THE FISH AND FISHERY OF THE SWAN ESTUARY

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ABSTRACT

A checklist is provided for the fish that have been caught in the Swan estuary. These species each fall into one of the following categories: 1. marine stragglers, 2. marine species which use estuaries extensively at some stage of their life cycle but spawn at sea, 3. estuarine species, i.e. those species which can pass through the whole of their life cycle in the estuary, 4. anadromous species, i.e. those species which migrate from the sea through the estuary to breeding grounds in reduced salinities or fresh water.

Examples of different life cycles are provided by reference to mullets (*Mugil cephalus* and *Aldrichetta forsteri*), gobbleguts (*Apogon ruepellii*), five species of hardyhead (Atherinidae), Perth herring (*Nematalosa vlaminghi*) and cobbler (*Cnidoglanis macrocephalus*). Details are provided for the commercial fish catches in the Swan estuary and for the recreational fishery for teleosts and prawns.

INTRODUCTION

Estuaries play an important role in the life cycle of many species of fish in temperate regions of both the Northern and Southern Hemispheres (Cronin & Mansueti 1971, Day *et al.* 1981, Potter *et al.* 1983, Dando 1984, Claridge *et al.* 1986). For example, estuaries act as nursery areas for some marine species and as a passage through which catadromous and anadromous species migrate *en route* to and from their feeding and breeding areas. A few teleosts have also become adapted to completing the whole of their life cycle within the confines of estuaries, and a limited number of freshwater fish penetrate into the upper reaches of estuaries, particularly when the salinities are low. The largest category of species found in checklists for estuaries is often the "marine straggler", which by definition is a marine species present in low numbers, generally at the seaward end of the estuary.

The importance of estuaries to commercial species of fish has been recognised by workers in many parts of the world. Indeed, this role has led to the widespread adoption of the term estuarine-dependent for those species found in abundance in estuaries (McHugh 1976, Pollard 1976, Claridge *et al.* 1986). Since the juveniles of many marine species found in large numbers in estuaries also use protected, inshore marine environments as nursery areas, it has recently been suggested that for this group the term "estuarine opportunist" would be more appropriate (Hedgpeth 1982, Lenanton & Potter 1987). Irrespective of whether the terms "estuarine dependent" or "estuarine opportunist" are used, the importance of estuaries to the fisheries of the Northern Hemisphere can be gauged by the fact that species found in abundance in estuaries contribute approximately 69% by weight to the commercial fishery for fish, crustaceans and molluscs of the United States (McHugh 1976). A similar value has been calculated for the fishery in New South Wales (Pollard 1976, 1981).

This short review provides a checklist of all species of fish recorded from the Swan estuary, and categorises the way in which they use this estuary. This review also gives details on the distribution, spawning times, growth rates and diet of the major species and an outline of the commercial and recreational fisheries in the Swan estuary. The last of these includes a description of fishing methods and localities, and the catch rates for the total fishery and the main target species.

CHECKLIST OF SPECIES

Following the definitions given by Lenanton and Potter (1987), each species found in the Swan estuary has been categorised as either estuarine (E), i.e. can spend the whole of the life cycle in estuarine environments, or anadromous (A), i.e. breeds above the limits of the upper estuary but spends a prolonged period as an adult feeding in marine environments, or marine, i.e. spawns at sea (Table 1). Species which breed in the upper estuary but spend time as an adult feeding at sea are termed semi-anadromous (SA). The marine category was further subdivided into i) marine straggler (M-S), ii) species which in south-western Australia are found mainly in estuaries at some early stage of their life (M-E), and iii) species which utilise both estuaries and inshore marine environments as nursery areas (M-E and IM).

Since the checklist of 110 fish in the Swan Estuary was provided by Chubb *et al.* (1979), a further 27 species have been added to the records for this system and this includes some species which have been caught only as larvae (F. Neira, unpublished data). Since these larvae came almost exclusively from the seaward end of the lower estuary, they have presumably either entered from the sea or are the product of spawning by a few transient adults which had entered the mouth of the estuary. For this reason they are placed in the marine straggler category. The records for the Swan Estuary thus now include 137 species representing 70 families (Table 1). Although there was one family of lamprey (Geotriidae), three of sharks (Heterodontidae, Carcharhinidae, Sphrynidae) and two of rays (Rhinobatidae, Myliobatidae), none of these were represented by large numbers. All of the remaining 64 families were teleosts.

Approximately 55% of the 137 species in the checklist could be categorised as marine stragglers (Table 1). The estuary is used as a migratory route to and from breeding areas by the Perth herring and the pouched lamprey. Since the Perth herring spawns in the upper estuary and spends at least part of its adult life feeding in the sea, it is regarded as semi-anadromous (Chubb & Potter 1984, 1986). Representatives of 12 teleosts designated as fresh water have been recorded from the estuary (Table 1).

Twelve species of teleost, each of which was often caught in large numbers, were capable of completing their life cycle within the Swan estuary. Some of these species, such as the gobbleguts, also breed in local marine environments (Chrystal *et al.* 1985). Although the same is not generally true of the bar-tailed flathead, yellow-tailed trumpeter and the mullet hardyhead, these species are found in marine environments farther to the north in the region of Shark Bay where there are no permanent estuaries (Lenanton 1977, Potter *et al.* 1986). By contrast, species such as the elongate and Wallace's hardyhead are only occasionally found outside estuaries in any part of their distribution (Prince *et al.* 1982, Prince & Potter 1983).

A total of 38 marine species use the Swan estuary as a nursery area, but of these only the sea mullet is not also found in large numbers as juveniles of 20-100mm in marine environments (Lenanton & Potter 1987). Species belonging to this category include several important commercial or recreational species in addition to sea mullet.

TABLE 1. Checklist of fish of the Swan estuary. Life cycle categories are: A - anadromous, SA - semi-anadromous, FW - freshwater, E - can pass through the whole of the life cycle in the estuary. Species which breed at sea: M-E - marine species found predominantly in the estuary at some stage of its life cycle, M-E & IM - marine species found in abundance in estuaries and inshore marine environments, M-S - marine species infrequently found in estuaries.
* larvae recorded in the lower estuary by F. Neira.

FAMILY	SPECIES NAME	COMMON NAME	LIFE CYCLE CATEGORY
GEOTRIIDAE	*Geotria australis* Gray 1851	Pouched lamprey	A
HETERODONTIDAE	*Heterodontus portusjacksoni* (Meyer 1793)	Port Jackson shark	M-S
CARCHARHINIDAE	*Carcharhinus leucas* (Müller & Henle 1841)	Bull shark	M-S
SPHYRNIDAE	*Sphyrna zygaena* (Linnaeus 1758)	Hammerhead shark	M-S
RHINOBATIDAE	*Aptychotremata vincentiana* (Haacke 1885)	Southern shovelnose ray	M-S
MYLIOBATIDAE	*Myliobatis australis* Macleay 1881	Eagle ray	M-S
ELOPIDAE	*Elops machnata* (Forsskal 1775)	Giant herring	M-S
MURAENIDAE	*Gymnothorax woodwardi* McCulloch 1912	Woodward's reef eel	M-S
OPHICHTHIDAE	*Cirrhimuraena calamus* (Gunther 1870)	Fringed-lipped snake eel	M-S
	Ophisurus serpens (Linnaeus 1758)	Serpent eel	M-S
CLUPEIDAE	**Sardinella lemuru* Bleeker 1853	Scaly mackerel	M-S
	**Hyperlophus vittatus* (Castlenau 1875)	Sandy sprat	M-E & IM
	**Nematalosa vlaminghi* (Munro 1956)	Perth herring	SA
	**Sardinops neopilchardus* (Steindachner 1879)	Pilchard	M-S
	**Spratelloides robustus* Ogilby 1897	Blue sprat	M-S
	**Etrumeus jacksoniensis* Macleay 1878		M-S
ENGRAULIDAE	*Engraulis australis* (Shaw 1790)	Southern anchovy	M-E & IM

SALMONIDAE	*Salmo gairdneri* Richardson 1836	Rainbow trout	FW
	Salmo trutta Linnaeus 1758	Brown trout	FW
GALAXIIDAE	*Galaxias occidentalis* Ogilby 1899	Western minnow	FW
CARANGIDAE	*Alectis ciliaris* (Bloch 1787)	Pennant trevally	M-S
	Pseudocaranx dentex Bloch & Schneider 1801	Skipjack trevally	M-E & IM
	Pseudocaranx wrighti Whitley 1931	Sand trevally	M-E & IM
	Seriola hippos Günther 1876	Samson fish	M-S
	**Trachurus novae-zelandiae* Richardson 1843	Yellowtail scad	M-E & IM
	Sparidentex hasta (Valenciennes 1830)		M-S
ARRIPIDAE	*Arripis georgianus* (Valenciennes 1831)	Australian herring	M-E & IM
	Arripis truttaceus Johnston 1883	South Australian salmon	M-E & IM
CAESIOSCORPIDAE	*Caesioscorpis theagenes* Whitley 1945	Fusilier sweep	M-S
NEMIPTERIDAE	**Pentapodus vitta* Quoy & Gaimard 1824	Butterfish	M-S
GERREIDAE	**Gerres subfasciatus* Cuvier 1830	Roach	M-E & IM
SPARIDAE	*Acanthopagrus butcheri* (Munro 1949)	Black bream	E
	Chrysophrys auratus (Schneider 1801)	Pink snapper	M-E & IM
	Rhabdosargus sarba Forsskal 1775	Tarwhine	M-E & IM
SCIAENIDAE	*Argyrosomus hololepi-dotus* (Lacépède 1802)	Mulloway	M-E & IM
MULLIDAE	*Upeneus tragula* Richardson 1846	Bar-tailed goatfish	M-S
	Parupeneus signatus (Günther 1867)	Black-spot goatfish	M-S
	Upeneichthys vlaminghi (Cuvier 1829)	Blue-spotted goat-fish	M-S
PEMPHERIDAE	*Pempheris klunzingeri* McCulloch 1911	Rough bullseye	M-S
KYPHOSIDAE	*Kyphosus sydneyanus* (Günther 1886)	Common buffalo bream	M-S

SCORPIDAE	*Neatypus obliquus* Waite 1905	Footballer sweep	M-S
	**Scorpis georgianus* Cuvier & Valenciennes 1832	Banded sweep	M-S
ENOPLOSIDAE	*Enoplosus armatus* (Shaw 1790)	Old wife	M-S
CICHLIDAE	*Tilapia zillii* (Gervais 1848)	Cichlid	FW
CHEILODACTYLIDAE	*Cheilodactylus gibbosus* Richardson 1841	Crested morwong	M-S
MUGILIDAE	*Aldrichetta forsteri* (Valenciennes 1836)	Yellow-eye mullet	M-E & IM
	Mugil cephalus Linnaeus 1758	Sea mullet	M-E
SPHYRAENIDAE	**Sphyraena obtusata* Cuvier 1829	Striped seaspike	M-S
ODACIDAE	*Neoodax balteatus* (Valenciennes 1839)	Little weed whiting	M-E & IM
	Haletta semifasciata (Valenciennes 1839)	Blue weed whiting	M-E & IM
	Odax cyanomelas Richardson 1850	Herring cale	M-S
MUGILOIDIDAE	**Parapercis haackei* (Steindachner 1884)	Wavy grubfish	M-S
BLENNIIDAE	*Omobranchus germaini* (Sauvage 1883)	Germain's blenny	M-S
	**Parablennius tasmanianus postoculomaculatus* Bath & Hutchins 1986	False Tasmanian blenny	M-E & IM
LEPTOSCOPIDAE	**Crapatalus arenarius* McCulloch 1915	Common sandfish	M-S
TRIPTERYGIIDAE	**Lepidoblennius marmoratus* (Macleay 1878)	Jumping blenny	M-S
CLINIDAE	*Cristiceps australis* Valenciennes 1836	Crested weedfish	M-S
CALLIONYMIDAE	**Callionymus goodladi* (Whitley 1944)	Goodlad's stinkfish	M-S
	Eocallionymus papilio Günther 1864	Painted stinkfish	M-S
	Dactylopus dactylopus (Valenciennes 1837)	Fingered dragonet	M-S

GOBIIDAE	*Areniogobius bifrenatus* (Kner 1865)	Bridled goby	M-E & IM
	Callogobius mucosus Günther 1872	Sculptured goby	M-E & IM
	Favonigobius lateralis (Macleay 1881)	Long-finned goby	M-E & IM
	Favonigobius punctatus	Spotted goby	E
	**Favonigobius suppositus* (Sauvage 1880)	Long-headed goby	E
	Priolepis nuchifasciatus (Günther 1874)	Goby tropical	M-S
	**Pseudogobius olorum* (Sauvage 1880)	Blue-spot goby	E
	Tridentiger trigonocephalus (Gill 1858)	Japanese goby	E
GONORYNCHIDAE	*Gonorynchus greyi* (Richardson 1845)	Beaked salmon	M-S
CYPRINIDAE	*Carassius auratus* (Linnaeus 1758)	Golden carp	FW
PLOTOSIDAE	*Cnidoglanis macrocephalus* (Valenciennes 1840)	Cobbler	M-E & IM
	Paraplotosus albilabris (Valenciennes 1840)	White lipped catfish	M-E & IM
	Tandanus bostocki Whitley 1944	Freshwater cobbler	FW
ANTENNARIIDAE	*Histrio histrio* (Linnaeus 1758)	Sargassum fish	M-S
BYTHITIDAE	*Dipulus caecus* Waite 1905	Orange eelpout	M-S
HEMIRAMPHIDAE	*Hyporhamphus melanochir* (Valenciennes 1846)	Southern sea garfish	M-E & IM
	Hyporhamphus regularis (Günther 1866)	Western river garfish	E
POECILIIDAE	*Gambusia affinis* (Baird & Girard 1853)	Mosquito fish	FW
ATHERINIDAE	*Allanetta mugiloides* (McCulloch 1913)	Mullet hardyhead	E
	Atherinosoma elongata (Klunzinger 1879)	Elongate hardyhead	E
	Atherinosoma presbyteroides (Richardson 1843)	Swan River hardyhead	M-E & IM
	Atherinosoma wallacei Prince, Ivantsoff & Potter 1982	Wallace's hardyhead	E
	Atherinomorus ogilbyi Whitley 1930	Ogilby's hardyhead	M-E & IM

MONOCENTRIDAE	*Cleidopus gloriamaris* De Vis 1882	Knight fish	FW
VELIFERIDAE	*Metavelifer multiradiatus* (Regan 1907)	Veilfin	M-S
FISTULARIIDAE	*Fistularia commersonii* Ruppell 1835	Smooth flutemouth	M-S
SYNGNATHIDAE	**Hippocampus angustus* Günther 1870	Western Australian seahorse	M-S
	Hippocampus breviceps Peters 1869	Short-snouted seahorse	M-S
	Histiogamphelus gallinaceus Hale 1941	Cocks-comb pipefish	M-S
	**Stigmatophora argus* (Richardson 1840)	Spotted pipefish	M-E & IM
	**Urocampus carinirostris* Castelnau 1872	Hairy pipefish	M-E & IM
	**Stigmatophora nigra* Kaup 1853		M-S
	**Syngnathus phillipi* Lucas 1891		M-S
	**Lissocampus* sp.		M-S
SCORPAENIDAE	**Gymnapistes marmoratus* (Cuvier 1829)	Devilfish	M-E & IM
TRIGLIDAE	*Chelidonichthys kumu* (Lesson & Garnot 1826)	Red gurnard	M-S
	Pterygotrigla polyommata (Richardson 1839)	Sharp-beaked gurnard	M-S
PLATYCEPHALIDAE	**Platycephalus endrachtensis* (Quoy & Gaimard 1824)	Bar-tailed flathead	E
	Leviprora inops Jenyns 1840	Long-headed flathead	M-S
	Platycephalus isacanthus Cuvier 1829	Flathead	M-E & IM
	Levipora laevigatus Cuvier 1829	Rock flathead	M-S
PEGASIDAE	**Parapegasus natans* (Linnaeus 1766)	Sea moth	M-S
PERCICHTHYIDAE	*Bostockia porosa* Castelnau 1873	Night fish	FW
	Maccullochella peeli (Mitchell 1839)	Murray cod	FW
TERAPONIDAE	**Amniataba caudavittatus* (Richardson 1845)	Yellow-tailed trumpeter	E
	**Pelates sexlineatus* (Quoy & Gaimard 1824)	Striped trumpeter	M-E & IM
	Pelsartia humeralis (Ogilby 1899)	Sea trumpeter	M-S

KUHLIIDAE	*Edelia vittata* Castelnau 1873	Western pygmy perch	FW
APOGONIDAE	**Apogon rueppellii* Günther 1859	Gobbleguts	E
	Siphamia cephalotes (Castelnau 1875)	Wood's siphon-fish	M-S
PERCIDAE	*Perca fluviatilis* Linnaeus 1758	Redfin perch	FW
SILLAGINIDAE	*Sillaginodes punctatus* (Cuvier 1829)	King George whiting	M-E & IM
	Sillago bassensis Cuvier 1829	School whiting	M-E & IM
	Sillago maculata Quoy & Gaimard 1824	Trumpeter whiting	M-E & IM
	Sillago schomburgkii Peters 1864	Yellow finned whiting	M-E & IM
RACHYCENTRIDAE	*Rachycentron canadus* Linnaeus 1766	Gobia	M-S
POMATOMIDAE	*Pomatomus saltator* (Linnaeus 1766)	Tailor	M-E & IM
SCOMBRIDAE	*Thunnus albacares* (Bonnaterre 1788)	Yellowfin tuna	M-S
BOTHIDAE	*Pseudorhombus jenynsii* (Bleeker 1855)	Small-toothed flounder	M-E & IM
PLEURONECTIDAE	*Amnotretis elongatus* McCulloch 1914	Elongate flounder	M-E & IM
CYNOGLOSSIDAE	**Cynoglossus maculipinnis* Rendahl 1921	Southern tongue sole	M-S
MONACANTHIDAE	*Bigener brownii* (Richardson 1846)	Spiny-tailed leatherjacket	M-S
	Bachaluteres jacksonianus (Quoy & Gaimard 1824)	Pygmy leatherjacket	M-S
	Chaetoderma penicilligera (Cuvier 1817)	Prickly leather-jacket	M-S
	Eubalichthys mosaicus (Ramsay & Ogilby 1886)	Mosaic leather-jacket	M-S
	Meuschenia freycineti (Quoy & Gaimard 1824)	Six-spined leather-jacket	M-S
	Monacanthus chinensis (Osbeck 1765)	Fan-bellied leatherjacket	M-S
	Penicipelta vittiger (Castelnau 1873)	Toothbrush leather-jacket	M-S
	**Scobinichthys granulatus* (Shaw 1790)	Rough leatherjacket	M-S

OSTRACIONTIDAE	*Anoplocapros lenticularis* (Richardson 1841)	White-barred boxfish	M-S
	Aracana aurita (Shaw 1798)	Shaw's cowfish	M-S
TETRAODONTIDAE	*Arothron hispidus* (Linnaeus 1758)	Stars and stripes toadfish	M-S
	Contusus brevicaudus Hardy 1981	Prickly pufferfish	M-E & IM
	Lagocephalus sceleratus (Gmelin 1788)	Silver pufferfish	M-S
	Torquiqener pleurograma (Regan 1903)	Common blowfish	M-E & IM
DIODONTIDAE	*Diodon nichthemerus* Cuvier 1813	Globe fish	M-S
MOLIDAE	*Mola ramsayi* (Giglioli 1883)	Short sun fish	M-S

TOTAL:	FAMILIES	70
	SPECIES	137

CATEGORY	NOS. OF SPECIES	(%)
A	1	(0.8%)
SA	1	(0.8%)
FW	12	(9.0%)
E	12	(9.0%)
M-E	1	(0.8%)
M-E & IM	37	(27.8%)
M-S	73	(54.9%)

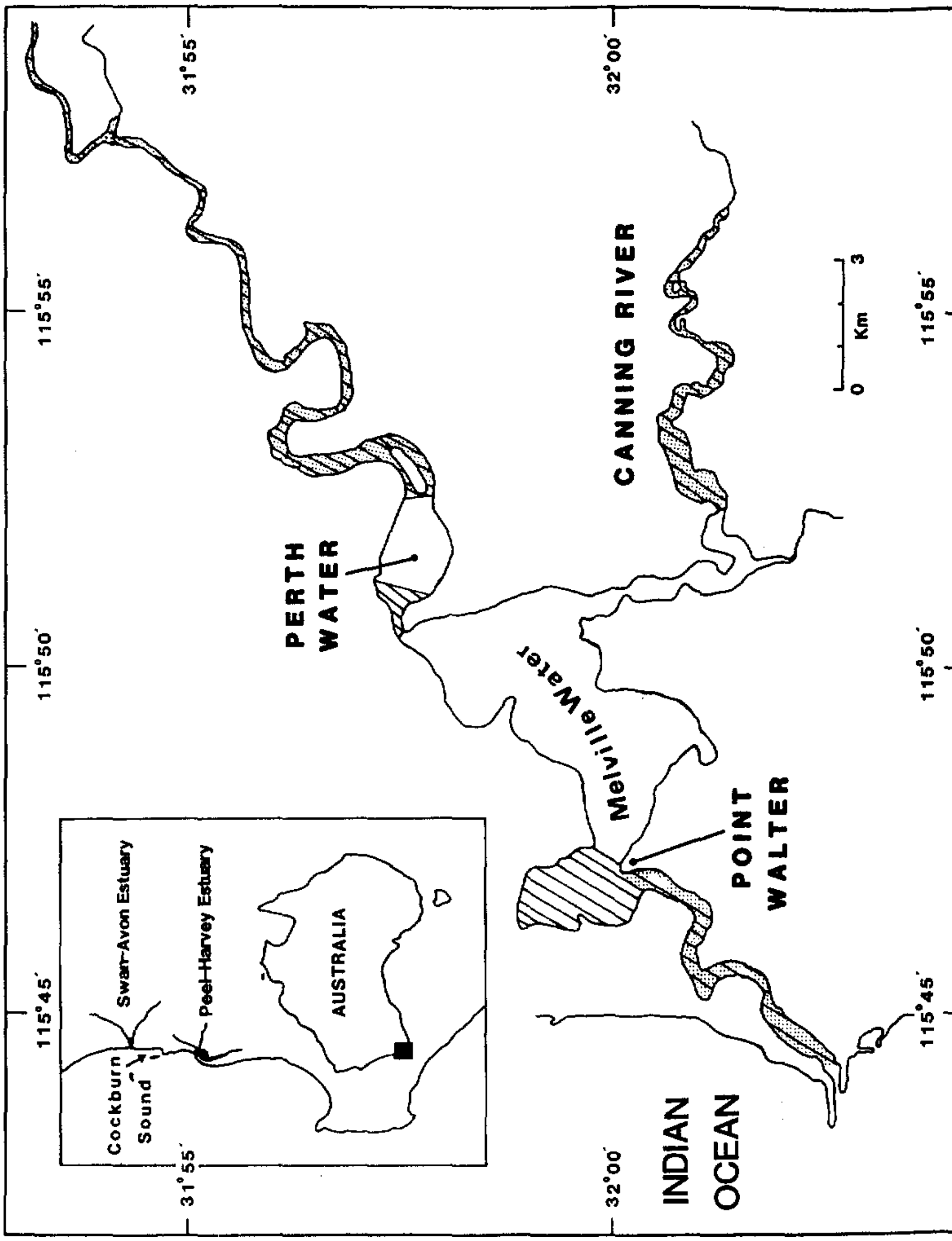

Fig. 1. Map showing waters closed to net fishing (///) in the Swan estuary. N.B. The lower and upper regions of the estuary are stippled.

Table 2. Numbers of the five atherinid species caught at each sampling site in the lower, middle and upper estuaries of the Swan-Avon River system during 1979 and 1980. Percentage of total number is given in parentheses. A blank space indicates that no species were caught. In increasing order, distance (km) of each site from the estuary mouth is shown in parentheses.

Species	Number in lower estuary at site:		Number in middle estuary at site:				Number in upper estuary at site				Total number
	1	2	3	4	9	5	10	11	6	8	
	(3.0)	(7.2)	(13.5)	(20.9)	(22.5)	(26.6)	(27.7)	(30.2)	(38.3)	(44.0)	
January-December 1979											
Atherinomorus ogilbyi	5428	645	7	301	1581	182	4		5		8153
	(66.6)	(7.9)	(0.1)	(3.7)	(19.4)	(2.2)	(<0.1)		(<0.1)		
Atherinosoma presbyteroides	2178	776	66		232						3252
	(67.0)	(23.9)	(2.0)		(7.1)						
Atherinosoma elongata	32	70	737	3	570	6					1418
	(2.3)	(4.9)	(52.0)	(0.2)	(40.2)	(0.4)					
Atherinosoma wallacei		2	32	2	535	225	315	1202	153	4678	7144
		(<0.1)	(0.4)	(<0.1)	(7.5)	(3.1)	(4.4)	(16.8)	(2.1)	(65.5)	
Atherinosoma mugiloides	16	25	1428	630	2260	709	960		1		6029
	(0.3)	(0.4)	(23.7)	(10.4)	(37.5)	(11.8)	(15.9)		(<0.1)		
January-December 1980											
Atherinomorus ogilbyi	353	104	25	355	9	45	9		1		901
	(39.2)	(11.5)	(2.8)	(39.4)	(1.0)	(5.0)	(1.0)		(0.1)		
Atherinosoma presbyteroides	3915	997	66	111	22						5111
	(76.6)	(19.5)	(1.3)	(2.2)	(0.4)						
Atherinosoma elongata	101	56	944		494						1595
	(6.3)	(3.5)	(59.2)		(31.0)						
Atherinosoma wallacei					149	8	188	336	27	750	1458
					(10.2)	(0.5)	(12.9)	(23.0)	(1.9)	(51.4)	
Atherinosoma mugiloides	2	215	96	225	123	89	277		106	95	1228
	(0.2)	(17.5)	(7.8)	(18.3)	(10.0)	(7.2)	(22.6)		(8.6)	(7.7)	

Particularly pertinent in this regard are the yellow-eye mullet, cobbler, tailor, garfish and mulloway (Lenanton 1978, 1984). The adults of each of these species, as well as their juveniles, are found in the estuary. There is also now good evidence that the cobbler, which is found in large numbers in the estuary, emigrates to marine areas for spawning (Nel *et al.* 1985).

DISTRIBUTION WITHIN THE ESTUARY

Although the teleosts found in the estuary are relatively mobile, some species tend to occur predominantly in one particular region. In the context of regions, it should be noted that we follow the use of the terms lower, middle and upper estuary as described by Chalmer *et al.* (1976). These regions are shown in Figure 1. One of the best examples of spatial partitioning within any family is that exhibited by the hardyheads (Atherinidae) (Prince *et al.* 1982; Table 2). The marine species, Ogilby's hardyhead and the Swan River hardyhead, enter the lower estuary, with the larger Ogilby's hardyhead penetrating the middle estuary in the summer and autumn. While the elongate and mullet hardyheads are typically found in the middle estuary during much of the year, numbers of the latter species migrate into the upper estuary in the summer months. Wallace's hardyhead is mainly restricted to the upper estuary and to the low salinity regions above Guildford (Table 2). All of these species, including even Wallace's hardyhead, have been found in salinities well in excess of full strength sea water. The distribution patterns of the estuarine species in regions where, particularly in the upper estuary, salinities can fall to relatively low levels are thus not apparently associated with an inability to osmoregulate in full strength sea water.

The gobies (Gobiidae) show a similar spatial partitioning to the hardyheads. Typically, the marine long-finned goby enters and occupies the lower estuary, whereas the blue-spot goby occurs in the middle and upper estuary and the long-headed goby is found in the upper estuary and upstream riverine regions of the Swan (H. Gill, pers. comm.).

The species which use the estuary as a nursery area penetrate the system to variable degrees. For example, the sea mullet passes far up the estuary and beyond what is regarded by Chalmers *et al.* (1976) as the limit of the upper estuary. By contrast, other marine teleosts such as the yellow-eye mullet and blowfish are only occasionally found in numbers above the middle estuary (Chubb *et al.* 1981, Potter *et al.* unpublished). Although a similar pattern is observed with cobbler, the immature juveniles of this species often enter the upper estuary in the summer and autumn when salinities increase in this region (Kowarsky 1975, Nel *et al.* 1985).

The sexually maturing adults of the Perth herring congregate near the top of the upper estuary in the summer, often in very large numbers (Chubb & Potter 1984). The resultant larvae gradually pass downstream and this eventually leads to the dispersion of young fish into the middle estuary.

Spawning Times

Both the sea and yellow-eye mullet spawn over several months between the autumn and spring (Thomson 1951, 1957a,b, Chubb *et al.* 1981; & Table 3). This feature enables the new recruits to enter the estuaries of south-western Australia at a time when any bars that form at the mouth of estuaries are most likely to be breached by freshwater discharge. Other marine species which also have a life cycle lasting for several years and sometimes spend a long period in the estuary, such as cobbler and blowfish, spawn in the late spring and early to mid-summer respectively and the resultant young tend to enter the estuary only when they are several months old (Nel *et al.* 1985, Potter *et al.* unpublished). The semi-anadromous Perth herring and the

TABLE 3. Spawning times of some fish species in the Swan estuary.

COMMON NAME	SPECIES	MONTHS	REFERENCE
Yellow-eye mullet	*Aldrichetta forsteri*	Mar-Sep	Thomson (1957a,b) Chubb *et al.* (1981)
Sea mullet	*Mugil cephalus*	Mar-Sep	Thomson (1957a) Chubb *et al.* (1981)
Tailor	*Pomatomus saltator*	Apr	Thomson (1957a)
Black bream	*Acanthopagrus butcheri*	Aug-Nov	Thomson (1957a)
Anchovy	*Engraulis australis*	Sep-Dec	L. Beckley (unpub.)
Elongate hardy-head	*Atherinosoma elongata*	Sep-Dec	Prince & Potter (1983)
Hardyhead	*Atherinosoma presbyteroides*	Sep-Dec	Prince & Potter (1983)
Wallace's hardy-head	*Atherinosoma wallacei*	Oct-Jan	Prince & Potter (1983)
Mullet hardyhead	*Allanetta mugiloides*	Nov-Feb	Prince & Potter (1983)
Ogilby's hardy-head	*Atherinomorus ogilbyi*	Nov-Jan	Prince & Potter (1983)
Cobbler	*Cnidoglanis macrocephalus*	Oct-Dec	Nel *et al.* (1985)
Perth herring	*Nematalosa vlaminghi*	Nov-Jan	Thomson (1957a) Chubb & Potter (1984)
Common blowfish	*Torquigener pleurogramma*	Nov-Jan	Potter *et al.* (in prep.)
Gobbleguts	*Apogon rueppellii*	Nov-Jan	Chrystal *et al.* (1985)
Yellow-fin whiting	*Sillago schomburgkii*	Sep	Thomson (1957a)
Bar-tailed flat-head	*Platycephalus endrachtensis*	Jan-Mar	Thomson (1957a)
Yellow-tailed trumpeter	*Amniataba caudavittatus*	Nov-Feb	J. Wallace (unpub.)

Table 4. Life cycle duration and growth of some fish in the Swan estuary.

COMMON NAME	SPECIES NAME	LENGTH RANGE (MM) AFTER ONE YEAR	MAXIMUM LENGTH (MM) AND AGE (YEARS) IN SWAN	REFERENCE
ONE YEAR LIFE CYCLE				
Presbyter's hardyhead	Atherinosoma presbyteroides	50-75	85 (1)	Prince and Potter (1983)
Elongata hardyhead	Atherinosoma elongata	50-80	85 (1)	Prince and Potter (1983)
Wallace's hardyhead	Atherinosoma wallacei	40-65	70 (1)	Prince and Potter (1983)
Mullet hardyhead	Allanetta mugiloides	50-70	70 (1)	Prince and Potter (1983)
TWO YEAR LIFE CYCLE				
Ogilby's hardyhead	Atherinomorus ogilbyi	40-80	160 (2)	Prince and Potter (1983)
Gobbleguts	Apogon rueppellii	45-80	104 (2)	Chrystal et al. (1985)
THREE OR MORE YEAR LIFE CYCLE				
Perth herring	Nematalosa vlaminghi	80-150	361 (8)	Chubb and Potter (1986)
Cobbler	Cnidoglanis macrocephalus	180-250	683 (6)	Nel et al. (1985)
Yellow-tailed trumpeter	Amniataba caudavittatus	70-160	289 (>4)	J. Wallace (unpublished)
Black bream	Acanthopagrus butcheri	100-160	>400 (>4)	P. Holt (unpublished)
Yellow-eye mullet	Aldrichetta forsteri	100-200	380 (>4)	Chubb et al., 1981
Sea mullet	Mugil cephalus	140-260	580 (>4)	Chubb et al., 1981
Common blowfish	Torquigener pleurogramma	75-130	229 (6+)	Potter et al., (unpublished)

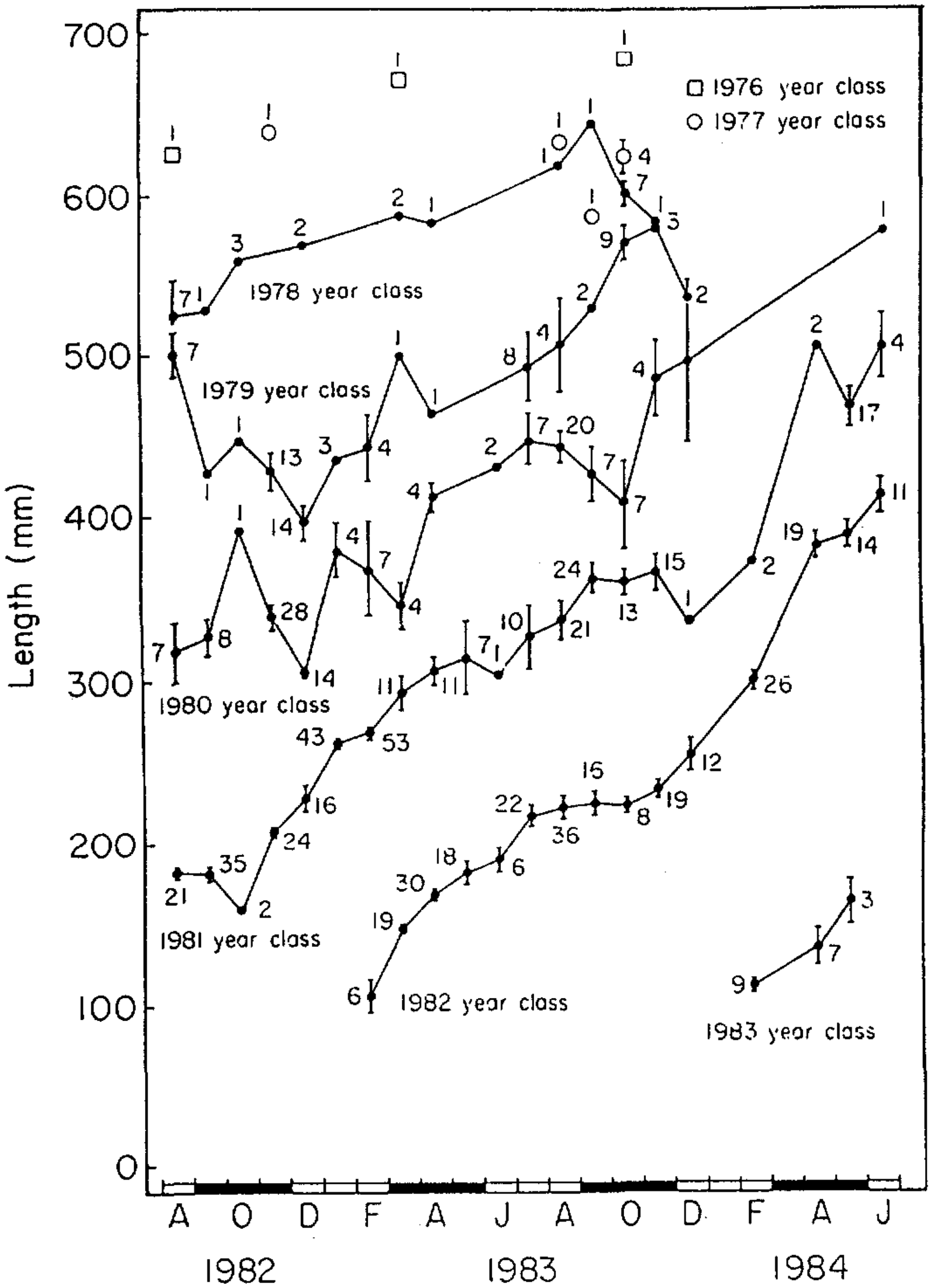

Fig. 2. The mean lengths (±1 standard error) for cobbler (*Cnidoglanis macrocephalus*) resulting from the 1976 to 1983 spawning season. (From Nel *et al.* 1985).

estuarine yellow-tailed trumpeter both breed in the upper estuary during the summer (Thomson 1957a, Chubb 1984, Chubb & Potter 1984). Apart from the tailor, which is said by Thomson (1957a) to spawn in April, all the other species listed in Table 3 breed during the spring or summer in either the estuary or the sea.

Life Cycle Duration and Growth Rates

There have now been a series of studies which have provided sound data on life cycle duration, age structure and growth rates of several species of teleost in the Swan estuary (Table 4). Four of the five species of atherinid occurring in this estuary have a one year life cycle and reach a total length at maturity of 45-85mm. The fifth species of atherinid, Ogilbyi's hardyhead, and the gobbleguts have a two year life cycle and within the Swan attain lengths up to approximately 160 and 104mm respectively. Species such as yellow-eye mullet, sea mullet, Perth herring, cobbler and blowfish are represented by several year classes and reach lengths ranging from 230mm for blowfish to 690mm for cobbler.

Growth of teleosts in the Swan estuary is seasonal, with increase in length occurring between the spring and autumn (Thomson 1951, Chubb *et al.* 1981, Nel *et al.* 1985, Chubb & Potter 1986). This feature is well illustrated by the trends shown by the 1982 year class of cobbler (Fig. 2). Growth of marine species during the early years is greater when they enter and remain within estuaries than when they use inshore marine waters. For example, cobbler reached a mean length greater than 200mm in the Swan estuary in 1983 compared with only 160mm in nearby marine waters (Nel *et al.* 1985, Lenanton & Potter 1987). Comparable values for the blowfish were 85-100mm and 65mm (Potter *et al.* in prep.). This serves to emphasise the value of estuaries as nursery areas for young fish. In this context, it is worth noting that, in comparison with inshore marine areas, estuaries in general provide a more abundant food source, a reduced level of piscivorous predation, calmer waters and an environment in which the osmotic pressure is closer to that of the body fluids of the fish (Blaber 1980, Blaber & Blaber 1980, Claridge *et al.* 1986).

Diet and Heavy Metal Concentrations

The fish inhabiting the Swan estuary can be grouped into four broad feeding categories, namely detritivore, carnivore, herbivore, and omnivore (Table 5). The abundant Perth herring and sea mullet are both detritivores, whereas cobbler, mulloway, tailor, blowfish, flathead, King George whiting, yellow-fin whiting and flounder are carnivores. The omnivorous group of fish include yellow-eye mullet and black bream. While the garfish and six-line trumpeter ingest some animal material, they can be broadly regarded as herbivores. It should be noted, however, that studies elsewhere in Australia have shown that the garfish changes from a herbivore to a carnivore at night (Robertson & Klummp 1983, Klummp & Nichols 1983). Amphipods and polychaetes are important prey for many of the species in the omnivore and carnivore categories (Table 5).

In a study of heavy metal concentrations in the muscle tissue of fish of the Swan estuary, Marks *et al.* (1980) found that the concentrations of nine heavy metals (Fe, Zn, Cu, Mn, Cd, Pb, Cr, Co, Ni) were very low in the five species studied (sea mullet, yellow-eye mullet, yellow-tailed trumpeter, black bream and Perth herring). In fact, the concentrations were close to the levels found in fish taken from very clean environments. The concentrations of heavy metals were greater, however, in detritivorous fish (sea mullet and Perth herring) than in species which fed mainly on polychaetes, molluscs, crustaceans, and plant material.

Table 5. Feeding category and main dietary items of some fish in the Swan estuary.

COMMON NAME	SPECIES NAME	MAIN PREY ITEMS	REFERENCE
Detritivores			
Perth herring	*Nematalosa vlaminghi*	Organic debris	Thomson (1957c)
Sea mullet	*Mugil cephalus* >40 mm	Diatoms, detritus, sand	Thomson (1966)
Herbivores			
Six-lined trumpeter	*Pelates sexlineatus*	Red and green algae	Wanning (unpublished)
Sea garfish	*Hyporhamphus melanochir*	*Zostera*, algae, diatoms	Thomson (1957c)
Omnivores			
Black bream	*Acanthopagrus butcheri*	Bivalves, polychaetes, amphipods, *Zostera*	Thomson (1957c)
Yellow-eye mullet	*Aldrichetta forsteri*	Algae, amphipods, univalves, bivalves	Thomson (1957c)
Carnivores			
Hardyheads	*Atherinosoma presbyteroides*	Planktonic and benthic crustaceans	Prince *et al*. (1982)
	Atherinosoma elongata	Benthic crustaceans, polychaetes	Prince *et al*. (1982)
	Atherinosoma wallacei	Planktonic crustaceans, flying insects	Prince *et al*. (1982)
	Atherinomorus ogilbyi	Benthic crustaceans, polychaetes	Prince *et al*. (1982)
	Allanetta mugiloides	Planktonic crustaceans	Prince *et al*. (1982)
Cobbler	*Cnidoglanis macrocephalus*	Amphipods, bivalves, polychaetes, algae	Nel *et al*. (1985)
Bar-tailed flathead	*Platycephalus endrachtensis*	Fish, shrimp, prawns	P. Chrystal (unpublished) Thomson (1957c)
Yellow-tailed trumpeter	*Amniataba caudavittatus*	Polychaetes, amphipods, molluscs	Thomson (1957c) J. Wallace (unpublished)
Gobbleguts	*Apogon rueppellii*	Amphipods, copepods, polychaetes	Chrystal *et al*. (1985)
Yellow-fin whiting	*Sillago schomburgkii*	Polychaetes, amphipods	Thomson (1957)
Tailor	*Pomatomus saltator*	Fish, shrimp	Thomson (1957c)
Mulloway	*Argyrosomus hololepidotus*	Fish, shrimp	Thomson (1957c)
Common blowfish	*Torquigener pleurogramma*	Amphipods, bivalves, polychaetes	Potter *et al*. (unpublished)

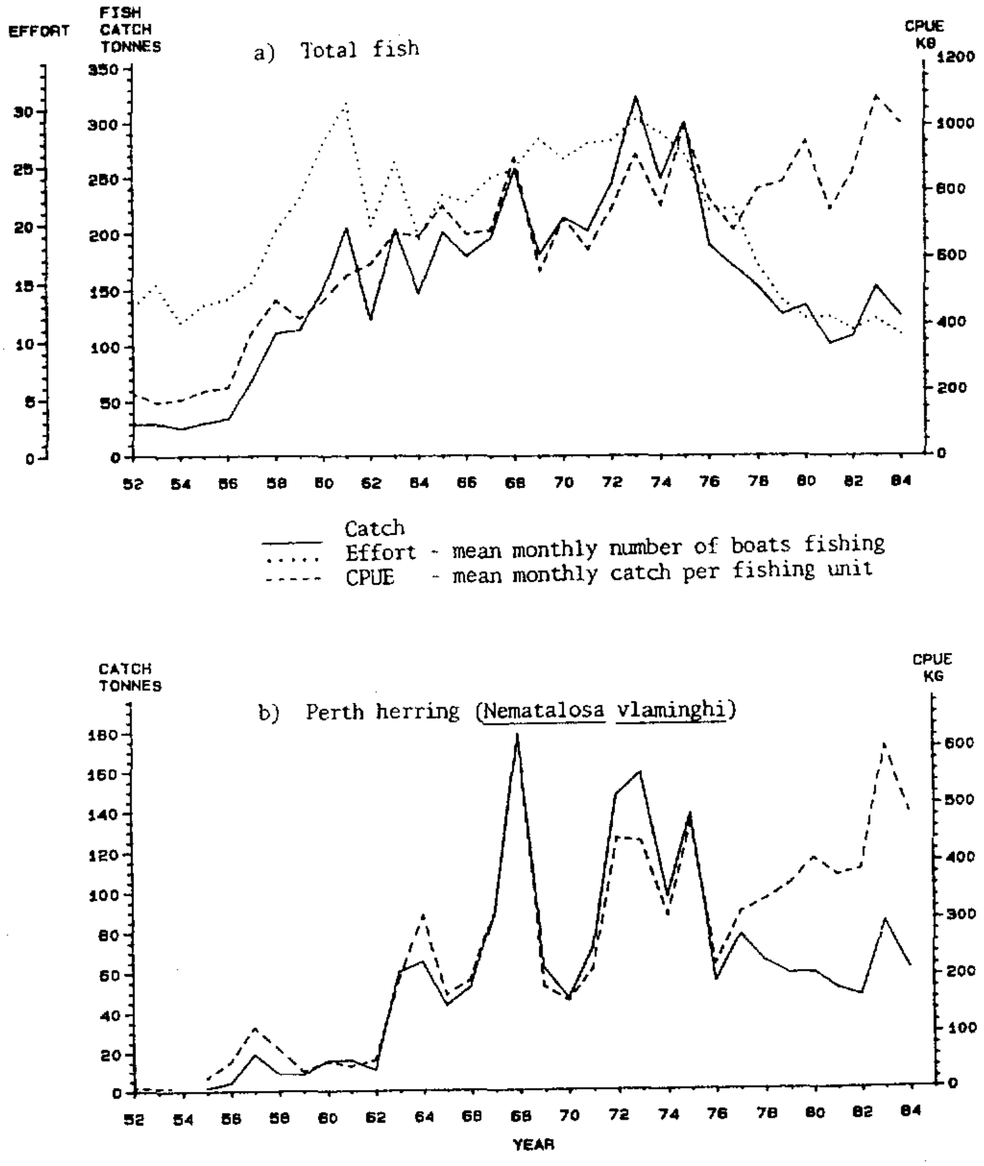

Fig. 3. Catch effort and catch per unit effort (CPUE) for all fish and Perth herring in the Swan estuary.

Commercial Fishery

Two main methods are employed by commercial fishermen, namely gill and haul netting. Gill nets, which are set overnight, are now usually made from monofilament mesh with a minimum mesh size of 63mm (Lenanton 1984). The size of mesh is adjusted for each target species. Thus, mesh sizes of 63 to 70mm are used to catch the yellow-eye and sea mullet, which have minimum legal lengths for capture of 230 and 240mm respectively. The minimum legal length for the capture of cobbler is 320mm and generally a mesh size of 76mm is used to catch this species.

In contrast to gill netting, haul netting involves searching for and encircling schools of fish with a net which is then pulled on to a boat. The minimum mesh permitted in haul nets is 57mm (Lenanton 1984). The length of the boats used by commercial fishermen is usually about 5m. Funnel traps are employed by some commercial fishermen for catching cobbler.

The use of nets and funnel traps, whether by professional or amateur fishermen, is restricted to Melville Water upstream of Point Walter, a section of Perth water downstream from the Causeway and a reach between Guildford railway bridge and the Middle Swan Road bridge in the riverine region just above the limit of the upper estuary (Fig. 1).

The total catch by all methods increased from 30 tonnes in 1952 to 320 tonnes in 1973 and then declined to values between 120 and 140 tonnes in the early 1980s (Fig. 3a). The initial rise was due to an increasing demand for yellow-eye mullet and Perth herring as bait fish for the rock lobster industry (Lenanton 1984). The subsequent decline during the 1970s was due to a fall in the number of commercial fishermen as a result of a planned reduction in the number of licenses issued by the government (Lenanton 1984). The maintenance since the early 1970s of a relatively high and constant catch per boat or catch per unit effort (CPUE) implies that the total abundance of commercially exploited fish has not declined in recent years (see also Lenanton *et al.* 1984). The fact that the CPUE increased during the 1940s and 1950s probably reflects a gradual increase in expertise and efficiency over this period of development of the fishery.

Perth herring, sea mullet, yellow-eye mullet and cobbler together contribute over 80% of the total annual fish catch from the Swan estuary (Lenanton 1984). The most important commercial species in terms of total catch is the Perth herring. Catches of this species reached a peak of 180 tonnes in 1968, fluctuated in the early 1970s from between 60 tonnes in 1970 and 160 tonnes in 1973 and then declined to levels between 50 and 90 tonnes in the early 1980s (Fig. 3b). The trends shown by the CPUE paralleled the total catch until 1976. Since that time the CPUE has increased while total catch as declined with a decline in effort (Fig. 3b). The CPUE for Perth herring follows a seasonal pattern in the Swan estuary, with peak values occurring in August and September, at the time when older Perth herring start moving from the sea towards their spawning grounds in the upper estuary (Chubb *et al.* 1984).

Although the catch of sea mullet varied annually between the middle 1950s and early 1970s, there was no conspicuous upward or downward trend over that period (Fig. 4a). While the catch declined after 1973 as a result of the reduction in fishing licenses, the CPUE remained at a similar level to that of the previous two decades.

The total catch of yellow-eye mullet has always been lower than that of sea mullet, with values ranging from two tonnes in 1952 to 30 tonnes in 1970 (Fig. 4b). As with sea mullet, the catches of yellow-eye have declined since 1976 (Fig. 4b) while the CPUE has remained at similar levels to those of the 1970s.

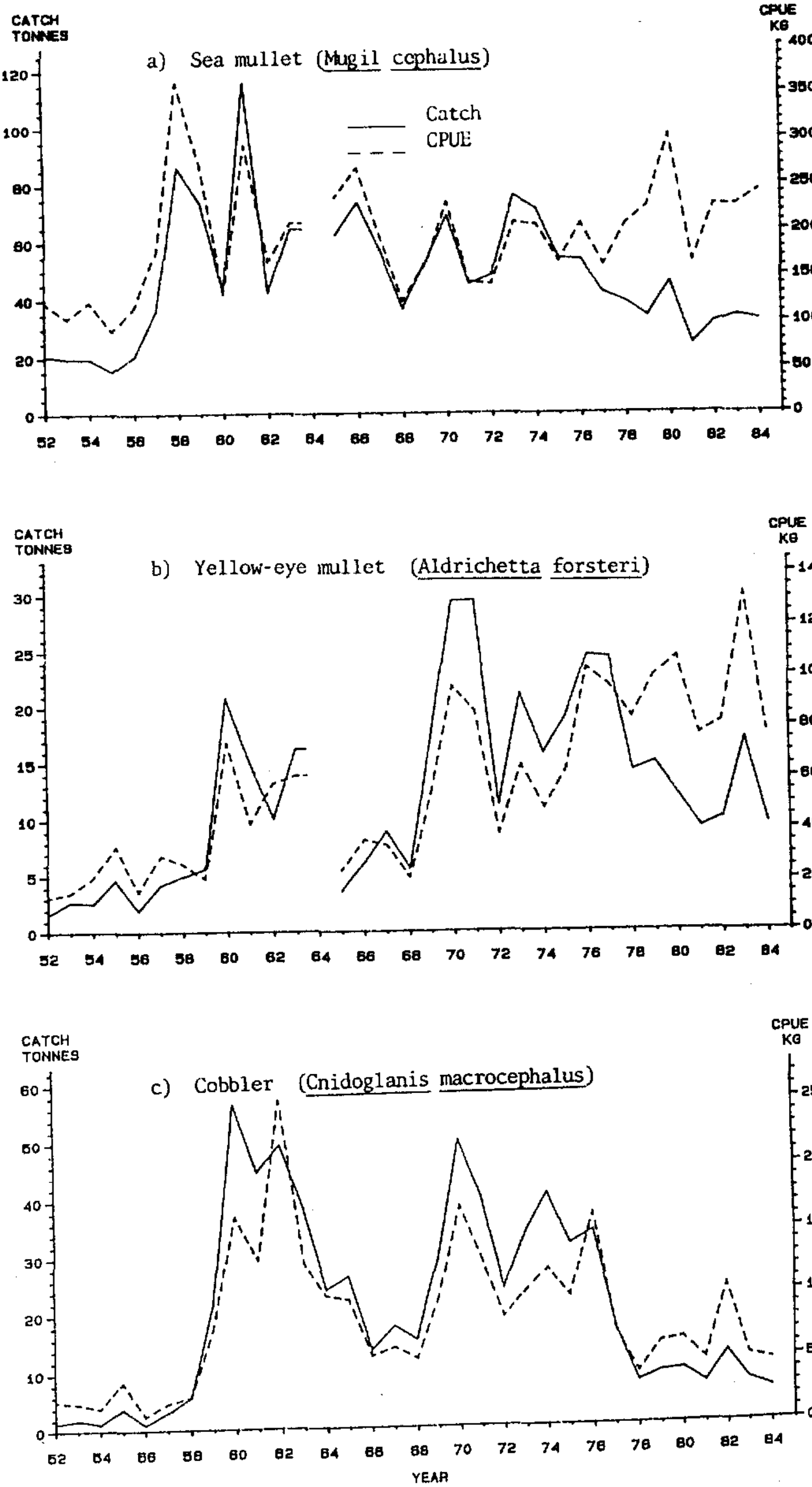

Fig. 4. Catch and catch per unit effort (CPUE) for sea mullet, yellow-eye mullet and cobbler in the Swan estuary.

In contrast to the data for the mullets, the trends shown by the CPUE for cobbler closely follow those of the catch for this species (Fig. 4c). Thus, the catches for cobbler were much lower between 1978 and 1984 than in nearly all of the years since 1959. Similarly, the CPUE between 1978 and 1984 was lower than that recorded between 1968 and 1976. This implies that the abundance of cobbler may have declined during recent years.

The fact that several marine species such as sea mullet, yellow-eye mullet and cobbler contribute to fisheries within the Swan estuary is due to the relatively large size to which they grow before returning to the sea. Thus sea mullet, yellow-eye mullet and cobbler start contributing to the commercial fishery after reaching approximately 12, 18 and 24 months of age respectively (Chubb *et al.* 1981, Nel *et al.* 1985). This in turn reflects the relatively longer period spent in the estuary by considerable numbers of these species than is the case for marine species using estuaries in temperate environments of the Northern Hemisphere (cf. Clardige *et al.* 1986).

Recreational Fishery

The recreational fishery in the Swan estuary comprises mainly an unlicensed line and crab fishery and a licensed net fishery for fish and, until recently, prawns (Lenanton 1978). Although the magnitude of the amateur catch from this estuary has not been investigated, the results of studies in other estuaries of south-western Australia (Lenanton & Caputi 1975) and in Cockburn Sound (Dybdahl 1979) suggest that it would be of similar size to that of the commercial fishery. The composition of the amateur catch differs markedly, however, from that of the commercial fishery. Thus, while Perth herring, sea mullet and yellow-eye mullet are the most important commercial species, they are only occasionally exploited recreationally. By contrast, black bream, tailor and mulloway are not particularly important from a commercial point of view, but do form the basis for the large amateur rod and line fishery in the Swan.

The majority of people participating in the licensed net fishery choose to fish for western school prawns, *Metapenaeus dalli* (Lenanton 1978). This species is estuarine *sensu stricto* in south-western Australia with a two-year life-cycle and is caught mainly in the middle estuary between November and February (Potter *et al.* 1986). This is also the time when breeding occurs.

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