance. Wallis Lake, which was once an intermittently closed estuary, needed five training wall projects, at an unknown cost, before it was kept permanently opened. Nevertheless, we anticipate additional pressure will be brought by local communities to create permanent entrances. This pressure will expand as the density of coastal population increases, and be expressed in terms of a need to “clean out the estuary”, to “restore flushing”, to “remove pollutants”, or to “eliminate smells”. Support for entrance modification might also come from anglers who assume greater catches of target finfish will be taken if entrances are permanently open. In contrast, other recreationalists prefer closed estuaries that sustain prawns (e.g., Coila Lake). The available evidence from NSW suggests that harvest from mostly closed estuaries can be greater than from open ones (Pollard 1994). Rarely would we expect requests from conservationists who seek to enhance biodiversity.

In an era of limited funds, an investment in training walls at any one estuary has to be weighed against maintaining the status quo at another estuary where development pressure is increasing, or against improving an estuary that is otherwise degraded. The advent of the Catchment Management Authorities suggests bidding wars in which one CMA might choose to install permanent entrances in all its closed lagoons and ignore water quality problems in its open lagoons.

Table 3. Number of individuals of species of fish found uniquely in each of the three surveys. R=resident species; M=migrant, T=transient; TT=tropical transient; see text in Methods for further details on residency status.

Genus/species	**Common name**	**Habitat preference other than estuarine seagrass**	**Lake Illawarra survey**			**Residence status**	**Comments**
			#1	#2	#3		
			Number of hauls				
			144	192	20		
			Number of fish				
Anguilla reinhardtii	Long-fin eel	Upper portions of estuaries and fresh water		1		M	Juvenile fish presumably migrating to fresh water
Hyperlophus vittatus	Sandy sprat	Coastal bays and ocean beaches	1			M	Juvenile
Tylosurus gavialoides	Stout longtom	Coastal reefs		1		T	Juvenile
Fistularia commersonii	Smooth flutemouth	Coastal reefs	1			M	Juveniles are common on estuarine muddy substrata
Pseudocaranx dentex	White trevally	Coastal waters and estuaries	1			T	Juvenile
Lethrinus genivittatus	Lancer	Coastal reefs and estuaries			1	TT	Juvenile captured in the entrance channel (marine tidal delta)
Parupeneus signatus	Black-spot goatfish	Coastal reefs and estuaries	3			M	Sub-adults
Scorpis lineolatus	Silver sweep	Coastal reefs	5			M	Juveniles
Atypichthys strigatus	Australian mado	Coastal and estuarine reefs			1	TT	Juvenile captured in the entrance channel (marine tidal delta)
Abudefduf sp.	Damselfish	Coastal reefs			1	TT	Juvenile captured in the entrance channel (marine tidal delta)
Sphyraena flavicauda	Yellowtail barracuda	Coastal reefs and estuary channels	1			T	Juvenile
Brachaluteres jacksonianus	Pygmy leatherjacket	Shallow seagrass and kelp	2			R	Presumed adults
Monacanthus chinensis	Fan-belly leatherjacket	Shallow rocky or weed areas and deep oceanic waters	7			M	Juveniles
Number of unique species			8	2	3		

Table 4. Comparison of number of species of fish found in beds of foreshore seagrass in relation to degrees of closure of NSW estuaries. Closure index derived primarily from Haines (2003) but also from West *et al.* (1985) and HRC (2002). Number of species are derived from West and Jones (2001) and Williams *et al.* (in prep.). # = category in which Lake Illawarra belongs on the basis of Survey 1; (*) = category in which Lake Illawarra would have appeared on the basis of Survey 2 or Survey 3.

Number of species of fish sampled in foreshore seagrass	**Number of estuaries in relation to closure time**					**Number of estuaries**
	Closed 100%-80% (Almost always closed)	Closed 80%-60% (Mostly closed)	Closed 60%-40%	Closed 40%-2% (Almost always open)	Closed 2%-0% (Always open)	
51-75 species	0	0	4#	2	13	19
26-50 species	4	3	3(*)	2	29	41
1-25 species	41	1	2	0	6	50
Total	45	4	9	4	48	110

Another CMA might adopt the reverse approach, ignoring the closed estuaries in favour treating water quality problems at source in the open or mostly open estuaries (e.g., by the installation of mini-wetlands to remove nutrients). How is the best mix of investment and resource management adjudicated? Lugg *et al.* (1998) suggested the way forward is to prepare an entrance management or lagoon opening strategy as a component of an estuary management plan. The strategy should be agreed to by representatives of the local community, local government and state government. The strategy can then be assessed environmentally by means of a regional environmental plan or a state environmental plan. In any case, manipulation of the mouths of estuaries is constrained by a number of bureaucratic factors, one of which is the requirement for a permit to dredge from NSW Fisheries unless another approval from an appropriate authority is obtained. A second requirement is a permit to harm marine vegetation, also administered by NSW Fisheries.

CONCLUSIONS

- A number of factors, including fish conservation, will influence the management of estuaries.
- No single sampling method can adequately describe estuarine fish communities
  - multiple surveys with any one method are necessary
  - multiple methods are necessary.
- On the basis of the limited sampling to date there appear to be inherent limitations on the number of species of fish in NSW estuaries due to entrance condition.

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Appendix 1. Species of fish taken in three recent surveys of foreshore seagrass at Lake Illawarra.

Family	**Genus/Species**	**Common name**	**Econ. important**	**Residence status** R	M	T	TT	**Survey 1** Oct 97 - Jun 00	**Survey 2** May 99 - May 00	**Survey 3** Mar-00
Anguillidae	*Anguilla reinhardtii*	Long-fin eel	✓	–	✓	–	–	–	✓	–
Clupeidae	*Herklotsichthys castelnaui*	Southern herring	–	✓	–	–	–	–	–	–
	Hyperlophus vittatus	Sandy sprat	✓	–	✓	–	–	✓	–	–
Hemiramphidae	*Hyporhamphus australis*	Sea garfish	✓	–	✓	–	–	✓	✓	–
	Hyporhamphus regularis ardelio	River garfish	✓	✓	–	–	–	–	–	✓
Belonidae	*Tylosurus gavialodes*	Stout longtom	–	–	–	✓	–	–	✓	–
Atherinidae	*Atherinosoma elongata*	Hardyhead	–	✓	–	–	–	✓	✓	–
	Atherinosoma microstoma	Small mouth hardyhead	–	✓	–	–	–	✓	✓	–
	Atherinomorus ogilbyi	Ogilby's hardyhead	✓	✓	–	–	–	–	–	✓
Pseudomugilidae	*Pseudomugil signifer*	Southern blue-eye	–	✓	–	–	–	✓	✓	–
Fistulariidae	*Fistularia commersonii*	Smooth flutemouth	–	–	✓	–	–	✓	–	–
Syngnathidae	*Urocampus carinirostris*	Hairy pipefish	–	✓	–	–	–	✓	✓	✓
	Vanacampus phillipi	Port Phillip pipefish	–	✓	–	–	–	✓	✓	–
	Vanacampus poecilolaemus	Long-snout pipefish	–	✓	–	–	–	✓	–	–
	Stigmatopora nigra	Wide-body pipefish	–	✓	–	–	–	✓	✓	–
Scorpaenidae	*Centropogon australis*	Fortescue	–	✓	–	–	–	✓	✓	✓
Platycephalidae	*Platycephalus fuscus*	Dusky flathead	✓	–	✓	–	–	–	–	–
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	–	✓	–	–	–	✓	✓	✓
Terapontidae	*Pelates sexlineatus*	Eastern striped trumpeter	✓	✓	–	–	–	✓	✓	✓
Sillaginidae	*Sillago ciliata*	Sand whiting	✓	–	✓	–	–	✓	✓	–
	Sillago maculata	Trumpter whiting	✓	✓	–	–	–	✓	✓	–

Pomatomidae	*Pomatomus saltatrix*	Tailor	✓	–	✓	–	–	✓	✓	–
Carangidae	*Pseudocaranx dentex*	White trevally	✓	–	–	✓	–	✓	–	–
Gerreidae	*Gerres subfasciatus*	Silver biddy	✓	✓	–	–	–	✓	✓	✓
Lethrinidae	*Lethrinus genivittatus*	Lancer	✓	–	–	–	✓	–	–	✓
Sparidae	*Acanthopagrus australis*	Yellow-finned bream	✓	–	✓	–	–	✓	✓	✓
	Rhabdosargus sarba	Tarwhine	✓	–	✓	–	–	✓	✓	✓
Mullidae	*Upeneus tragula*	Bar-tail goatfish	–	✓	–	–	–	✓	–	✓
	Parupeneus signatus	Black-spot goatfish	✓	–	✓	–	–	✓	–	–
Monodactylidae	*Monodactylus argenteus*	Silver batfish	✓	–	✓	–	–	✓	✓	–
Girellidae	*Girella tricuspidata*	Blackfish	✓	–	✓	–	–	✓	✓	✓
Scorpididae	*Scorpis lineolatus*	Silver sweep	✓	–	✓	–	–	✓	–	–
Enoplosidae	*Enoplosus armatus*	Old wife	–	–	–	✓	–	✓	✓	–
Microcanthidae	*Atypichthys strigatus*	Australian mado	–	–	–	✓	–	–	–	✓
Pomacentridae	*Abudefduf* sp.	Damselfish (juvenile)	✓	–	–	–	✓	–	–	✓
Mugilidae	*Liza argentea*	Flat-tail mullet	✓	✓	–	–	–	–	–	–
	Mugil cephalus	Sea mullet	✓	–	✓	–	–	✓	✓	–
	Myxus elongatus	Sand mullet	✓	–	✓	–	–	✓	✓	✓
Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	✓	–	–	✓	–	✓	–	–
Labridae	*Achoerodus viridis*	Eastern blue groper	✓	–	✓	–	–	✓	✓	✓
Blenniidae	*Petroscirtes lupus*	Brown sabretooth blenny	–	✓	–	–	–	✓	✓	✓
Gobiidae	*Arenigobius bifrenatus*	Bridled goby	–	✓	–	–	–	✓	✓	✓
	Arenigobius frenatus	Half-bridled goby	–	✓	–	–	–	✓	✓	✓
	Bathygobius kreffti	Frayed-fin goby	–	✓	–	–	–	✓	✓	✓
	Favonigobius exquisitus	Exquisite sand-goby	–	✓	–	–	–	✓	✓	✓
	Favonigobius lateralis	Long-finned goby	–	✓	–	–	–	✓	✓	✓
	Favonigobius tamarensis	Tamar River goby	–	✓	–	–	–	✓	✓	✓
	Gobiopterus semivestitus	Glass goby	–	✓	–	–	–	✓	✓	✓

	Pseudogobius olorum	Blue-spot goby	–	✓	–	–	–	✓	✓	✓
	Redigobius macrostoma	Large-mouth goby	–	✓	–	–	–	✓	✓	✓
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	–	✓	–	–	–	✓	✓	✓
	Philypnodon sp.	Gudgeon	–	✓	–	–	–	✓	✓	–
Siganidae	*Siganus nebulosus*	Happy moments	✓	–	–	✓	–	✓	✓	✓
Paralichthyidae	*Pseudorhombus arsius*	Large-tooth flounder	✓	✓	–	–	–	✓	–	–
Pleuronectidae	*Ammotretis rostratus*	Long-snout flounder	✓	✓	–	–	–	–	–	–
Monacanthidae	*Acanthaluteres spilomelanurus*	Bridled leatherjacket	–	–	✓	–	–	✓	✓	–
	Brachaluteres jacksonianus	Pygmy leatherjacket	–	✓	–	–	–	✓	–	–
	Meuschenia freycineti	Six-spine leatherjacket	✓	–	✓	–	–	✓	✓	✓
	Meuschenia trachylepis	Yellow-finned leatherjacket	✓	–	✓	–	–	✓	✓	✓
	Meuschenia sp.	Leatherjacket	–	–	✓	–	–	–	✓	–
	Monacanthus chinensis	Fan-belly leatherjacket	✓	✓	✓	–	–	✓	–	–
	Nelusetta ayraudi	Chinaman leatherjacket	✓	–	✓	–	–	✓	✓	–
	Penicipelta vittiger	Toothbrush leatherjacket	✓	–	✓	–	–	✓	✓	–
	Scobinicthys granulatus	Rough leatherjacket	✓	–	✓	–	–	✓	✓	–
Tetraodontidae	*Arothron firmamentum*	Starry toadfish	–	✓	–	–	–	✓	–	–
	Arothron hispidus	Stars and stripes toadfish	–	–	–	–	✓	–	–	✓
	Tetractenos glaber	Smooth toadfish	–	✓	–	–	–	✓	✓	✓
	Tetractenos hamiltoni	Common toadfish	–	✓	–	–	–	✓	✓	✓
	Torquigener pleurogramma	Weeping toado	–	✓	–	–	–	–	–	–
Diodontidae	*Dicotylichthys punctulatus*	Three-bar porcupinefish	–	✓	–	–	–	✓	✓	✓
Tot	**70**	**70**	**34**	**37**	**24**	**6**	**3**	**56**	**47**	**34**

R = permanent resident, i.e., the entire lifecycle is spent in estuaries
M = migrant, i.e., resident during juvenile stages, thence moving offshore to spawn
T = transient, moves opportunistically between inshore waters and estuaries
TT = tropical transient, delivered to NSW waters in larval or juvenile form by the East Australian Current