SEASONAL DISTRIBUTION PATTERNS OF FISHES WITHIN THE BATHURST HARBOUR ESTUARY, SOUTHWESTERN TASMANIA

by Graham J. Edgar

(with four tables and six text-figures)

EDGAR, G.J., 1991 (20:xii): Seasonal distribution patterns of fishes within the Bathurst Harbour estuary, southwestern Tasmania. *Pap. Proc. R. Soc. Tasm.* 125: 37-44. https://doi.org/10.26749/rstpp.125.37 ISSN 0080-4703. Zoology Department, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001.

The distribution of fishes within the Bathurst Harbour estuary was surveyed by gillnet on five occasions and by seine on three occasions, between October 1988 and July 1989. Fish distributions did not noticeably change within the estuary in response to seasonal changes in salinity. A number of fishes were, however, possibly prevented from entering the estuary during February 1989 because of low oxygen concentrations then prevailing. The assemblage of Bathurst Harbour fishes collected by gillnet was unusual in being dominated by sharks and skates, with all of the common species also being distributed in water depths >50 m along the continental shelf. Thus it has many characteristics typical of a deep water assemblage. Included amongst the Bathurst Harbour fishes was a previously unknown species of skate which may be restricted to the estuary. By far the most common of the larger fishes was the white-spotted dogfish *Squalus acanthias*; this species comprised 86% of the total gillnet catch. Despite these large catches, a tagging study in which a very high proportion (25%) of tagged dogfish were recaptured indicated that the total population in the estuary was not exceptionally large, being in the order of only 2900 animals. Tagged dogfish roamed widely through the estuary.

Key Words: Bathurst Harbour, Port Davey, fish, seine, estuary, species richness, *Squalus acanthias*, *Raja* sp., Tasmania

INTRODUCTION

The Port Davey/Bathurst Harbour estuarine system has a number of unusual features. It is the southernmost large estuary in Australia, and is one of only three large Australian estuaries which are highly stratified, with a darkly-stained, brackish surface layer overlying clear marine bottom waters (the others being Macquarie Harbour and the Huon River estuary — Edgar & Cresswell 1991). The area is also isolated and consequently remains the least anthropogenically disturbed large estuary in southern Australia. As part of the first study of the major hydrological and biological components of the Bathurst Harbour estuary (Edgar 1991, Edgar & Cresswell 1991), the distribution of fishes was investigated between October 1988 and July 1989, with the results described here.

The fish fauna of Port Davey and Bathurst Channel has been previously surveyed during short visits by B. Hutchins (Museum of Western Australia), P. Last (Tasmanian Fisheries Development Authority) and G. Edgar (National Parks and Wildlife Service). A checklist of fish species recorded during these surveys and other sources was subsequently compiled (Edgar 1984). A total of only 73 fish species had been recorded from the Port Davey/Bathurst Harbour region prior to the present study. The ichthyofauna is thus depauperate compared to other large estuaries, presumably because of its southern location.

METHODS

Seine Netting

Fishes were collected using a 50 m long beach seine (12 mm mesh) set in a semicircular arc from the beach. A total of 24 sites from Bathurst Harbour to Kelly Basin were sampled from 27 to 29 July 1989, 23 of these sites from 16 to 18 February 1989, and 18 sites from 29 to 30 November 1988. The locations of the sites are shown in figure 1. The abundances of fishes at each site were recorded using a log 3 abundance ranking scale (as in table 1). Two replicate hauls were conducted at each site.

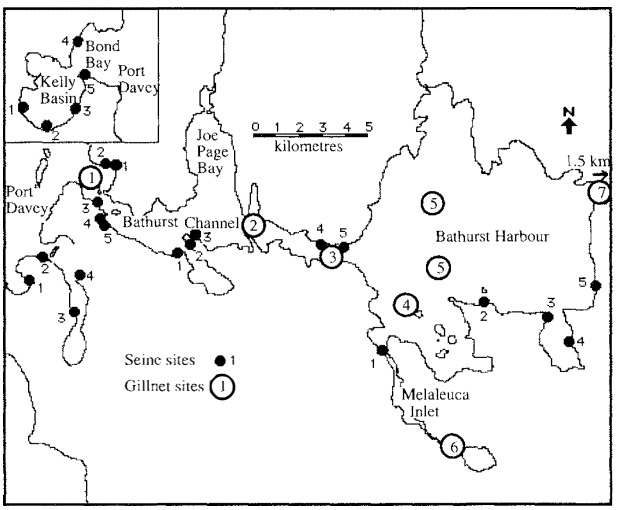

FIG. 1 — Locations of fish sampling sites. Seine sites are separately numbered in five areas: Kelly Basin, Hannant Inlet, Bathurst Channel West, Bathurst Channel East and Bathurst Harbour (see table 1). Gillnet sites: 1 – Channel Entrance; 2 – Bathurst Narrows; 3 – Eastern Bathurst Channel; 4 –Celery Top Islands; 5 – Bathurst Harbour (northern and southern sections); 6 – Melaleuca Inlet; 7 – Old River.

TABLE 1

Mean abundances of fish species collected by seine net during November, February and July field trips.

Abundances are recorded on a log 3 abundance scale (i.e. 1 indicates 1 individual, 2 indicates 2-3 individuals, 3 indicates 4-9 individuals, etc.) .Blank spaces indicate no fish were collected, dashes that no sample was made. Site locations are shown in fig. 5.1. Taxonomic authorites are listed by Last *et al.* (1983).

Species	Month	Kelly Basin					Hannant Inlet				Bathurst Channel West					Bathurst Channel East					Bathurst Harbour				
		1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Raja lemprieri	Feb				-								1	1											
Retropinna tasmanica	Dec	-	-			-	-						-	-						3			3		
	Feb				-								1						1	1	1		4	2	
	Jul																		1		1	3	3	3	2
Lovettia sealii	Feb				-																				1
	Jul								1																
Galaxias maculatus	Dec	-	-			-	-			1			-	-							3	1	3		
	Feb				-					2			3		2	1			3		4			2	
	Jul															1					1	4	1		1
Hyporhamphus melanochir	Dec	-	-	1		-	-						-	-											
Atherinasoma microstoma	Dec	-	-	4	3	-	-	1	6				-	-		7	6			3	4		3	4	
	Feb		3		-				7	2				1		7	5		4	4	4	2		4	5
	Jul	9			2										2		3			3		3		1	5
Kestratherina brevirostris	Dec	-	-	1		-	-	-					-	-											
	Feb	2			-																				
	Jul	2	2											3											
Leptatherina	Dec	-	-	5	6	-	-		4				-	-					2	7			6		
presbyteroides	Feb	5	6	7	-	8	6	5		5	4	7	6	7	6			6	4	5		4	4	5	3
	Jul	1	4	8	5	8	5	4	7	7			3	6	7	4	8	5	6	6	6	1		4	2
Hippocampus abdominalis	Dec	-	-			-	-						-	-					1	1					
	Feb				-												1			1					
	Jul																			1					
Mitotichthys semistriatus	Feb				-										1										
Stigmatopora argus	Dec	-	-			-	-		1				-	-											
	Feb										1			1	1					1		1		1	
Gymnapistes marmoratus	Feb	5	6														4		1						
	Jul	5	2																1						
Platycephalus bassensis	Feb		1		-																				
Arripis trutta	Dec	-	-	3	1	-	-	4			5	5	-	-	5										
	Feb		1	2	-	1	2				3														
	Jul			1		2	3	5		4	3	1		2	1			1							
Aldrichetta forsteri	Dec	-	-	2		-	-	2		5		6	-	-						1					
	Feb	2		3	-	2	2				3	3													
	Jul				6	2	4	1		4	3	1		3				3		5					
Neoodax balteatus	Feb	5	6										1	5	1	1	5		1	2		4			
	Jul	5	3													1	3								
Leseurina sp.	Dec	-	-		1	-	-	3					-	-											
	Feb				-		2	3																	
	Jul						1	3																	
Pseudophritis urvillii	Dec	-	-			-	-						-	-		2	2		3	2	3	2			1
	Feb	3	1		-				3					2		2	3		3	3	4	3	1	2	4
	Jul	3	3																		3			1	2
Cristiceps australis	Feb		2	1					1	1				2	2		2			1					
	Jul								1																
Heteroclinus perspicillatus	Feb	1	1		-																				
	Jul	1							1																
*Nesogobius hindsbyi**	Dec	-	-	4		-	-						-	-	3	4	4		3						
	Feb	4	5	5									6	4	4	4	4	4	3	2				2	
	Jul	2	3	4									4	3	2				2	2		1			1
Nesogobius sp.1*	Dec		-	-		-	-		5	3	2		-	-											
	Feb				-				3	3	2														
	Jul					3			1		1				3	2	2		2						
Ammotretis liturata	Dec	-	-	3	2	-	-				1		-	-											
	Feb			1	-		2	4				1													
Ammotretis rostratus	Dec	-	-			-	-			4		3	-	-				1							
	Feb			4	-		2			4	2	5	2					2							5
	Jul			2	1	3	1			3		4													1
Rhombosolea tapirina	Dec	-	-	3		-	-			3		3	-	-		1					1				1
	Feb	2		3					1		1	2												1	3
	Jul			1		3	1			3		1	1					1							

Table 1 cont.

Species	Month	Kelly Basin					Hannant Inlet				Bathurst Channel West					Bathurst Channel East					Bathurst Harbour				
		1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Acanthaluteres	Feb		5							1					3		3		2	4	2	4	4	3	
spilomelanurus	Jul	3	3																						
Contusus brevicaudus	Jul						1																		
Contusus richei	Jul						1				3	1													
Torquigener glaber	Dec	-	-	2		-	-					1	-	-	1	1	2		2	1				7	
	Feb	2	1	4	-		3		1	3	8	8	5	5	7	7	6	4	3	3	5	3	3	4	3
	Jul	1		5		1	3	2	1	2	2	4	4	1	2	2	2	3	1	3		3	1	1	2

* The two *Nesogobius* species were difficult to distinguish at some sites, particularly when small, so it is possible that some specimens may have been assigned to the wrong species.

Gillnetting

Gillnets (50 m long, 105 mm mesh) were set overnight in seven areas along the Bathurst Harbour estuary: Old River, Melaleuca Inlet, Bathurst Harbour, Celery Top Islands, Eastern Bathurst Channel, Bathurst Narrows and Bathurst Channel entrance (fig. 1). Four replicate nets were generally set in each area during the five field trips (October 1988, November/December1988, February 1989, May 1989 and July 1989), with the following exceptions: Eastern Bathurst Channel in October (two replicates only), December (3) and May (2); Bathurst Harbour in October (2); Melaleuca Inlet in May (2); and the Old River (not sampled in February, May or July). The Bathurst Harbour site was separated into northern and southern sections; two nets were placed in each section except during October, when the southern section only was sampled.

Because a single species, the white-spotted dogfish (*Squalus acanthias*), dominated the catches at all sites and was clearly a key component of the Bathurst Harbour ecosystem, some basic life-history research was conducted on this species. A total of 108 individuals from five sites were tagged by placing yellow plastic cattle eartags in the baso-distal section of the first dorsal fin, by recording their fork length and sex. Whenever tagged individuals were recaptured their length was remeasured and locality recorded. The size-frequency distribution of *S. acanthias* within the estuary was determined during the July 1989 field trip by measuring the length and determining the sex of all captured dogfish.

Statistical Analysis

Sites were classified by calculating a similarity matrix between pairs of sites using the Pearson correlation coefficient. The information in the similarity matrix has been hierarchically grouped using average linkage and presented as a dendrogram. A corresponding inverse analysis for fishes using the same data set was also made.

RESULTS

Seine Netting

A total of 29 fish species was collected by beach seine from the Bathurst Harbour estuary and Kelly Basin (table 1). Slightly more species were collected during the February survey (26) than during July (23), even though one more site was sampled on the latter occasion.

Three major groupings of sites are apparent when sites are classified by their February fish faunas (fig. 2). The two sheltered Kelly Basin sites (KB1 and KB2) were quite different to other sites. These sites both contained relatively diverse assemblages of fishes associated with seagrass beds. The other major division between sites was between locations east and west of the centre of Bathurst Channel; the only two exceptions to this major dichotomy were that Balmoral Beach (EC3), an exposed sandy beach in eastern Bathurst Channel, grouped with western Bathurst Channel sites, and the Hannant Inlet south site (HI3) grouped with eastern Bathurst Channel sites.

During July, sites separated much more on the physical characteristics of the site rather than on geographic position. Separate major groupings occurred between sites with fine sediment (silt and clay) and sites with coarse sediment (pebbles and sand) within the estuary (fig. 2). The Kelly Basin sites, three of the Bathurst Harbour sites and the Bramble Cove sites in Bathurst Channel showed little similarity with other sites.

The inverse classification of the February and July data sets showed analagous patterns to the site classification (fig. 3). During February, the two major groups of fishes were those associated with sites adjacent to Port Davey and those associated with sites further up the estuary, while in July, habitat type was much more important. The three major groups of fishes in July included a fine sediment and seagrass associated group, a coarse sediment group, and a group found only in the upper reaches of the estuary. The latter group contained two species only (*Galaxias maculatus* and *Retropinna tasmanica*). The coarse sediment group was the least homogeneous, with marine-influenced species (*Aldrichetta forsteri, Contusus richei, Arripis trutta* and *Leseurina* sp.) linking to more estuarine species at a relatively low level of similarity (fig. 3).

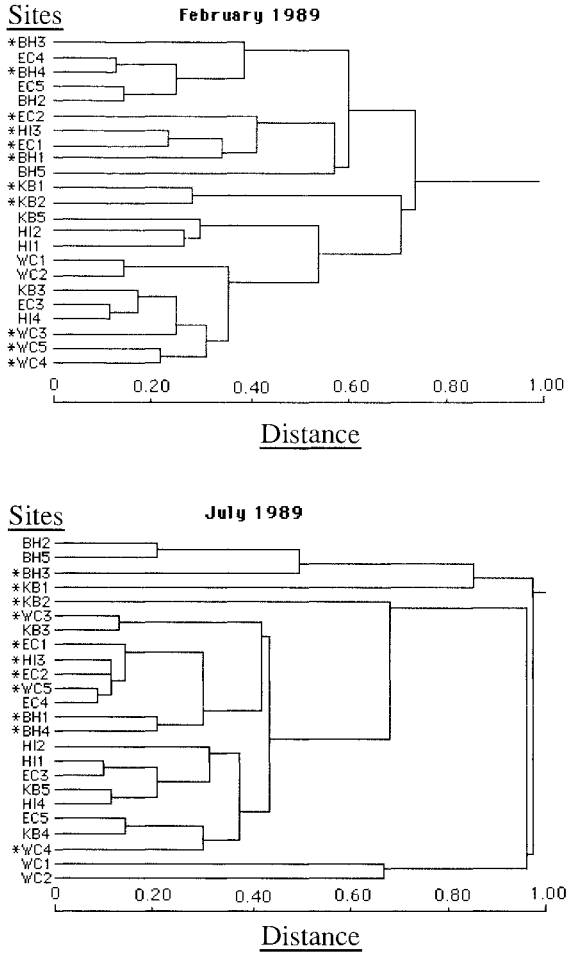

*FIG. 2 — Classification of sites using beach seine data. Sites are listed by area (Kelly Basin, KB; Hannant Inlet, HI; West Bathurst Channel, WC; East Bathurst Channel, EC; Bathurst Harbour, BH) and site number (fig. 5.1). * indicates that site has fine-sediment substratum.*

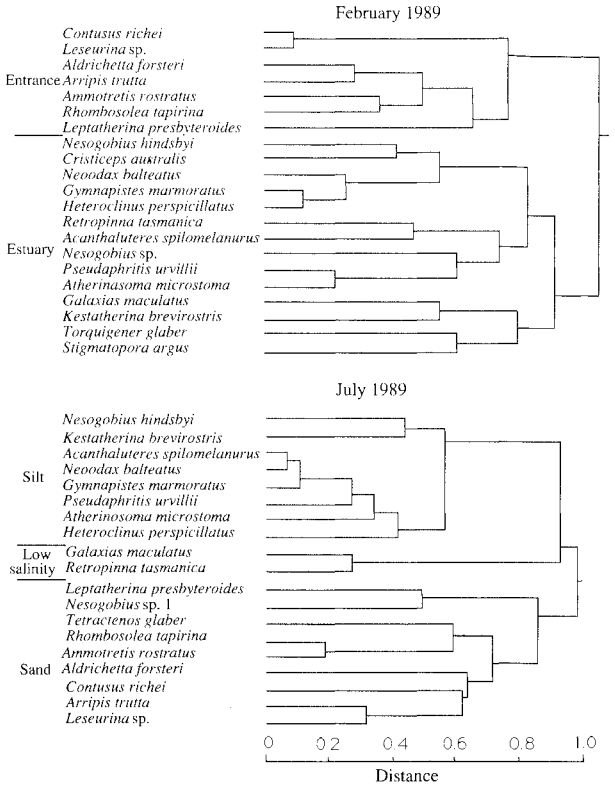

FIG. 3 — Inverse classification of February and July beach seine data.

The diversity of fishes collected by beach seine was related to both the salinity and substratum type of the habitat. The number of species collected from sites with soft sediments decreased up the estuary, while the opposite trend was found at sites with coarse sediments. This is shown in fig. 4 where the total number of fishes collected at each site is plotted against the winter (July) salinity. The difference between these two regressions was found to be highly significant ($P<0.01$) using Analysis of Covariance (table 2). Note that, although salinity and substratum type were related to fish diversity in this analysis, the analysis does not indicate that either of these factors were directly responsible for fish distribution patterns. Other physical factors were strongly correlated with salinity and substratum type; for example, wave exposure was correlated with sediment type and nitrate levels with surface salinity, so the effects of particular physical factors could not be separated.

Gillnetting

Fishes collected during the gillnetting survey are listed in table 3. Almost all of these species are widely distributed around Tasmania. The only surprising catch was a previously unknown species of skate collected from the centre of Bathurst Harbour. Three specimens of this fish were caught during the study, two of them being retained and lodged at CSIRO, Division of Fisheries. The species shows closest similarity to the New Zealand skate *Raja nasuta*, but reaches maturity at a much smaller size (P.R. Last, pers. comm.).

Sharks and rays dominated the fish assemblage in the Bathurst Harbour estuary. The ten elasmobranch species collected by gillnet included the three most common fishes and also 95% of total fish numbers. The white-spotted dogfish *Squalus acanthias* was by far the most abundant large species in the area, comprising 86% of the total catch. Teleosts were most common at the western entrance to Bathurst Channel; however, even at this site they were less abundant than sharks.

Very few fish were collected in areas with considerable freshwater input, i.e. the Old River and Melaleuca Inlet. Eels were probably the dominant fish in these areas but were virtually impossible to catch using gillnets. Few species were also found in the centre of Bathurst Harbour, probably because of the lack of rocky substrata in the area. The abundance of dogfish in this area was, however, extremely high.

The population structure of *Squalus acanthias* differed markedly between different sites in the estuary (fig. 5). Large females and immature juveniles were collected at the Port Davey entrance to Bathurst Channel in July 1989, with mature males and a few small juveniles being found in Bathurst Harbour. The central area of Bathurst Channel was an overlap area in which the two groups of animals

TABLE 2
Results of analysis of covariance

Compares the regressions relating total number of fish species collected by seining at a site and the winter (July 1989) salinity of the site for coarse sediment (cobbles/sand) and fine sediment (silt/mud) habitats.

Effect	d.f.	MS	F	P
Substrate	1	25.44	8.80	0.008
Salinity	1	3.47	1.20	0.287
Substrate × salinity	1	35.05	12.12	0.002
Error	19	2.89		

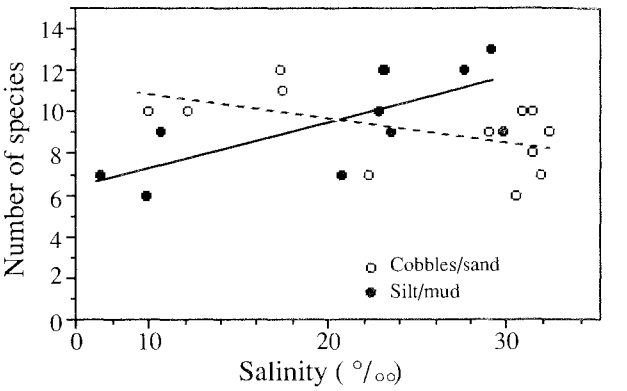

FIG. 4 — The relationships between the number of fishes collected by beach seine at different sites and the winter (July 1989) salinity at those sites for two different habitat types: coarse-sediment (cobbles/sand) and fine-sediment (silt/mud) substrata.

TABLE 3
Number of fishes collected in gillnets set at different sites

Site	Old River	Melaleuca Inlet	Bathurst Harbour	Celery Top Islands	Eastern Bathurst Channel	Bathurst Narrows	Channel Entrance	Total
Number of nettings	8	18	18	20	15	20	20	119
Species								
Heterodontus portusjacksoni	0	0	0	0	0	1	0	1
Notorhynchus cepedianus	0	0	0	0	0	0	3	3
Cephaloscyllium laticeps	0	0	0	0	0	0	2	2
Galeorhinus galeus	0	0	0	0	1	1	1	3
Mustelus antarcticus	0	0	3	14	19	24	6	66
Squalus acanthias	0	0	687	190	149	316	89	1431
Raja lemprieri	0	0	0	0	1	0	0	1
Raja whitleyi	0	0	0	1	0	0	0	2
Raja sp.	0	0	3	0	0	0	0	3
Callorhynchus millii	0	0	3	13	24	5	1	46
Anguilla australis	0	1	0	0	0	0	0	1
Pseudophycis bachus	0	4	4	9	8	11	4	40
Pseudophycis barbatus	0	0	0	0	0	0	1	1
Cyttus australis	0	0	0	0	0	0	3	3
Hippocampus abdominalis	1	0	0	0	0	0	0	1
Stigmatopora argus	0	0	0	1	0	1	0	2
Neosebastes scorpaenoides	0	0	0	2	2	2	9	15
Cheilidonichthys kumu	1	2	0	7	3	0	0	13
Platycephalus bassensis	0	0	0	1	2	3	0	6
Pentaceropsis recurvirostris	0	0	0	0	0	0	1	1
Nemadactylus macropterus	0	0	0	2	0	0	0	2
Latridopsis forsteri	0	0	0	0	0	8	8	16
Notolabrus fucicola	0	0	0	0	0	2	1	3
Number of species	2	3	5	10	9	11	14	23

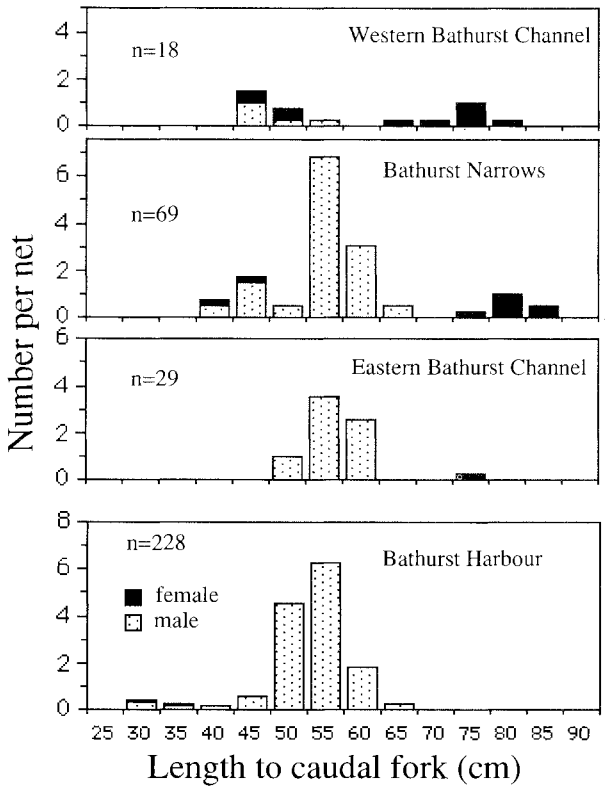

FIG. 5 — Mean number of white-spotted dogfish in different size-classes collected per net in different areas of the Bathurst Harbour estuary in July 1989. The Celery Top Island and Bathurst Harbour data have been combined. n = total number of animals collected.

coexisted. These size-distribution patterns did not remain constant throughout the year, however, as no large females were collected in February. Many of the large females were pregnant, one of them releasing four young after capture at Bathurst Narrows in November. The Bathurst Harbour estuary may be used for mating as well as spawning. Almost all large males were mature, releasing sperm on capture.

An extremely high proportion of tagged dogfish were recaptured. Of the total of 108 tagged animals, 27 (= 25%) were recaptured during the study (i.e. the 25 shown in table 4 and two recaptured in December). A further three tagged fishes were caught by visiting fishermen. Most of the recaptured animals were taken at sites away from their release points, in three cases at the other end of the estuary (fig. 6). No obvious patterns were evident in the movement of animals, dogfish from any site having approximately equal probability of being recaptured at any other site in the area (fig. 6).

A small number (11) of gummy shark, *Mustelus antarcticus*, were also tagged and released during the study in Bathurst Channel. Two of these sharks were recaptured two months after release near where they were tagged, at Platypus Point and Gull Islet at the eastern end of Bathurst Channel.

DISCUSSION

The two methods of fish sampling, beach seining and gillnetting, yielded different faunas. Only four species, thornback skate *Raja lemprieri*, sand flathead *Platycephalus bassensis*, spotted pipefish *Stigmatopora argus* and wide-bellied seahorse *Hippocampus abdominalis*, were collected using both methods. Because no prior gillnetting study had been done in the Bathurst Harbour estuary, many of the fishes collected using this technique were new to the area (10 species). Beach

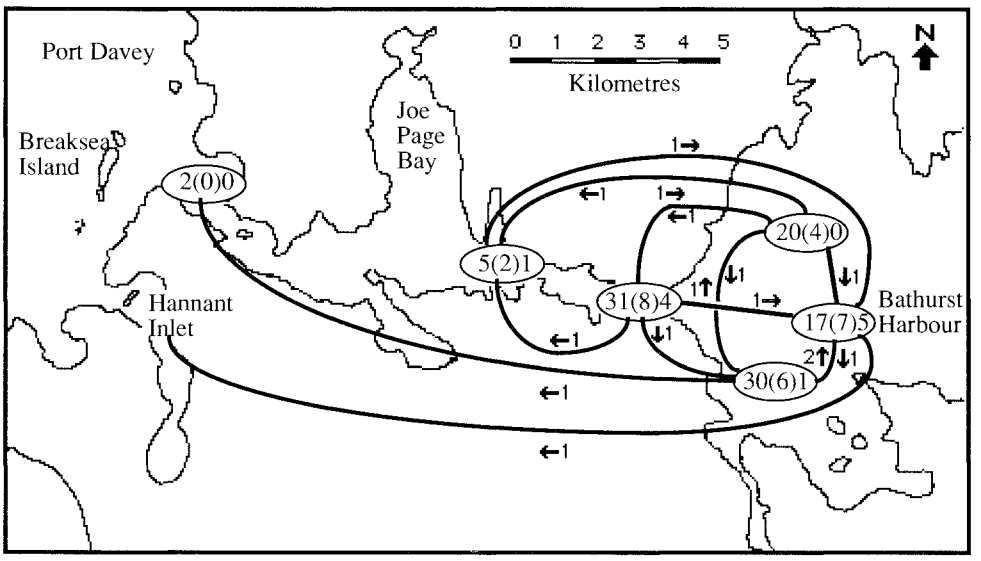

FIG. 6 — Movement of tagged white-spotted dogfish in the Bathurst Harbour estuary. For each site the total number of dogfish released at that site is initially shown (followed by the number which were tagged at that site and later recaptured) followed by the number recaptured at the same site. One individual, not shown on the figure, was released at Celery Top Islands and recaptured in Bond Bay, northwestern Port Davey.

seining provided seven additions to the list of fishes previously known for the Port Davey region (Last 1983, Edgar 1984). The only notable new record collected by seine was the Tasmanian whitebait, *Lovettia sealii*, a species which has been commercially overexploited elsewhere in Tasmania (Last *et al.* 1983). Even though only two specimens of *L. sealii* were collected during the study, this fish may occur in high population densities in Bathurst Harbour, since its open water habitat was not adequately sampled using a seine net and specimens could easily pass through the 12 mm net mesh.

The other notable species collected during the study was the undescribed species of skate (*Raja* sp.) taken in Bathurst Harbour. The restricted range of this ray is extremely unusual for a marine fish, so it is possible that the species also occurs in deeper waters off the Tasmanian coast. It is, however, also possible that the species is confined to Bathurst Harbour, because extensive trawl surveys made around Tasmania during the past decade would be expected to have yielded the species, if at all widespread (P.R. Last, pers. comm.), particularly as all other Australian skates which occur in shallow water have been collected on numerous occasions. The only estuarine locality outside Bathurst Harbour in which the skate is likely to occur is Macquarie Harbour. During a gillnet survey of Macquarie Harbour by the Division of Sea Fisheries and the Inland Fisheries Commission, a number of skates were collected which may have been the undescribed species but were assumed to be the common thornback skate (*Raja lemprieri*), so were not closely examined (A. Schaap, pers. comm.).

The entire assemblage of larger fishes in the Bathurst Harbour estuary was unusual in being dominated by species which are also commonly found in the deeper waters (>50 m) of the continental shelf. Gillnet samples were dominated, both in species and population numbers, by elasmobranchs. Sharks and rays generally increase in abundance and species richness offshore (Last & Harris 1981). *Squalus acanthias*, the most abundant species in Bathurst Harbour, has been found below 700 m (Hart 1973). The three common teleosts collected by gillnet, red gurnard *Cheilidonichthys kumu*, gurnard perch *Neosebastes scorpaenoides* and red cod *Pseudophycis bachus*, have also all been commonly recorded on the continental shelf below 50 m depth (Last & Harris 1981).

Low oxygen concentrations within the estuary during February 1989 (Edgar & Cresswell 1991) probably greatly affected the distribution of fishes, preventing a number of species from entering the estuary and causing the beach-seined sites to group on a geographic Port Davey/Bathurst Harbour basis rather than a habitat basis (fig. 2). The recorded oxygen levels (≈35% saturation; Edgar & Cresswell 1991) were certainly lower than salmonids can withstand for long periods (Alabaster & Lloyd 1983), a possible reason for trout not being recorded from the area. It is notable that all of the large active teleosts collected by beach seine and gillnet (i.e. the Australian salmon *Arripis trutta*, yellow-eye mullet *Aldrichetta forsteri*, bastard trumpeter *Latridopsis forsteri*, morwong *Nemadactylus macropterus* and purple wrasse *Notolabrus fucicola*) were not taken past Bramble Cove in summer but were found through Bathurst Channel in other seasons. Salinity is clearly not the primary environmental factor affecting species distribution in the area or the opposite trends would have been found, with marine species penetrating up the estuary in greatest numbers in summer.

The general decrease in the number of fish species collected by beach seine from sandy habitats as one moves toward the sea (fig. 4) was unexpected as it is contrary to the trends for fine-sediment associated fishes (fig. 4), gillnetted fishes (table 3), and planktonic (Edgar & Cresswell 1991) and benthic taxa (Edgar 1991). Perhaps this increase was trophically related; in contrast to fishes in silt habitars, most of the fishes collected from sand and cobbles were planktivorous open-water fishes and the abundances of planktonic prey rapidly increased up the estuary (Edgar & Cresswell 1991). Species associated with fine-sediment habitats probably decreased up the estuary primarily because dense seagrass beds occurred on silt sediments only in marine areas, with seagrasses becoming quite sparse in less saline waters. A component of fish species was commonly found only in association with seagrasses (e.g. *Gymnapistes marmoratus, Neoodax balteatus*).

The life history of the white-spotted dogfish, *Squalus acanthias*, is probably better known than any other shark. The species has been intensively studied because of its commercial importance and wide distribution around the world. Most of the information pertaining to the biology of this species has been summarised by Compagno (1984), who reported that:

(i) *S. acanthias* cannot survive freshwater for more than a few hours but tolerates brackish water;
(ii) it is a slow-growing species which is very long lived;
(iii) the species occurs in schools which are segregated by sex;
(iv) only males and large pregnant females generally occur in shallow water;
(v) pregnant females congregate in enclosed shallow bays where they release 1 to 20 young; and
(vi) the species prefers water between 7°C and 15°C, making latitududinal and depth migrations to stay within the optimal range.

In all respects this information agrees with observations made during the present study:

(i) *S. acanthias* was not collected in Melaleuca Inlet or the Old River but was widespread in the more marine sections of the estuary;
(ii) tagged individuals were slow growing, with many tagged animals not increasing in length while liberated and the fastest-growing animal increasing only 20 mm in 8 months;
(iii) large numbers of fishes were collected in small sections of gillnet, indicating a schooling habit, and there was also a clear size separation of stocks within the estuary (fig. 5);
(iv) intermediate-sized (55-65 cm) females were not collected;
(v) large pregnant females were found along Bathurst Channel between July and November, including one animal which released four young when brought into the boat; and
(vi) numbers of captured animals were lowest during the summer survey, the period when water temperatures fell outside the preferred 7–15 °C range.

Although the very high numbers of dogfish captured in Bathurst Harbour suggest that an extremely large population exists in the area, the high proportion of tagged animals which were recaptured belies this. *Squalus acanthias* are slow swimmers, which keep a regular pace in their nomadic movements (Compagno 1984). They wandered throughout the estuary rather than remained in localised populations (fig. 6). The high capture rates, therefore, appear to have had as much to do with dogfish behaviour as with population densities. During each night an individual dogfish probably travels several kilometres, and thus has an appreciable probability of encountering a set net. Approximately 10%

TABLE 4
Numbers* of *Squalus acanthias* captured, tagged and recaptured during the February, May and July 1989 gillnet surveys

	Feb	May	Jul
Number of captured animals	198	291	346
Number of tagged animals recaptured	8†	10†	7
Number of tagged animals previously released	65	101	108
Number of surviving tagged animals	64	92	92
Population estimate	1609	2677	4547

* Population estimates based on these numbers are also given. The number of surviving tagged animals is the number of tagged animals released less the number of tagged animals which had died on recapture during a previous survey, e.g. 108 animals had been released prior to the May survey, 16 of which had been recaptured and not rereleased. Three tagged dogfish, which are not listed here but are incorporated into figure 6, were recaptured by yachtsmen.
† Two fish were collected in February and another in May with their dorsal fins hole punched and torn. These fish had lost their tags and are included in the total.

of previously tagged fish were recaptured (table 4) during each survey, with a mean of 2900 animals estimated to have been present in Bathurst Harbour and Bathurst Channel over the three survey periods (table 4). However, this population number may be overestimated, because calculations did not take into account any handling or tag-induced mortality of released animals, and this could well have been considerable. Assuming that the total population in the 60 km^2 area of the Bathurst Harbour estuary was 2900 fish, each overnight set of a gillnet in Bathurst Harbour caught ≈1.3% of the total population (i.e. 38 fish). Netting within the estuary therefore appears to significantly affect local population numbers.

ACKNOWLEDGEMENTS

The study greatly benefited from advice and the loan of equipment by Peter Davies, Wayne Fulton and Andrew Sanger (Inland Fisheries Commission), and Peter Last and John Stevens (CSIRO Division of Fisheries Research). Comments on a draft of this manuscript by John Stevens were also much appreciated. Funding was provided by the Tasmanian Department of Parks, Wildlife and Heritage.

REFERENCES

ALABASTER, J.S. & LLOYD, R., 1983: *WATER QUALITY CRITERIA FOR FRESHWATER FISH.* 2nd edn, FAO Butterworths.

COMPAGNO, L.J.V., 1984: *AN ANNOTATED AND ILLUSTRATED CATALOGUE OF SHARK SPECIES KNOWN TO DATE. PART 1. HEXANCHIFORMES TO LAMNIFORMES. FAO Species Catalogue Vol. 4. Sharks of the World.* FAO, Rome.

EDGAR, G.J., 1984: Marine life and potential marine reserves in Tasmania. Part 2. *Nat. Parks Wildl. Serv. Occ. Pap.* 7: 1-102.

EDGAR, G.J., 1991: The distribution of mobile epifauna associated with rope fibre habitats within the Bathurst Harbour estuary, south-western Tasmania. *Estuar. Coast. Shelf Sci.,* in press.

EDGAR, G.J. & CRESSWELL, G.R., 1991. Seasonal changes in hydrology and the distribution of plankton in the Bathurst Harbour estuary, southwestern Tasmania. 1988-1989. *Pap. Proc. R. Soc. Tasm.* 125: 000–000.

HART, J.L., 1973. Pacific fishes of Canada. *Bull. Fish. Mar. Board Can.* 180: 1-740.

LAST, P.R., 1983. Aspects of the ecology and zoogeography of fishes from soft-bottom habitats of the Tasmanian shore zone. Unpubl. Ph.D. thesis, University of Tasmania.

LAST P.R. & HARRIS, J.G.K., 1981: New locality records and preliminary information on demersal fish faunal assemblages in Tasmanian waters. *Pap. Proc. R. Soc. Tasm.* 115:189-209.

LAST, P.R., SCOTT, E.O.G. & TALBOT, F.H., 1983: *FISHES OF TASMANIA.* Tasmanian Fisheries Development Authority, Hobart.

(accepted 3 May 1991)