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Catch Evaluation of Target, By-product and By-catch Species Taken by Gillnets and Longlines in the Shark Fishery of South-eastern Australia

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Abstract

Experimental demersal gillnets and demersal longlines were deployed from research vessels on grounds of *Mustelus antarcticus* during 1973–76. Gillnet mesh-size had major effects on catch composition and catch rate, whereas gillnet hanging ratio, hook-size, hook shank-length and hook-spacing had minor effects. The gillnets and longlines were much more effective at catching chondrichthyans than teleosts, and catches of species of cephalopoda, bivalvia, gastropoda, mammalia, aves and reptilia were negligible. Any reduction in the present legal minimum mesh-size of 6 inch the shark fishery would markedly increase by-catch. In gillnets monitored by scientific observers aboard commercial vessels during 1998–01, the ratio of the number of chondrichthyan to teleost animals was ~24:1 in Bass Strait and ~5:1 in South Australia. In Bass Strait between 1973–76 and 1998–2001, the catch rate by 6 inch mesh gillnets of chondrichthyans declined by one-third, whereas a change in the catch rate of teleosts was not statistically detectable. Most of this decline is explained by reductions of 54% by *Cephaloscyllium laticeps* and of 87% by *Galeorhinus galeus*. The retained commercial catch was 74% of the chondrichthyan animals and 58% of the teleosts caught; only 3% of the chondrichthyans and 2% of the teleosts were discarded dead. There are occasional interactions with protected species (marine mammals and *Carcharodon carcharias*).

Key words: Australia, by-catch, catch rates, gillnet, longline, observers, shark fishery

Introduction

The International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) recognises that the life history characteristics of chondrichthyan species can lead to low 'biological productivity' making these animals more prone to overexploitation from fishing than most teleost and invertebrate species. The IPOA-Sharks, developed by the Food and Agriculture Organization of the United Nations, also recognizes that these species require special management, research, and monitoring if they are to be harvested sustainably (Anon., 2000). Globally, the catches of chondrichthyans are often under-reported and it is likely to go unrecognized that many species, particularly those taken as by-catch, are at high risk (Walker, 1998). 'Critical by-catches' pertains to species or populations that are in danger of extinction, and 'unsustainable by-catches' are by-catches of species or populations that are not currently at risk but will decline at current levels of by-catch (Hall, 1996).

In Australia, several initiatives in recent years have created legislative requirements to evaluate catch composition and catch rates of all species of fish in Australian fisheries. The requirements apply to both targeted and non-targeted species. Non-targeted species comprise by-product (species where the catch is mostly retained) and by-catch (species where the catch is mostly discarded). In response to legislative obligations, the Commonwealth Government has recently developed by-catch action plans for major Australian fisheries. The Government has also responded to the legislative requirement for "strategic assessment" of certain fisheries for ecological impacts on a) target and by-product species, b) by-catch species, c) threatened, endangered and protected species, d) marine habitats, and e) marine food chains. The process requires collection of appropriate data, risk assessment, and appropriate management responses. Also as a signatory nation to the IPOA-Sharks, Australia has developed a National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks), which identifies catch evaluation and risk assessment of chondrichthyan species as high priority needs.

The present study is designed to evaluate the catch composition and catch rates in the shark fishery of southern Australia. The catch of each species was evaluated in terms of whether the animals were landed on board 'live' or 'dead' and whether they were 'retained' or 'discarded'. The study addresses catches taken both by demersal monofilament gillnets and demersal longlines from data available for the two periods of 1973–76 and 1998–2001.

Materials and Methods

Data utilized in the present study were collected opportunistically during three separate investigations. Data from the first of these investigations were collected on two research vessels during 1973–76, where the biology of gummy shark (*Mustelus antarcticus*) and the length selective characteristics of fishing gear were investigated (Walker, 1983). Data from the second of these investigations were collected on two commercial fishing vessels during 1998 as part a pilot fixed-station fishery-independent survey designed to determine survey intensity for monitoring abundance of harvested species (Punt *et al.*, 2002). Data from the third investigation were collected on eight fishing vessels during 1999–2001 as part of a study of common sawshark (*Pristiophorus cirratus*), southern sawshark (*P. nudipinnis*), and elephant fish (*Callorhinchus milii*).

During 1973–76, most of the research sampling was undertaken in Bass Strait, with a small amount of sampling undertaken in waters off the east and south coasts of Tasmania and in waters off South Australia. Five separate experiments were undertaken to test for the effects of gillnet mesh size, gillnet hanging ratio, hook size, hook shank length and hook spacing on catch rate. During 1998–2001, sampling was undertaken during normal commercial fishing operations in Bass Strait and South Australia. For Bass Strait, comparisons of catch rates from gillnet with 6 inch mesh were made between 1973–76 and 1998–2001. Other than recording mesh size of gillnets, it was not possible to control the design of the fishing gear or undertake experiments during the second period. Catch rates for gillnet 7 inch mesh size and longlines with Mustad 11/O long-shank hooks during 1973–76 are also presented for Bass Strait, because these gears were used extensively by the fishing industry during that period. For Tasmania, similar data are presented for 1973–76, but there are no data for 1998–2001. For South Australia, there are insufficient data for 1973–76, but gillnet 6 inch mesh and 6½ inch mesh size data are presented for 1998–2001. During 1998–2001, most of the fishing gear deployed in South Australia and Tasmania was 6½ inch mesh size and most of the fishing gear deployed in Bass Strait was with 6 inch mesh.

Field sampling 1973–76

During June 1973 to November 1976, catch composition and catch rates were examined at 162 fishing sites during 155 fishing days on the FV *Moondara* and FRV *Sarda*, at depths of 9–79 m on the continental shelf between Streaky Bay, South Australia; Gabo Island, Victoria; and Hobart, Tasmania. Most fishing sites were in Bass Strait (126 sites), but some were off eastern Tasmania, south of latitude 41° South (20 sites), and off South Australia (16 sites) (Fig. 1a).

Longlines used consisted of 400 hooks attached to two separate lines. The hooks (2/O–10/O Mustad short-shank and 11/O Mustad long-shank) were clipped 5, 7.5, 10, or 20 m apart to a sinking super saran rope main line. Each hook was connected to one end of a 1 m long snood, constructed of 6 mm diameter braided polypropylene, by a 10 cm long monel wire trace. The other end of the snood was attached to the main line by way of a snap-clip. Each of 12 gillnets was 250 m long and ~1.7 m deep. Eight had a hanging ratio of 0.60 and mesh sizes ranging 2–9 inch mesh (51–229 mm), in steps of 1 inch mesh (25 mm). Two had a hanging ratio of 0.53 and mesh sizes of 6 inch mesh (152 mm) and 7 inch mesh (178 mm), and two had a hanging ratio of 0.67 and mesh sizes of 6 and 7 inch mesh.

The monofilament polyamide webbing used to construct the nets was green, double knotted, double selvedge, and of neutral buoyancy. The bridle and headline were made of 10 mm (diameter) polypropylene rope. The headline with attached webbing was 250 m long. Vinyl floats ('3TV-5' each with 128 g wt upthrust) were attached to the headline at 5 m intervals. The leadline was made of 6 mm diameter polyethylene rope, with eight 57 g lead weights per 5 m. The leadline was made 5% longer than the headline to reduce the incidence of tangling when setting of the nets. The number of meshes deep, the thickness of the filaments of the webbing (0.47–1.05 mm), and the breaking strain of the filaments varied with mesh size (101–467 Newton) (Table 1).

The gillnets and longlines were set on the seabed mainly between the times of 0400 hr and 0600 hr; the nets were set first, followed by the longlines. Set as groups of two or three nets, the ends of the headlines of adjoining nets were connected and separated by 100 m lengths of 10 mm diameter polypropylene rope. Two lead anchor weights (each 12.5 kg) were attached to the bridles at the two ends of each net. Two buoy lines, with buoys, were attached to the headlines of the nets at the two free ends of each group of nets. Similar configurations of buoy lines, buoys, and anchor weights were adopted for each longline. The groups of nets and the two longlines were usually set in a line 100–300 m apart.

Five separate experiments were undertaken during 1973–76 using various combinations of this fishing gear

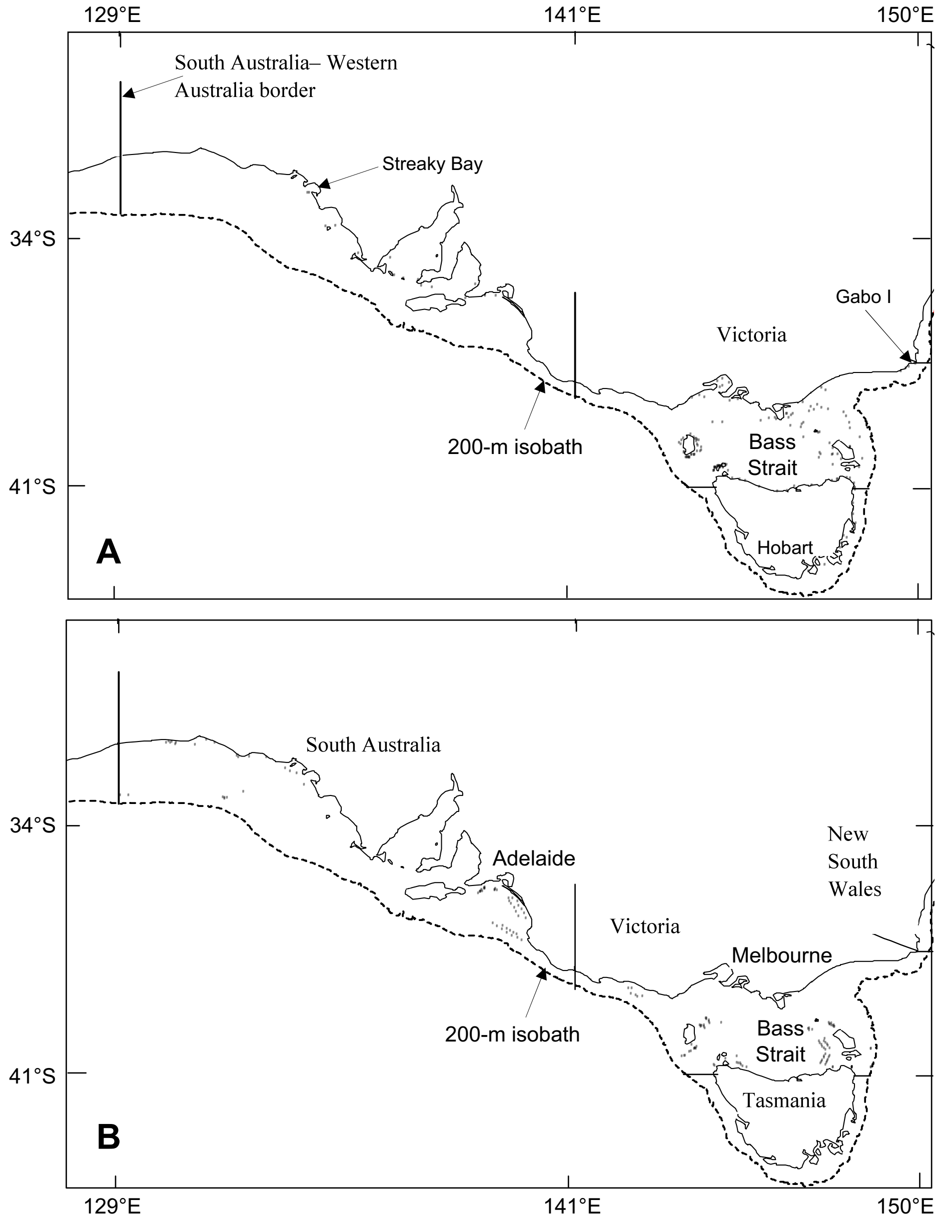

Fig. 1. (**A**) Fishing sites during 1973–76 and (**B**) fishing sites during 1998–2001.

to determine the effects on the catch rate for each species. Three experiments tested the effects of mesh size of gillnets (2–9 inch mesh), hanging ratio of gillnets (0.53, 0.60, and 0.67), and hook size (short-shank Mustad 2/O–10/O), respectively. Two experiments tested the effects of hook size (short-shank Mustad 5/O and 10/O), hook shank length (Mustad short-shank 10/O and long-shank 11/O), and hook spacing (Mustad long-shank 11/O 5, 10 and 20 m). Mean fishing times for the gears were 6.1 hr for Experiment 1, 6.3 hr for Experiment 2, 4.3 hr for Experiment 3, 4.3 hr for Experiment 4, and 3.2 hr for Experiment 5 (Table 2).

Field sampling 1998–2001

During November 1998 to February 2001, nine different commercial vessels were used during 10 separate fishing trips for sampling at 153 fishing sites (91 sites in Bass Strait and 62 sites off South Australia) (Fig. 1b). The vessels operated under normal commercial fishing conditions, where the fishing gear consisted of 6 inch or 6½ inch mesh size gillnets. The vessels were all licensed to deploy gillnets up to a maximum of 4 200 m long and 20 meshes deep; each gillnet was ~2.4 m deep with a hanging ratio of ~0.60. The thickness and breaking strain

TABLE 1. Variable characteristics of the eight experimental gillnets used for Experiments 1 and 2.

Mesh size (inch)	Number of meshes deep (mm)	Filament thickness (N)	Breaking strain
2	42	0.47	101
3	28	0.57	146
4	21	0.66	193
5	17	0.74	240
6	14	0.81	285
7	12	0.87	326
8	10	0.90	348
9	9	1.05	467

TABLE 2. Summary of fishing gear specifications and variables for each of five experiments and for between period and between gear statistical tests.

Experiment/ test	Period	Fishing gear	Fishing gear specifications	Explanatory variables	Gear units	Times set
Expt 1	1973–76	Gillnet	8 mesh-sizes[1] × 1 hanging-ratio	Mesh-size	8 × 250 m	73
Expt 2	1973–76	Gillnet	2 mesh-sizes[2] × 3 hanging-ratios[3]	Hanging-ratio	6 × 250 m	32
Expt 3	1973–76	Longline	8 hook-sizes[4] × 1 shank-length[5] × 1 space[6]	Hook-size	8 × 50 hks	39
Expt 4	1973–76	Longline	3 hook-sizes[7] 2 shank-lengths[8] 2 spaces[9]	Hook-size, shank-length, hook-spacing	4 × 50 hks	41
Expt 5	1973–76	Longline	3 hook-sizes[7] 2 shank-lengths[8] 2 spaces[10]	Hook-size, shank-length, hook-spacing	4 × 50 hks	22
Between periods	1973–76 1998–01	Gillnet	1 mesh-size × 2 periods[11] (Bass Strait only)	Period	172 × 250 m 91 × 4 200 m	172 91

[1] Mesh-sizes 2-, 3-, 4-, 5-, 6-, 7-, 8- and 9-inch of hanging-ratio 0.60
[2] Mesh-sizes 6- and 7-inch
[3] Gillnet hanging ratios of 0.53, 0.60 and 0.67
[4] Hook-sizes Mustad 2/O, 3/O, 4/O, 5/O, 7/O, 8/O, 9/O and 10/O
[5] Short-shank
[6] 7.5 m hook-space
[7] Hook-sizes Mustad 5/O, 10/O and 11/O
[8] Short-shank and long-shank
[9] 10- and 20 m hook-spaces
[10] 5- and 10 m hook-spaces
[11] Periods 1973–76 and 1998–2001

of the filaments of the gillnet webbing were ~0.90 mm and ~359 Newton, respectively. The gear was set on the seabed, mostly twice a day. Those set between the times of 2100 hr and 0500 hr were mostly hauled after sunrise, whereas those set between the times of 0800 hr and 2000 hr were mostly hauled after sunset. Mean fishing time for the gear was 8.2 hr. Depths at the fishing sites ranged 17–130 m; there were only 10 sites >79 m (all in South Australia), the maximum depth fished during 1973–76. The full length of gillnet was deployed at most fishing sites (4 200 m at 128 sites) or a little less was deployed when the gear was damaged (4 000 m at 21 sites). Half the available gillnets were set when searching for target species or when avoiding strong tidal flow or damage to the catch from predation (2 100 m at 2 sites, and 2 000 m at 2 sites).

Data collection

When hauling the fishing gear, the catch was sorted for up to 22 sampling units of fishing gear. All chondrichthyes, teleostei, cephalopoda, mammalia, aves, and reptilia, and selected (large sized) species of crustacea, bivalvia, gastropoda, were identified and counted. No information was recorded for other invertebrate and chordate taxonomic groups. Common, scientific, and family name for each animal identified was assigned according to the Codes for Australian Aquatic Biota (CAAB) maintained by CSIRO Division of Marine Research as of June 2002. In addition, during 1998–2001, where practical, each animal caught was classed as 'live', 'dead', or 'unknown' when removed from the water, and classed as 'retained' or 'discarded'. Because 'sea lice' (isopods and copepods) and leatherjackets (family *Monocanthidae*), can cause damage and loss of a portion of the catch, the proportion of each retained animal was recorded.

Data analysis

The data were managed and analysed using the statistical package SAS (Ver. 8.1, SAS Institute, North Carolina, USA). Catch rates were statistically tested for each of the five experiments separately and for each of three regions adopted for comparisons of the fishing gears used most widely in the shark fishery during 1973–76 and 1998–2001. For each experiment, the data were pooled over all fishing sites, whereas, for inter-period and commercial gear comparisons, the data were separated into the three regions Bass Strait, Tasmania, and South Australia. For the purpose of the present study, a one way analysis of variance was applied to test for the effect of each of several explanatory (independent) variables separately for each species and each major taxonomic group. For each analysis separately, the variance was tested for homogeneity and, where this was true, the following model was applied.

$$Catch\ \ rate = Explanatory\ \ variable(s) + \tilde{\varepsilon}$$

In the model, ε is the error term and catch rate is the number of animals caught divided by the fishing effort, where fishing effort was applied separately in the model for each of several alternative units. For gillnets, the unit of fishing effort applied was 'metre-lift-hours', and, for longlines, the unit of fishing effort applied was 'hook-lifts' (number of hooks). The explanatory variable in the model varied depending on experiment or on region for the inter-period or gear comparisons. The explanatory variable was mesh size for Experiment 1, hanging ratio for Experiment 2, and hook size for Experiment 3, and the three explanatory variables were hook size, hook shank-length, and hook-space for each of Experiments 4 and 5. For inter-period comparisons, the explanatory variable was sampling period for gillnet 6 inch mesh size in Bass Strait and, for commercial gear comparisons, the explanatory variable was mesh size for gillnet 6 inch and 6½ inch mesh size in South Australia during 1998–2001. No statistical test was applied to the data presented for Tasmania during 1973–76.

Results

During 1973–76 and 1998–2001 combined, a much higher number of animals and a higher number of species were caught by gillnets (22 918 animals, 124 species) than by longlines (4 006 animals, 54 species). The wider range of gillnet mesh sizes and longline hook sizes deployed caught both a higher number of animals and higher number of species during 1973–76 (16 657 animals, 112 species) than during 1998–2001 (10 267 animals, 65 species), despite a much lower fishing effort during 1973–76. Some of the differences in numbers of animals and numbers of species caught between the two periods can be explained by longlines being used only during 1973–76 (4 006 animals, 54 species). However, most of the differences in the numbers caught is explained by eight mesh sizes (2–9 inches) used during 1973–76 (12 651 animals, 104 species) and only two mesh sizes (6 and 6½ inches) during 1998–2001 (10 267 animals, 65 species).

The catch comprised mostly chondrichthyes (21 633 animals, 33 species) and teleosts (5 118 animals, 87 species), with small quantities of cephalopoda (26 animals, 4 species), bivalvia (14 animals, 1 species), gastropoda (9 animals, 1 species), crustacea (121 animals, 3 species), and mammalia (3 animals, 2 species) (Table 3).

A breakdown of the number of different chondrichthyan and teleost species caught and number of animals caught by species for each of the five experiments undertaken during 1973–76 is presented in Table 4. Catch rates are presented separately where explanatory variables were

TABLE 3. Number of animals and number of species caught by gillnet and longline during 1973–76 and 1998–2001.

Taxonomic group	No. of animals 1973–76 Longline	Gillnet	Total	1998–2001 Gillnet	Total	No. of species 1973–76 Longline	Gillnet	Total	1998–2001 Gillnet	Total
Chondrichthyes	3 093	9 104	12 197	9 436	21 633	23	27	31	22	33
Teleostei	905	3 501	4 406	712	5 118	28	70	74	35	87
Cephalopoda	8	14	22	4	26	3	4	4	2	4
Bivalvia	–	14	14	–	14	–	1	1	–	1
Gastropoda	–	–	–	9	9	–	–	–	1	1
Crustacea	–	18	18	103	121	–	2	2	3	3
Mammalia	–	–	–	3	3	–	–	–	2	2
Aves	–	–	–	–	–	–	–	–	–	–
Reptilia	–	–	–	–	–	–	–	–	–	–
Total	4 006	12 651	16 657	10 267	26 924	54	104	112	65	131

TABLE 4. Summary of results from five experiments.

Expt	Fishing gear	No. species caught Chondricthyans	Teleosts	No. animals caught Chondricthyans	Teleosts	No. species sig.[1] Chondricthyans	Teleosts
1	Gillnet	25	63	5 038	2 284	8	13
2	Gillnet	14	16	1 117	148	–	–
3	Longline	18	16	1 291	561	1	–
4	Longline	25	63	827	109	–	1
5	Longline	11	5	366	80	–	–

[1] Statistically significant

statistically significant for several species (Experiment 1) or where the data are of special interest (Experiment 3). Separate tables are also presented of catch rates for comparison between the 1973–76 and 1998–2001 sampling periods in Bass Strait, and of available data for 1973–76 in Tasmania and for 1998–2001 in South Australia. In each table, the catch rates are presented by species categorised as chondrichthyes, teleostei, cephalopoda, and other. The category "Other" includes bivalvia, gastropoda, crustacea and mammalia. Within each taxonomic category, the species are ordered from the highest to lowest on the basis of the number of animals caught. The probability values for the effects of various variables tested by 'one way analysis of variance' are presented where the condition of homogeneity of variance is met.

Experiment 1: Effect of gillnet mesh size on catch rates

Results from Experiment 1 (Table 5) indicate that the effect of gillnet mesh size on catch rate was statistically highly significant for many of the species caught. Overall the gillnets had much higher catch rates of chondrichthyans than of teleosts for all mesh sizes 3–9 inches, but the 2 inch mesh had a higher catch rate of teleosts than of chondrichthyans. There is a roughly linear relationship between the ratio of the number of chondrichthyans divided by the number of teleosts against mesh size where the ratio increases with increasing mesh size (Fig. 2).

Of the total catch of 7 356 animals across all species and mesh sizes, more than two thirds were chondrichthyans (5 038 animals, 68%) and most of the rest were teleosts (2 284 animals, 31%). Together, cephalopoda (9 animals), bivalvia (14), and crustacea (11) made up <1% of the catch. No gastropoda, mammalia, aves or reptilia were caught. There were 25 species of chondrichthyes, 62 species of teleostei plus *Monacanthidae* (covering unidentified animals in this family), 3 species of cephalopoda, 1 species of bivalvia, and 1 species of crustacea.

The highest catch rates of chondrichthyans were taken in larger mesh sizes than the highest catch rates of teleosts. The highest catch rate of chondrichthyans was in the 4 inch mesh (25%), followed by 3 inch mesh (20%), 5 inch mesh (15%), 2 inch mesh (11%), 6 inch mesh (10%), 7 inch mesh (10%), 8 inch mesh (5%), and 9 inch

TABLE 5. Experiment 1: Effect of gillnet mesh-size on number of animals caught off south-eastern Australia during 1973–76. Eight fishing gear sampling units of gillnet, each 250 m long, and of 8 mesh-sizes (2–9 inch) were set at each of 73 sites; s.e., standard error; *P*, probability value for an effect of mesh-size; $P \geq 0.05$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

		Mean (s.e.) No. of animals caught per 1 000 km-hours								Animals caught		
Common name or effort	Scientific name	2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Number	%	*P*
Fishing effort (km-hours)		113	112	109	110	114	110	110	111			
Number of fishing gear sampling units		73	73	73	73	73	73	73	73			
Chondrichthyes												
Piked spurdog	*Squalus megalops*	3 524(1363)	5 915(2368)	5 904(1959)	1 181(445)	320(140)	66(45)	62(52)	88(62)	1850	36.7	.0000***
Gummy shark	*Mustelus antarcticus*	221(102)	518(158)	1 669(398)	1 965(385)	1 390(259)	832(207)	428(97)	214(77)	850	16.9	.0000***
Port Jackson shark	*Heterodontus portusjacksoni*	125(77)	141(60)	398(154)	404(112)	641(171)	797(163)	465(122)	519(142)	367	7.3	.0035**
School shark	*Galeorhinus galeus*	427(206)	559(235)	871(455)	723(385)	187(78)	463(143)	301(81)	278(76)	352	7.0	.5207
Elephant fish	*Callorhinchus milii*	69(58)	334(165)	582(261)	996(503)	666(355)	704(481)	217(154)	245(142)	351	7.0	.4117
White-spotted spurdog	*Squalus acanthias*	233(172)	139(129)	922(491)	517(359)	432(357)	205(175)	1 62(130)	50(50)	302	6.0	.3724
Common sawshark	*Pristiophorus cirratus*	335(127)	510(169)	469(136)	774(291)	332(105)	105(39)	76(42)	–	295	5.9	.0017**
Draughtboard shark	*Cephaloscyllium laticeps*	131(117)	113(56)	161(73)	179(52)	332(104)	1 151(373)	308(94)	106(50)	294	5.8	.0000***
Southern sawshark	*Pristiophorus nudipinnis*	269(72)	574(259)	448(178)	354(148)	99(45)	32(19)	34(17)	6(6)	185	3.7	.0054**
Gulf catshark	*Asymbolus vincenti*	157(99)	182(85)	78(78)	–	–	–	–	–	49	1.0	.0434*
Rusty catshark	*Parascyllium ferrugineum*	28(21)	166(68)	87(44)	45(45)	24(24)	9(9)	–	–	39	0.8	.0103*
Southern eagle ray	*Myliobatis australis*	14(14)	–	–	7(7)	–	9(9)	19(14)	232(198)	25	0.5	.2560
Broadnose sevengill shark	*Notorynchus cepedianus*	20(14)	–	36(29)	50(32)	14(12)	52(26)	79(38)	–	24	0.5	.1851
Varied catshark	*Parascyllium variolatum*	26(18)	66(61)	5(5)	10(10)	–	–	–	–	15	0.3	.4224
Australian angel shark	*Squatina australis*	42(42)	–	–	10(10)	–	35(35)	10(10)	54(24)	13	0.3	.4346
Bronze whaler	*Carcharhinus brachyurus*	–	–	–	33(33)	–	35(27)	–	32(32)	8	0.2	.5552
Longnose skate	*Raja* sp A	–	–	–	8(8)	15(11)	–	17(12)	–	5	0.1	.2546
Southern dogfish	*Centrophorus uyato*	–	–	–	57(57)	–	–	–	–	4	0.1	
Sparsely-spotted stingaree	*Urolophus paucimaculatus*	–	–	–	9(9)	–	–	7(7)	14(14)	3	0.1	.6337
Whiskery shark	*Furgaleus macki*	–	–	–	–	–	13(13)	10(10)	–	2	0.0	.5377
Shortfin mako	*Isurus oxyrinchus*	–	–	–	–	–	–	14(14)	–	1	0.0	
Thresher shark	*Alopias vulpinus*	–	–	–	–	–	–	–	11(11)	1	0.0	
Ornate wobbegong	*Orectolobus ornatus*	–	–	–	8(8)	–	–	–	–	1	0.0	
Smooth hammerhead	*Sphyrna zygaena*	–	–	–	–	–	–	–	18(18)	1	0.0	
Melbourne skate	*Raja whitleyi*	–	9(9)	–	–	–	–	–	–	1	0.0	
Sub-total	*Chondrichthyes*	5621(1475)	9 227(2516)	11 628(2632)	7 329(1361)	4 451(770)	4 507(790)	2 211(370)	1 867(358)	5 038	100.0	.0000***
Teleostei												
Sand flathead	*Platycephalus bassensis*	7 433(4106)	2 173(488)	368(101)	94(54)	135(113)	–	–	–	770	33.7	.0029**
Yellowtail scad	*Trachurus novaezelandiae*	2 316(1774)	12(9)	9(9)	–	–	–	–	–	223	9.8	.1066
Ruddy gurnard perch	*Neosebastes scorpaenoides*	315(134)	495(146)	741(268)	39(23)	35(26)	10(10)	–	39(28)	159	7.0	.0000***
Butterfly perch	*Caesioperca lepidoptera*	1 420(749)	–	6(6)	–	–	–	–	–	151	6.6	.0008***
Silverbelly	*Parequula melbournensis*	637(419)	259(238)	6(6)	–	–	–	–	–	108	4.7	.0795
Goldspot flathead	*Neoplatycephalus aurimaculatus*	524(307)	360(191)	91(32)	26(15)	–	–	–	–	92	4.0	.0160*
Unspecified leatherjacket	*Family Monacanthidae*	15(15)	626(378)	–	25(25)	8(8)	–	–	–	64	2.8	.0100*
Long-finned pike	*Dinolestes lewini*	366(298)	11(11)	–	13(13)	–	–	–	–	50	2.2	.1723
Barracouta	*Thyrsites atun*	7(7)	69(50)	359(235)	5(5)	–	–	–	–	45	2.0	.0349*
Jackass morwong	*Nemadactylus macropterus*	–	161(83)	131(101)	62(44)	–	–	–	–	42	1.8	.0717
Senator fish	*Pictilabrus laticlavius*	464(464)	122(122)	–	–	–	–	–	–	42	1.8	.4829
Tiger flathead	*Neoplatycephalus richardsoni*	458(293)	137(80)	25(18)	41(32)	–	–	–	–	33	1.4	.0361*
Bastard trumpeter	*Latridopsis forsteri*	–	8(8)	156(148)	112(70)	–	–	11(11)	11(11)	33	1.4	.3604
Queen snapper	*Nemadactylus valenciennesi*	–	13(13)	109(76)	54(46)	36(28)	54(38)	34(29)	–	29	1.3	.4696
Southern goatfish	*Upeneichthys vlamingii*	65(29)	199(79)	11(11)	–	–	–	–	–	28	1.2	.0000***

TABLE 5. (Cont'd). Experiment 1: Effect of gillnet mesh-size on number of animals caught off south-eastern Australia during 1973–76. Eight fishing gear sampling units of gillnet, each 250 m long, and of 8 mesh-sizes (2–9 inch) were set at each of 73 sites; s.e., standard error; *P*, probability value for an effect of mesh-size; $P \geq 0.05$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

		Mean (s.e.) No. of animals caught per 1 000 km-hr								Animals caught		
Common name or effort	Scientific name	2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Number	%	*P*
Barber perch	*Caesioperca rasor*	308(221)	44(38)	–	–	–	–	–	–	27	1.2	.0762
White trevally	*Pseudocaranx dentex*	231(198)	35(17)	25(18)	9(9)	–	24(24)	–	–	27	1.2	.2938
Bearded rock cod	*Pseudophycis barbata*	59(29)	101(58)	167(108)	–	9(9)	–	–	–	25	1.1	.0579
Yank flathead	*Platycephalus speculator*	1 155(1143)	131(87)	40(31)	8(8)	–	15(15)	–	–	25	1.1	.4466
Saddled wrasse	*Notolabrus fucicola*	28(28)	61(33)	123(78)	13(13)	–	11(11)	–	–	24	1.1	.0859
Herring cale	*Odax cyanomelas*	70(63)	61(61)	7(7)	–	–	–	–	–	20	0.9	.4849
Globefish	*Diodon nicthemerus*	143(132)	–	13(13)	–	–	–	–	–	20	0.9	.3311
Red gurnard	*Chelidonichthys kumu*	41(27)	24(17)	114(62)	–	–	–	–	–	19	0.8	.0107*
Velvet leatherjacket	*Meuschenia scaber*	22(16)	213(170)	–	–	–	–	–	–	19	0.8	.1542
Long-snouted boarfish	*Pentaceropsis recurvirostris*	–	–	–	75(32)	17(12)	35(22)	42(21)	19(19)	18	0.8	.0291*
Magpie perch	*Cheilodactylus nigripes*	10(10)	8(8)	8(8)	76(38)	30(21)	45(37)	12(12)	–	17	0.7	.1836
Chinaman-leatherjacket	*Nelusetta ayraudi*	–	190(183)	9(9)	17(17)	–	–	–	–	16	0.7	.4076
Brown-spotted wrasse	*Notolabrus parilus*	–	61(61)	26(26)	5(5)	–	–	–	–	14	0.6	.5320
Brown-striped leatherjacket	*Meuschenia australis*	–	94(71)	–	10(10)	–	–	–	–	13	0.6	.1086
Butterfly gurnard	*Lepidotrigla vanessa*	–	69(37)	41(24)	–	–	–	–	–	12	0.5	.0065**
Blue-throated wrasse	*Notolabrus tetricus*	14(14)	–	10(10)	57(29)	6(6)	6(6)	–	–	12	0.5	.0207*
Blue warehou	*Seriolella brama*	11(11)	21(21)	21(15)	38(32)	–	–	–	–	11	0.5	.5099
Rough gurnard perch	*Neosebastes pandus*	24(24)	58(58)	–	–	–	–	–	–	10	0.4	.5064
Sergeant baker	*Aulopus purpurissatus*	–	27(16)	47(26)	–	–	–	–	–	8	0.4	.0071**
Redfish	*Centroberyx affinis*	–	85(85)	–	–	–	10(10)	–	–	7	0.3	.4537
Bight redfish	*Centroberyx gerrardi*	–	–	–	8(8)	–	55(55)	–	–	7	0.3	.4606
Sandpaper fish	*Paratrachichthys* sp *1*	75(75)	–	–	–	–	–	–	–	6	0.3	.4301
Rosy wrasse	*Pseudolabrus psittaculus*	43(24)	–	–	–	–	–	–	–	6	0.3	
Jewfish	*Argyrosomus japonicus*	–	–	–	8(8)	–	50(41)	–	–	5	0.2	.2119
Rock ling	*Genypterus tigerinus*	11(11)	22(16)	–	10(10)	–	–	–	–	4	0.2	.3290
Silver dory	*Cyttus australis*	–	–	14(14)	–	16(11)	–	–	–	4	0.2	.3074
Eastern school whiting	*Sillago flindersi*	23(16)	5(5)	–	–	–	–	–	–	4	0.2	.0815
Marblefish	*Aplodactylus arctidens*	–	–	7(7)	19(19)	–	–	–	–	4	0.2	.4963
King George whiting	*Sillaginodes punctata*	32(22)	18(18)	–	–	–	–	–	–	3	0.1	.1881
Common bullseye	*Pempheris multiradiatus*	19(13)	10(10)	–	–	–	–	–	–	3	0.1	.1886
Toothbrush leatherjacket	*Acanthaluteres vittiger*	–	31(18)	–	–	–	–	–	–	3	0.1	
Snapper	*Pagrus auratus*	–	–	–	–	–	18(18)	–	8(8)	2	0.1	.5116
Sea sweep	*Scorpis aequipinnis*	–	–	–	16(16)	–	–	–	–	2	0.1	
Striped trumpeter	*Latris lineata*	–	–	–	–	–	8(8)	9(9)	–	2	0.1	.5394
Horse-shoe leatherjacket	*Meuschenia hippocrepis*	–	–	17(17)	–	–	–	–	–	2	0.1	
Ornate cowfish	*Aracana ornata*	11(11)	–	9(9)	–	–	–	–	–	2	0.1	.5391
John dory	*Zeus faber*	12(12)	–	–	–	–	–	–	–	1	0.0	
Harlequin fish	*Othos dentex*	–	–	–	8(8)	–	–	–	–	1	0.0	
Blue devil	*Paraplesiops meleagris*	–	17(17)	–	–	–	–	–	–	1	0.0	
Southern cardinalfish	*Vincentia conspersa*	15(15)	–	–	–	–	–	–	–	1	0.0	
Tailor	*Pomatomus saltatrix*	11(11)	–	–	–	–	–	–	–	1	0.0	
Eastern Australian salmon	*Arripis trutta*	–	–	–	15(15)	–	–	–	–	1	0.0	
Zebra fish	*Girella zebra*	–	–	14(14)	–	–	–	–	–	1	0.0	
Old wife	*Enoplosus armatus*	–	–	10(10)	–	–	–	–	–	1	0.0	
Dusky morwong	*Dactylophora nigricans*	–	–	10(10)	–	–	–	–	–	1	0.0	
Western blue groper	*Achoerodus gouldii*	–	–	–	17(17)	–	–	–	–	1	0.0	

TABLE 5. (Cont'd). Experiment 1: Effect of gillnet mesh-size on number of animals caught off south-eastern Australia during 1973–76. Eight fishing gear sampling units of gillnet, each 250 m long, and of 8 mesh-sizes (2–9 inch) were set at each of 73 sites; s.e., standard error; *P*, probability value for an effect of mesh-size; $P \geq 0.05$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

		Mean (s.e.) No. of animals caught per 1 000 km-hr								Animals caught		
Common name or effort	Scientific name	2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Number	%	*P*
Speckled stargazer	*Kathetostoma canaster*	9(9)	–	–	–	–	–	–	–	1	0.0	
Six-spined leatherjacket	*Meuschenia freycineti*	7(7)	–	–	–	–	–	–	–	1	0.0	
Sub-total	*Teleostei*	16 401(5423)	6 031(1020)	2 746(585)	881(185)	293(123)	340(105)	108(38)	77(36)	2284	100.0	.0000***
Cephalopoda												
Gould's squid	*Nototodarus gouldi*	15(15)	35(18)	–	–	–	–	–	–	6	66.7	.0254*
Giant cuttlefish	*Sepia apama*	24(18)	–	–	–	–	–	–	–	2	22.2	
Octopus	*Octopus pallidus*	–	–	–	10(10)	–	–	–	–	1	11.1	
Sub-total	*Cephalopoda*	40(24)	35(18)	–	10(10)	–	–	–	–	9	100.0	.0257*
Other												
Commercial scallop	*Pecten fumatus*	–	–	–	–	136(136)	–	–	–	14		.4301
Swollen spider crab	*Leptomithrax gaimardii*	–	–	–	–	–	–	54(54)	129(129)	11		.5078

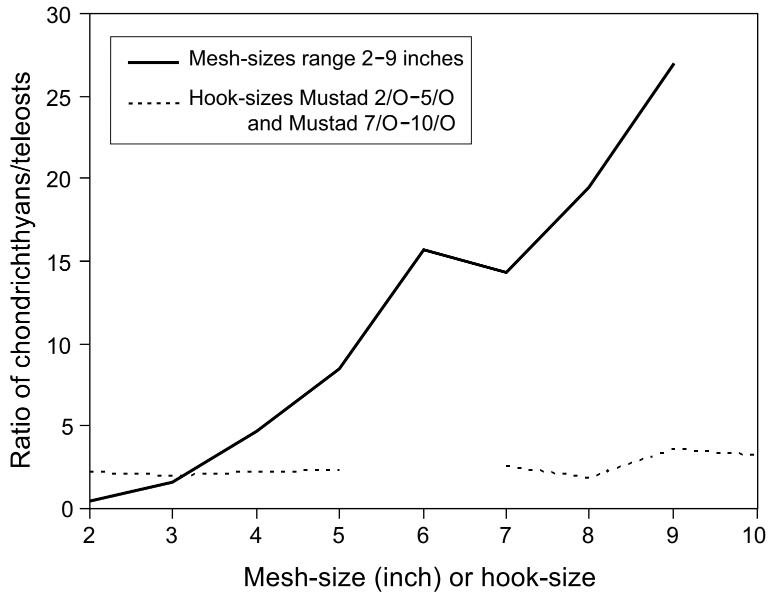

Fig. 2. Ratio of number of animals of chondrichthyes/number of animals of teleostei against gillnet mesh-size or hook-size. Mesh-sizes range 2–9 inches and hook-sizes Mustad 2/O–5/O and Mustad 7/O–10/O.

mesh (4%). The highest catch rate of teleosts was in the 2 inch mesh (54%), followed by 3 inch mesh (27%), 4 inch mesh (12%), 5 inch mesh (2%), 6 inch mesh (1%), 7 inch mesh (1%), 8 inch mesh (1%), and 9 inch mesh (0%).

Over all eight mesh sizes observed, the catch rates of chondrichthyan species varied widely, with two species, *Squalus megalops* (37%) and *Mustelus antarcticus* (17%), accounting for more than half these animals. Seven other species had similar catch rates and accounted for most of the rest of the animals captured. The catch rates of teleost fishes also varied widely between species, where *Platycephalus bassensis* (34%), constituted more than one-third of these animals. This species along with nine other species provided three-fourths of the teleost animals. The remaining 25% of animals caught comprised 52 species and unidentified fishes of the family *Monocanthidae* (Table 5).

Most chondrichthyan and teleost species exhibit a pattern of a highest catch (mode) for a particular mesh size, the catch falling progressively with both decreasing and increasing mesh size. The modal catch corresponded to 3 inch mesh for *Pristiophorus nudipinnis*, *Asymbolis vincenti*, and *Parascyllium ferrugineum*; 4 inch mesh for *Squalus megalops*, *Galeorhinus galeus*, and *Squalus acanthias*; 5 inch mesh for *Mustelus antarcticus*, *Callorhinchus milii*, and *Pristiophorus cirratus*; 7 inch mesh for *Heterodontus portusjacksoni*, and *Cephaloscyllium laticeps*; and 9 inch mesh for *Myliobatis australis*. Most of the *Platycephalus bassensis* catch, expressed as a percentage of the total number of teleost fishes caught, were taken by the 2 inch (21%), 3 inch (10%) and 4 inch (2%) mesh. Other teleost species taken predominantly by the 2 inch mesh size include *Trachurus novaezelandiae* (10%), *Caesioperca lepidoptera* (7%), *Parequula melbournensis* (3%), *Neoplatycephalus aurimaculatus* (2%), and *Dinolestes lewini* (2%). *Nemadactylus macropterus* was mainly taken by 3 inch mesh size (1%) and *Neosebastes scorpaenoides* by 4 inch mesh size (3%). The 6 and 7 inch meshes, used commercially in the fishery, each took 10% of the chondricthyan animals and 1% of the teleost animals (Table 5).

Experiment 2: Effect of gillnet hanging ratio on catch rates

For Experiment 2, there were sufficient data to test 9 chonchrichthyan species and 11 teleosts for the effect of gillnet hanging ratio for the 6 inch and 7 inch mesh sizes on catch rate. The effect of hanging ratio was statistically not significant for any of these species.

Experiment 3: Effect of hook size on catch rates

Results from Experiment 3 indicate that the effect of hook size for the eight short-shank Mustad 2/O, 3/O, 4/O, 5/O, 7/O, 8/O, 9/O, and 10/O hooks with a 7.5 m hook space on catch rate was statistically significant for only one of the 18 chondrichthyan species (*Heterodontus* *portusjacksoni*) and none of the 16 teleost species caught (Table 6). The results were pooled over all hook sizes because of the lack of statistical significance of hook size. Similarly, the effect of hook size was not statistically significant for either the 18 chondrichthyan species pooled or the 16 teleost species pooled. Of the total catch of 1 856 animals, across all species and hook sizes, more than two-thirds were chondrichthyans (1 291 animals, 70%) and most of the rest were teleosts (561 animals, 30%). There was a small catch of three species of cephalopoda (4 animals, <1%), and zero catches of animals of bivalvia, gastropoda, crustacea, mammalia, aves, and reptilia. For the chondrichthyans, the catch rates were similar for the three top species: *Squalus megalops* (27%), *Mustelus antarcticus* (24%), and *Cephaloscyllium laticeps* (22%). For the teleosts, the catch was dominated by two species: *Platycephalus bassensis* (47%) and *Neosebastes scorpaenoides* (37%) (Table 6).

Experiments 4 and 5: Effects of hook size, shank length and hook space on catch rates

As expected, the catch rates for the top four or five chondrichthyan species and top two teleost species caught during Experiments 4 and 5 were similar to those caught during Experiment 3. Across these two experiments, the effects of hook size, shank length, and hook space on catch rates were not statististically significant, with one exception. Shank length of hook for the teleost *Neosebastes scorpaenoides* was statistically significant (P <0.01) in Experiment 4; a higher catch rate was obtained with short shank hooks than long shank hooks.

Effects of sampling period and commercial fishing gears on catch rates

Catch rates for commercial fishing gears were available from fishing aboard research vessels during 1973–76 and from commercial shark fishing vessels during 1998–2001. In Bass Strait, direct comparisons in catch rate between 1973–76 and 1998–2001 can only be made for gillnet 6 inch mesh (Table 7a). These data indicate a statistically significant decrease in the catch rate for all chondrichthyan fishes, and no significant difference in the catch rate for all teleost fishes. Among the chondrichthyan species, *Cephaloscyllium laticeps* exhibits a statistically significant decrease of 54% and *Galeorhinus galeus* exhibits a statistically highly significant decrease of 87% between the two periods. One species, *Notorynchus cepedianus*, taken in low numbers during 1973–76 exhibits a statistically highly significant increase in catch. In addition, 10 chondrichthyan species and 17 teleost species exhibit zero catch rates during 1973–76 and low catch rates during 1998–2001, whereas, conversely, 3 chondrichthyan species and 5 teleost species had low catch rates during 1973–76 and zero catch rates during 1998–2001. These differences are interpreted as an artifact of the data where the probability of catching low numbers of animals of species that are either rare or of low catchability in the depth range 0–79 m was higher during 1998–01 than during 1973–76. This is because the total fishing effort was 12.2 times higher during 1998–01 than during 1973–76. For these reasons, the effect of sampling period was not tested for any species where the catch rate was zero during either 1973–76 or 1998–2001 (Table 7a).

In Tasmania, there were too few data to properly characterise catch composition and catch rates. The data suggest that catch rates of *Squalus acanthias* in Tasmania were higher than in Bass Strait and South Australia (Table 7b).

In South Australia, the catch rate by gillnet was statistically significantly higher in 6 inch mesh than in 6½ inch mesh size for all chondrichthyans combined, but the effect of mesh size was not significant for teleosts. Most of the higher catch rate by the 6 inch mesh size for *Mustelus antarcticus* and *Notorynchus cepedianus*. As in Bass Strait and Tasmania, catch rates of teleosts was low compared with chondrichthyan species in South Australia (Table 7c).

There were some minor differences in catch rates between Bass Strait, Tasmania, and South Australia. Among the chondrichthyan species, the data suggest that the catch rates of *Cephaloscyllium laticeps*, *Pristiophorus cirratus*, *P. nudipinnis*, and *Callorhinchus milii* were higher in Bass Strait than in South Australia. Several minor species, *Myliobatis australis*, *Carcharhinus brachyurus*, and *Alopias vulpinis*, were more common in South Australia than in Bass Strait. Among the teleosts, several species appeared in the catch off South Australia that were absent or provided very low catch rates in Bass Strait and Tasmania. These species include *Centroberyx gerrardi*, *Kyphosus gibsoni*, and *Nemadactylus valenciennesi*. One species, *Platycephalus bassensis*, appears to be less common in South Australia than in Bass Strait and Tasmania.

Breakdown of total catch as retained and discarded, and live and dead

Percentages of the commercial catch taken as retained and discarded animals, broken down as live and dead, for 1998–2001 are presented for Bass Strait (8 198 animals) and South Australia (2 069 animals) separately. The catches were taken by 6 inch mesh in Bass Strait and a combination of 6 inch and 6½ inch mesh in South Australia. The catch rate of chondrichthyans in Bass

TABLE 6. Experiment 3: Effect of hook-size on the number of animals caught off south-eastern Australia during 1973–76. Eight fishing gear sampling units of 50 hooks for each of 8 Mustad hook-sizes, with short-shank and 7.5-m hook-space, were set at each of 39 sites; s.e., standard error; *P*, probability value for an effect of hook-size; * *P*<0.05, ** *P*<0.01, *** *P*<0.001.

Common name or effort	Scientific name	Mean (s.e.) number of animals caught per 100 000 hook-lifts	Animals caught Number	%	*P*
Fishing effort (100 hook-lifts)		156			
Number of fishing gear sampling units		312			
Chondrichthyes					
Piked spurdog	*Squalus megalops*	2 205 (373)	344	26.6	.3951
Gummy shark	*Mustelus antarcticus*	1 974 (196)	308	23.9	.7553
Draughtboard shark	*Cephaloscyllium laticeps*	1 859 (195)	290	22.5	.9746
School shark	*Galeorhinus galeus*	923 (131)	144	11.2	.5478
Gulf catshark	*Asymbolus vincenti*	314 (65)	49	3.8	.1319
Rusty catshark	*Parascyllium ferrugineum*	192 (69)	30	2.3	.5755
Port Jackson shark	*Heterodontus portusjacksoni*	147 (34)	23	1.8	.0486*
Melbourne skate	*Raja whitleyi*	135 (49)	21	1.6	.2843
Southern fiddler ray	*Trygonorrhina fasciata*	128 (49)	20	1.5	.9245
Common sawshark	*Pristiophorus cirratus*	122 (30)	19	1.5	.8066
White-spotted spurdog	*Squalus acanthias*	90 (39)	14	1.1	.6211
Broadnose sevengill shark	*Notorynchus cepedianus*	58 (31)	9	0.7	.5479
Longnose skate	*Raja* sp *A*	51 (22)	8	0.6	.2234
Elephant fish	*Callorhinchus milii*	32 (17)	5	0.4	.7109
Southern sawshark	*Pristiophorus nudipinnis*	19 (19)	3	0.2	.4312
Shortfin mako	*Isurus oxyrinchus*	13 (9)	2	0.2	.5406
Smooth stingray	*Dasyatis brevicaudata*	6 (6)	1	0.1	
Sandyback stingaree	*Urolophus bucculentus*	6 (6)	1	0.1	
Sub-total	*Chondrichthyes*	8276 (500)	1291	100.0	.2268
Teleostei					
Sand flathead	*Platycephalus bassensis*	1 705 (212)	266	47.4	.1282
Ruddy gurnard perch	*Neosebastes scorpaenoides*	1 327 (220)	207	36.9	.8344
Bearded rock cod	*Pseudophycis barbata*	154 (39)	24	4.3	.8460
Jackass morwong	*Nemadactylus macropterus*	71 (33)	11	2.0	.5612
Red rock cod	*Scorpaena papillosa*	64 (33)	10	1.8	.7442
Red gurnard	*Chelidonichthys kumu*	64 (31)	10	1.8	.1398
Tiger flathead	*Neoplatycephalus richardsoni*	58 (25)	9	1.6	.7380
Yank flathead	*Platycephalus speculator*	32 (17)	5	0.9	.2310
Blue-throated wrasse	*Notolabrus tetricus*	32 (17)	5	0.9	.7444
Silverbelly	*Parequula melbournensis*	26 (20)	4	0.7	.1033
Goldspot flathead	*Neoplatycephalus aurimaculatus*	19 (11)	3	0.5	.5916
Sergeant baker	*Aulopus purpurissatus*	13 (9)	2	0.4	.5407
Butterfly gurnard	*Lepidotrigla vanessa*	13 (9)	2	0.4	
Senator fish	*Pictilabrus laticlavius*	6 (6)	1	0.2	
Rosy wrasse	*Pseudolabrus psittaculus*	6 (6)	1	0.2	
Velvet leatherjacket	*Meuschenia scaber*	6 (6)	1	0.2	
Sub-total	*Teleostei*	3 596 (340)	561	100.0	.5775
Cephalopoda		2 205 (373)			
Giant cuttlefish	*Sepia apama*	13 (9)	2	50.0	.5399
Gould's squid	*Nototodarus gouldi*	6 (6)	1	25.0	
Octopus	*Octopus pallidus*	6 (6)	1	25.0	
Sub-total	*Cephalopoda*	26 (13)	4	100.0	.7534

TABLE 7A. Comparison of number of animals caught by various fishing gears in Bass Strait between 1973–76 and 1998–2001. s.e., standard error; *P*, probability value for a difference in catch between 1973–76 and 1998–2001 for 6-inch mesh-size; *P*≥0.05, * *P*<0.05, ** *P*<0.01, *** *P*<0.001.

		Mean (s.e.) number of animals caught per 100,000 hook-lifts or 1000 km-hr					
		1973–76			1998–2001	Number	
Common name or effort	Scientific name	Hooks	7-inch	6-inch	6-inch	caught	*P*
Fishing effort (100 hook-lifts or gillnet km-hr)		126	220	271	3 317		
Number of fishing gear sampling units		148	139	172	91		
Chondrichthyes							
Gummy shark	*Mustelus antarcticus*	4 055 (430)	1 105 (153)	1457 (197)	1 220 (118)	4 797	.4067
Draughtboard shark	*Cephaloscyllium laticeps*	1 141 (175)	1 063 (217)	660 (112)	305 (53)	1609	.0265*
Common sawshark	*Pristiophorus cirratus*	33 (13)	171 (34)	381 (76)	292 (35)	1145	.4112
Elephant fish	*Callorhinchus milii*	20 (14)	515 (261)	340 (154)	229 (57)	910	.6068
Port Jackson shark	*Heterodontus portusjacksoni*	255 (62)	684 (154	269 (63)	160 (41)	794	.2354
School shark	*Galeorhinus galeus*	2 041 (360)	360 (78)	246 (47)	32 (8)	425	.0012**
Piked spurdog	*Squalus megalops*	314 (119)	46 (26)	115 (53)	71 (26)	326	.5576
Southern sawshark	*Pristiophorus nudipinnis*	247 (74)	57 (21)	151 (42)	68 (11)	299	.1561
Broadnose sevengill shark	*Notorynchus cepedianus*	91 (38)	15 (11)	1 (1)	17 (6)	71	.0009***
White-spotted spurdog	*Squalus acanthias*	313 (95)	61 (52)	46 (26)	–	65	
Southern eagle ray	*Myliobatis australis*	14 (14)	11 (8)	7 (7)	11 (3)	45	.6839
Sparsely-spotted stingaree	*Urolophus paucimaculatus*	–	–	7 (5)	12 (4)	43	.4962
Australian angel shark	*Squatina australis*	–	23 (19)	4 (4)	8 (2)	31	.5289
Melbourne skate	*Raja whitleyi*	64 (33)	6 (6)	–	>0 (>0)	9	
Gulf catshark	*Asymbolus vincenti*	18(8)	–	–	–	5	
Western shovelnose ray	*Aptychotrema vincentiana*	–	–	–	1 (1)	5	
Shortfin mako	*Isurus oxyrinchus*	–	–	–	1 (1)	4	
Rusty catshark	*Parascyllium ferrugineum*	14 (14)	5 (5)	10 (10)	–	4	
Varied catshark	*Parascyllium variolatum*	7(7)	–	–	–	3	
Longnose skate	*Raja* sp *A*	3(3)	–	–	>0 (>0)	2	
Smooth stingray	*Dasyatis brevicaudata*	7(7)	–	–	–	2	
Thresher shark	*Alopias vulpinus*	–	–	–	>0 (>0)	1	
Bronze whaler	*Carcharhinus brachyurus*	–	–	4 (4)	–	1	
Thornback skate	*Raja lemprieri*	3(3)	–	–	–	1	
Skates (unspecified)	*Raja* spp	–	–	–	>0 (>0)	1	
Sub-total	*Chondrichthyes*	8 640 (630)	4121 (467)	3 699 (349)	2 429 (144)	10 598	.0104*
Teleostei							
Sand flathead	*Platycephalus bassensis*	642 (142)	40 (24)	86(70)	3 (1)	126	.3907
Long-snouted boarfish	*Pentaceropsis recurvirostris*	2 (2)	42 (17)	62(19)	17 (3)	73	.0868
Blue warehou	*Seriolella brama*	–	30 (30)	–	15 (5)	60	
Jack mackerel	*Trachurus declivis*	–	–	–	16 (12)	53	
White trevally	*Pseudocaranx dentex*	–	12 (12)	–	11 (8)	46	
Latchet	*Pterygotrigla polyommata*	–	–	–	7 (5)	23	
Blue-throated wrasse	*Notolabrus tetricus*	86 (38)	8 (6)	8 (5)	4 (2)	22	.4774
Ruddy gurnard perch	*Neosebastes scorpaenoides*	186 (58)	4 (4)	15 (11)	–	20	
Magpie perch	*Cheilodactylus nigripes*	–	5 (5)	8 (6)	4 (2)	17	.6495
Goldspot flathead	*Neoplatycephalus aurimaculatus*	–	–	47 (47)	–	14	

TABLE 7A. (Cont'd). Comparison of number of animals caught by various fishing gears in Bass Strait between 1973–76 and 1998–2001. s.e., standard error; *P*, probability value for a difference in catch between 1973–76 and 1998–2001 for 6-inch mesh-size; $P \geq 0.05$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

		Mean (s.e.) number of animals caught per 100,000 hook-lifts or 1000 km-hr					
			1973–76		1998–2001	Number	
Common name or effort	Scientific name	Hooks	7-inch	6-inch	6-inch	caught	*P*
Queen snapper	*Nemadactylus valenciennesi*	–	19 (19)	17 (17)	1 (1)	14	.4997
Bight redfish	*Centroberyx gerrardi*	– –	–	4 (2)	12		
Red gurnard	*Chelidonichthys kumu*	2 (2)	–	3 (3)	2 (1)	10	.8514
Bearded rock cod	*Pseudophycis barbata*	12 (10)	–	11 (8)	1 (1)	12	.3704
Barracouta	*Thyrsites atun*	–	–	–	3 (2)	8	
Deepsea trevalla	*Hyperoglyphe antarctica*	–	–	–	2 (2)	6	
Swallow-tail	*Centroberyx lineatus*	–	–	–	1 (1)	5	
Sergeant baker	*Aulopus purpurissatus*	3 (3)	–	–	1 (1)	4	
Silver dory	*Cyttus australis*	–	–	13 (7)	–	4	
Giant boarfish	*Paristiopterus labiosus*	–	–	–	2 (1)	4	
Knifejaw	*Oplegnathus woodwardi*	–	–	–	1 (1)	4	
Pink ling	*Genypterus blacodes*	–	–	–	1 (1)	3	
Tiger flathead	*Neoplatycephalus richardsoni*	3 (3)	–	–	1 (>0)	3	
Snapper	*Family Pagrus auratus*	14 (14)	–	4 (4)	>0 (>0)	3	.5025
Jackass morwong	*Family Nemadactylus macropterus*	–	19 (11)	–	1 (1)	6	
Stargazer	*Family Uranoscopidae*	2 (2)	–	–	1 (>0)	3	
Leatherjacket	*Family Monacanthidae*	–	–	3 (3)	1 (1)	3	
Bastard trumpeter	*Latridopsis forsteri*	–	–	10 (7)	–	2	
Greenback flounder	*Rhombosolea tapirina*	–	–	–	1 (>0)	2	
Red cod	*Pseudophycis bachus*	2 (2)	–	–	–	1	
Redfish	*Centroberyx affinis*	–	5 (5)	–	–	1	
Tailor	*Pomatomus saltatrix*	–	4 (4)	–	–	1	
Marblefish	*Aplodactylus arctidens*	–	–	3 (3)	–	1	
Western blue groper	*Achoerodus gouldii*	–	–	–	>0 (>0)	1	
Saddled wrasse	*Notolabrus fucicola*	–	6 (6)	–	–	1	
Common stinkfish	*Synchiropus calauropomus*	–	–	4 (4)	–	1	
Sub-total	*Teleostei*	955 (167)	195 (49)	294 (130)	102 (18)	569	.2827
Cephalopoda							
Octopus	*Octopus pallidus*	–	–	–	1 (1)	3	
Giant cuttlefish	*Sepia apama*	17 (14)	–	–	–	2	
Gould's squid	*Nototodarus gouldi*	–	–	–	>0 (>0)	1	
Sub-total	*Cephalopoda*	17 (14)	–	–	1 (1)	6	
Other							
Swollen spider crab	*Leptomithrax gaimardii*	–	–	–	24 (13)	83	
Southern rock lobster	*Jasus edwardsii*	–	–	–	1 (1)	2	
False bailer shell	*Livonia mammilla*	–	–	–	3 (1)	9	
Australian fur seal	*Arctocephalus pusillus dorifer*	–	–	–	1 (>0)	2	

TABLE 7B. Comparison of number of animals caught by various fishing gears in Tasmania during 1973–76. (s.e. is standard error).

Common name or effort	Scientific name	Mean (s.e.) number of animals caught per 100 000 hook-lifts or 1000 km-hr			Number caught
		Hooks	7-inch	6-inch	
Fishing effort (100 hook-lifts or gillnet km-hr)		8	35	36	
Number of fishing gear sampling units		4	23	23	
Chondrichthyes					
Gummy shark	*Mustelus antarcticus*	2 000 (736)	846 (349)	1 962 (486)	117
White-spotted spurdog	*Squalus acanthias*	125 (125)	689 (556)	1 288 (1 124)	78
Elephant fish	*Callorhinchus milii*	–	480 (224)	911 (332)	50
Piked spurdog	*Squalus megalops*	750 (250)	19 (19)	759 (280)	36
Draughtboard shark	*Cephaloscyllium laticeps*	375 (125)	220 (92)	214 (122)	19
School shark	*Galeorhinus galeus*	1 000 (0)	59 (44)	18 (18)	11
Southern sawshark	*Pristiophorus nudipinnis*	–	79 (47)	197 (89)	10
Port Jackson shark	*Heterodontus portusjacksoni*	–	135 (80)	83 (83)	6
Common sawshark	*Pristiophorus cirratus*	–	–	120 (56)	4
Broadnose sevengill shark	*Notorynchus cepedianus*	250 (250)	–	37 (37)	3
Longnose skate	*Raja* sp *A*	–	–	48 (34)	2
Sub-total	*Chondrichthyes*	4 500 (1021)	2 527 (716)	5 637 (1534)	336
Teleostei					
Jackass morwong	*Nemadactylus macropterus*	–	–	107 (76)	5
Striped trumpeter	*Latris lineata*	–	73 (40)	22 (22)	4
Sand flathead	*Platycephalus bassensis*	125 (125)	–	37 (37)	2
Bearded rock cod	*Pseudophycis barbata*	125 (125)	–	–	1
Red rock cod	*Scorpaena papillosa*	125 (125)	–	–	1
Tiger flathead	*Neoplatycephalus richardsoni*	125 (125)	–	–	1
Sub-total	*Teleostei*	500 (204)	73 (40)	166 (100)	14
Other					
Commercial scallop	*Pecten fumatus*	–	–	432 (432)	14

Strait was ~2.5 times higher than that in South Australia, whereas the catch rate of teleosts in Bass Strait was about half that in South Australia (Tables 8a, b).

Chondrichthyan fishes provided a higher proportion of the commercial catch in Bass Strait (95%) than in South Australia (82%), whereas teleost fishes provided a higher proportion of the catch in South Australia (18%) than in Bass Strait (4%). In Bass Strait, of the chondrichthyan fishes (7 761 animals), 74% (38% live and 36% dead) were retained and 26% (24% live and 2% dead) were discarded, and of the teleost fishes (337 animals), 54% were retained (40% live and 14% dead) and 46% were discarded (18% live and 28% dead). In South Australia, of the chondrichthyan fishes (1 675 animals), 72% (42% live and 30% dead) were retained and 28% (25% live and 3% dead) were discarded, and, of the teleost fishes (375 animals), 91% were retained (91% live and 0% dead) and 9% were discarded (7% live and 2% dead).

In Bass Strait, 48% the catch of chondrichthyan animals was the target species *Mustelus antarcticus*, 28% comprised by-product species (*Pristiophorus cirratus*, *Callorhinchus milii*, *P. nudipinnis*, *Galeorhinus galeus*, and *Notorynchus cepedianus*), and 24% comprised 10 by-catch species. The 3 principal chondrichthyan by-catch species, *Cephaloscyllium laticeps* (13%), *Heterodontus portusjacksoni* (7%), and *Squalus megalops* (3%), were discarded live, except for 6% of *Squalus megalops*, which was discarded dead. In South Australia, 55% of the catch of chondrichthyan fishes was *Mustelus antarcticus*, 19% comprised by-product species (*Pristiophorus cirratus*, *Callorhinchus milii*, *P. nudipinnis*, *Galeorhinus galeus*, *Sphyrna zygaena*, *Notorynchus cepedianus*, and *Furgaleus macki*), and 26% comprised 9 by-catch species. The three most caught by-catch species, *Heterodontus portusjacksoni* (15%), *Squalus megalops* (4%), and *Myliobatis australis* (3%), were discarded live, except for 9% of *Myliobatis australis* discarded dead.

In Bass Strait, none of the 26 teleost species caught provide high catches; 54% of the animals were retained. Most of the catch of the top 4 species (*Seriolella brama*, *Pentaceropsis recurvirostris*, *Trachurus declivis*, and

TABLE 7C. Comparison of number of animals caught by various fishing gears in South Australia during 1998–2001. s.e., standard error; *P*, probability value for a difference in catch between 6 and 6½-inch mesh-size during 1998–2001; *P*≥0.05, **P*<0.05, ** *P*<0.01, *** *P*<0.001.

Common name or effort	Scientific name	Mean (s.e.) number of animals caught per 100 000 hook-lifts or 1 000 km-hr: 6-inch	Mean (s.e.) number of animals caught per 100 000 hook-lifts or 1 000 km-hr: 6½-inch	No. caught	*P*
Fishing effort (100 hook-lifts or gillnet km-hr)		531	1 335		
Number of fishing gear sampling units		14	48		
Chondrichthyes					
Gummy shark	*Mustelus antarcticus*	1 150 (202)	253 (44)	939	.0000***
Port Jackson shark	*Heterodontus portusjacksoni*	61 (15)	141 (53)	315	.4232
School shark	*Galeorhinus galeus*	–	94 (50)	139	
Smooth hammerhead	*Sphyrna zygaena*	2 (2)	75 (30)	77	.2011
Piked spurdog	*Squalus megalops*	4 (3)	62 (37)	71	.3962
Southern eagle ray	*Myliobatis australis*	62 (19)	20 (7)	53	.0145*
Bronze whaler	*Carcharhinus brachyurus*	2 (2)	45 (19)	45	.2152
Common sawshark	*Pristiophorus cirratus*	2 (2)	40 (13)	43	.1190
Southern sawshark	*Pristiophorus nudipinnis*	18 (7)	14 (7)	29	.7411
Broadnose sevengill shark	*Notorynchus cepedianus*	37 (13)	2 (1)	27	.0000***
Elephant fish	*Callorhinchus milii*	16 (5)	9 (4)	23	.3896
Thresher shark	*Alopias vulpinus*	25 (13)	10 (7)	19	.2930
Australian angel shark	*Squatina australis*	9 (4)	16 (10)	19	.7146
Spotted wobbegong	*Orectolobus maculatus*	–	4 (2)	4	
Whiskery shark	*Furgaleus macki*	–	1 (1)	2	
Skates (unspecified)	*Raja spp*	–	2 (1)	2	
Sparsely-spotted stingaree	*Urolophus paucimaculatus*	3 (3)	–	2	
White shark	*Carcharodon carcharias*	–	–	1	
Draughtboard shark	*Cephaloscyllium laticeps*	–	–	1	
White-spotted spurdog	*Squalus acanthias*	2 (2)	–	1	
Western shovelnose ray	*Aptychotrema vincentiana*	–	1 (1)	1	
Sub-total	*Chondrichthyes*	1 394 (208)	788 (110)	1 813	.0116*
Teleostei					
Bight redfish	*Centroberyx gerrardi*	10(10)	43 (20)	64	.3789
Southern drummer	*Kyphosus gibsoni*	–	36 (26)	62	.4496
Long-snouted boarfish	*Pentaceropsis recurvirostris*	36(13)	29 (11)	61	.7483
Queen snapper	*Nemadactylus valenciennesi*	12(8)	31 (14)	48	.4888
Snapper	*Pagrus auratus*	42(32)	12 (7)	36	.1772
Dusky morwong	*Dactylophora nigricans*	–	17 (9)	24	
Western blue groper	*Achoerodus gouldii*	6(4)	14 (7)	21	.5701
Red gurnard	*Chelidonichthys kumu*	33 (10)	–	18	
Jewfish	*Argyrosomus japonicus*	10 (7)	3 (2)	14	.1943
Magpie perch	*Cheilodactylus nigripes*	8 (7)	5 (3)	13	.5919
Yellow-spotted boarfish	*Paristiopterus gallipavo*	–	3 (2)	6	
Leatherjacket	*Family Monacanthidae*	–	6 (4)	6	
Latchet	*Pterygotrigla polyommata*	–	4 (2)	5	
Sand flathead	*Platycephalus bassensis*	8 (3)	1 (1)	5	.0378*
Tiger flathead	*Neoplatycephalus richardsoni*	5 (4)	–	3	
Sergeant baker	*Aulopus purpurissatus*	–	1 (1)	2	
Blue-throated wrasse	*Notolabrus tetricus*	4 (4)	–	2	
Pink ling	*Genypterus blacodes*	2 (2)	–	1	
Mirror dory	*Zenopsis nebulosus*	–	>0 (>0)	1	
Ruddy gurnard perch	*Neosebastes scorpaenoides*	–	–	1	
Jack mackerel	*Trachurus declivis*	–	1 (1)	1	
Samsonfish	*Seriola hippos*	–	1 (1)	1	

TABLE 7C. (Cont'd). Comparison of number of animals caught by various fishing gears in South Australia during 1998–2001. s.e., standard error; *P*, probability value for a difference in catch between 6 and 6½-inch mesh-size during 1998–2001; $P \geq 0.05$, *$P<0.05$, ** $P<0.01$, *** $P<0.001$.

Common name or effort	Scientific name	Mean (s.e.) number of animals caught per 100 000 hook-lifts or 1 000 km-hr 6-inch	6½-inch	No. caught	*P*
Bumpnose trevally	*Carangoides hedlandensis*	–	2 (2)	1	
Sweep	*Scorpis lineolatus*	–	1 (1)	1	
Old wife	*Enoplosus armatus*	–	1 (1)	1	
Wrasse	*Labridae* spp	–	1 (1)	1	
Greenback flounder	*Rhombosolea tapirina*	2 (2)	–	1	
Toadfish	*Tetraodon erythrotaenia*	–	1 (1)	1	
Sub-total	*Teleostei*	179 (58)	212 (67)	401	.7952
Other					
Swollen spider crab	*Leptomithrax gaimardii*	7 (7)	14 (11)	13	.7404
Southern rock lobster	*Jasus edwardsii*	–	3 (2)	4	
Southern bay lobster	*Ibacus peronii*	2 (2)	–	1	
Common dolphin	*Delphinus delphis*	2 (2)	–	1	

Pseudocaranx dentex), together providing 61% of the catch of teleost fishes, were retained, except for *T. declivis* which was discarded (68% live and 32% dead). In South Australia, most of the catch of 27 teleost species were retained (91%). The top 4 species (*Kyphosus gibsoni*, *Centroberyx gerrardi*, *Pentaceropsis recurvirostris*, and *Nemadactylus valenciennesi*) provided 58% of the catch.

Three wildlife interactions occurred during 1998–2001 as part of the present study. Two Australian fur seals (*Arctocephalus pusillus dorfer*) were discarded dead in Bass Strait and one common dolphin (*Delphinus delphis*) was discarded dead in South Australia.

Discussion

From the mid-1920s when the fishery began until the early-1970s, *Galeorhinus galeus* was the principal target species taken by baited hooks on longlines. Since the early-1970s, most of the catch was taken by gillnets and targeting switched early and rapidly from *G. galeus* to *Mustelus antarcticus* in Bass Strait. However, in South Australia and Tasmania, as the abundance of *G. galeus* continually declined, the species switch was more gradual (Walker, 1999). Since 2001, a total allowable catch applies to each species. Today, most fishing effort in the fishery targets *M. antarcticus*, which is the more biologically productive species (Walker, 1998; Pribac *et al.*, 2004); the earlier practice of targeting *Galeorhinus galeus* has ceased almost completely. Common sawshark (*Pristiophorus cirratus*), southern sawshark (*P. nudipinnis*), elephant fish (*Callorhinchus milii*), and broadnose sevengill shark (*Notorynchus cepedianus*) are taken as by-product, although not all fishers retained these species earlier in the history of the fishery.

Of the total catch of *M. antarcticus* produced from the fishery during 2000 (1 651 tons, carcass weight), 91% was taken by demersal monofilament gillnet and 9% was taken by demersal longline (Walker *et al.*, 2003). The fishing effort was distributed in Bass Strait (55% of gillnet effort, 30% of longline effort), South Australia (40% of gillnet effort, 64% of longline effort), and Tasmania (5% of gillnet effort, 6% of longline effort). Most of the gillnet effort deployed in Bass Strait and Tasmania was 6 inch mesh size, whereas most deployed in South Australia was 6½ inch mesh size. Baited Mustad 11/O long-shank hooks were mostly used on the longlines.

Ten important conclusions are drawn from the present study about the catch rates of gillnets and longlines deployed in the fishery on the continental shelf in the depth range 9–130 m:

1. Both gillnets and longlines are much more effective at catching chondrichthyan species than teleost species, and catches of species of cephalopoda, bivalvia, gastropoda, mammalia, aves and reptilia are negligible.

2. The effect of gillnet mesh size on catch rates is strong, whereas the effects of gillnet hanging ratio, hook size, hook shank length, and hook space are weak.

TABLE 8A. Breakdown of total catch by gill-net 6-inch mesh size as retained, discarded, live, and dead animals for each species in Bass Strait during 1998–2001. Catch-per-unit effort (CPUE) is measured as number of animals per 1000 km-hr.

			Total catch (%)								
			Retained		Discarded		Total catch (%)		Total catch (%)		No.
Common name or effort	Scientific name	CPUE	Live	Dead	Live	Dead	Live	Dead	Retained	Discarded	caught
Fishing effort (km-hr)		3 317									
Chondrichthyes											
Gummy shark	*Mustelus antarcticus*	1 114	40	59	–	1	40	60	99	1	3 697
Draughtboard shark	*Cephaloscyllium laticeps*	312	–	–	100	–	100	–	–	100	1 034
Common sawshark	*Pristiophorus cirratus*	304	77	22	–	1	77	23	99	1	1 008
Elephant fish	*Callorhinchus milii*	223	70	28	1	1	71	29	98	2	741
Port Jackson shark	*Heterodontus portusjacksoni*	157	–	–	100	–	100	–	–	100	521
Piked spurdog	*Squalus megalops*	77	–	–	94	6	94	6	–	100	254
Southern sawshark	*Pristiophorus nudipinnis*	67	78	20	–	2	78	22	98	2	223
School shark	*Galeorhinus galeus*	32	29	68	1	2	30	70	97	3	105
Broadnose sevengill shark	*Notorynchus cepedianus*	18	17	83	–	–	17	83	100	–	59
Sparsely-spotted stingaree	*Urolophus paucimaculatus*	12	–	–	77	23	77	23	–	100	41
Southern eagle ray	*Myliobatis australis*	12	–	–	79	21	79	21	–	100	41
Australian angel shark	*Squatina australis*	7	–	17	67	16	67	33	17	83	24
Western shovelnose ray	*Aptychotrema vincentiana*	2	–	–	80	20	80	20	–	100	5
Shortfin mako	*Isurus oxyrinchus*	1	–	25	25	50	25	75	25	75	4
Thresher shark	*Alopias vulpinus*	–	100	–	–	–	100	–	100	–	1
Longnose skate	*Raja* sp *A*	–	–	–	100	–	100	–	–	100	1
Melbourne skate	*Raja whitleyi*	–	–	–	100	–	100	–	–	100	1
Skates (unspecified)	*Raja* spp	–	–	–	100	–	100	–	–	100	1
Sub-total	*Chondrichthyes*	2 339	38	36	24	2	62	38	74	26	7 761
Teleostei											
Blue warehou	*Seriolella brama*	17	25	33	–	42	25	75	58	42	55
Long-snouted boarfish	*Pentaceropsis recurvirostris*	16	92	6	–	2	92	8	98	2	54
Jack mackerel	*Trachurus declivis*	16	–	–	68	32	68	32	–	100	53
White trevally	*Pseudocaranx dentex*	13	43	57	–	–	43	57	100	–	44
Latchet	*Pterygotrigla polyommata*	7	–	–	–	100	–	100	–	100	23
Magpie perch	*Cheilodactylus nigripes*	4	–	–	64	36	64	36	–	100	14
Bight redfish	*Centroberyx gerrardi*	4	67	25	–	8	67	33	92	8	12
Sand flathead	*Platycephalus bassensis*	3	9	–	36	55	45	55	9	91	11
Blue-throated wrasse	*Notolabrus tetricus*	3	33	23	11	33	44	56	56	44	9
Red gurnard	*Chelidonichthys kumu*	2	25	–	–	75	25	75	25	75	8

TABLE 8A. (Cont'd). Breakdown of total catch by gillnet 6-inch mesh size as retained, discarded, live, and dead animals for each species in Bass Strait during 1998–2001. Catch-per-unit effort (CPUE) is measured as number of animals per 1000 km-hr.

			Total catch (%)				Total catch (%)		Total catch (%)		No.
			Retained		Discarded						
Common name or effort	Scientific name	CPUE	Live	Dead	Live	Dead	Live	Dead	Retained	Discarded	caught
Barracouta	*Thyrsites atun*	2	–	–	–	100	–	100	–	100	8
Deepsea trevalla	*Hyperoglyphe antarctica*	2	–	100	–	–	–	100	100	–	6
Swallow-tail	*Centroberyx lineatus*	2	100	–	–	–	100	–	100	–	5
Bearded rock cod	*Pseudophycis barbata*	1	–	–	–	100	–	100	–	100	4
Giant boarfish	*Paristiopterus labiosus*	1	100	–	–	–	100	–	100	–	4
Knifejaw	*Oplegnathus woodwardi*	1	100	–	–	–	100	–	100	–	4
Queen snapper	*Nemadactylus valenciennesi*	1	50	50	–	–	50	50	100	–	4
Sergeant baker	*Aulopus purpurissatus*	1	–	–	–	100	–	100	–	100	3
Pink ling	*Genypterus blacodes*	1	33	67	–	–	33	67	100	–	3
Jackass morwong	Family *Nemadactylus macropterus*	1	33	–	–	67	33	67	33	67	3
Tiger flathead	Family *Neoplatycephalus richardsoni*	1	50	50	–	–	50	50	100	–	2
Stargazer	Family *Uranoscopidae*	1	–	–	100	–	100	–	–	100	2
Greenback flounder	*Rhombosolea tapirina*	1	100	–	–	–	100	–	100	–	2
Leatherjacket	*Family Monacanthidae*	1	–	–	50	50	50	50	–	100	2
Snapper	*Pagrus auratus*	–	100	–	–	–	100	–	100	–	1
Western blue groper	*Achoerodus gouldii*	–	–	–	100	–	100	–	–	100	1
Sub-total	*Teleostei*	102	40	14	18	28	58	42	54	46	337
Cephaplopoda											
Octopus	*Octopus pallidus*	1	33	–	67	–	100	–	33	67	3
Gould's squid	*Nototodarus gouldi*	–	100	–	–	–	100	–	100	–	1
Sub-total	*Cephalopoda*	1	50	–	50	–	100	–	50	50	4
Other											
Swollen spider crab	*Leptomithrax gaimardii*	25	–	–	70	30	70	30	–	100	83
Southern rock lobster	*Jasus edwardsii*	1	100	–	–	–	100	–	100	–	2
False bailer shell	*Livonia mammilla*	3	67	–	33	–	100	–	67	33	9
Australian fur seal	*Arctocephalus pusillus dorifer*	1	–	–	–	100	–	100	–	100	2

TABLE 8B. Breakdown of total catch by gillnet 6 inch and 6 1/2 inch mesh size as retained, discarded, live, and dead animals for each species in South Australia during 1998–2001. Catch-per-unit effort (CPUE) is measured as number of animals per 1 000 km-hr.

			Total catch (%)								
			Retained		Discarded		Total catch (%)		Total catch (%)		No.
Common name or effort	Scientiifc name	CPUE	Live	Dead	Live	Dead	Live	Dead	Retained	Discarded	caught
Fishing effort (km-hr)		1 865									
Chondrichthyes											
Gummy shark	*Mustelus antarcticus*	497	47	52	–	1	47	53	99	1	928
Port Jackson shark	*Heterodontus portusjacksoni*	138	–	–	100	–	100	–	–	100	257
School shark	*Galeorhinus galeus*	44	94	2	4	–	98	2	96	4	82
Smooth hammerhead	*Sphyrna zygaena*	41	97	2	–	1	97	3	99	1	77
Piked spurdog	*Squalus megalops*	38	–	–	100	–	100	–	–	100	71
Southern eagle ray	*Myliobatis australis*	28	2	–	89	9	91	9	2	98	53
Common sawshark	*Pristiophorus cirratus*	23	91	7	2	–	93	7	98	2	43
Bronze whaler	*Carcharhinus brachyurus*	23	100	–	–	–	100	–	100	0	42
Southern sawshark	*Pristiophorus nudipinnis*	14	63	30	4	3	67	33	93	7	27
Broadnose sevengill shark	*Notorynchus cepedianus*	13	21	–	–	79	21	79	21	79	24
Elephant fish	*Callorhinchus milii*	12	68	14	9	9	77	23	82	18	22
Thresher shark	*Alopias vulpinus*	10	5	–	32	63	37	63	5	95	19
Australian angel shark	*Squatina australis*	10	21	–	68	11	89	11	21	79	19
Spotted wobbegong	*Orectolobus maculatus*	2	100	–	–	–	100	–	100	–	4
Skates (unspecified)	*Raja spp*	1	–	–	100	–	100	–	–	100	2
Sparsely-spotted stingaree	*Urolophus paucimaculatus*	1	–	–	50	50	50	50	–	100	2
Whiskery shark	*Furgaleus macki*	1	100	–	–	–	100	–	100	–	1
White-spotted spurdog	*Squalus acanthias*	1	–	–	100	–	100	–	–	100	1
Western shovelnose ray	*Aptychotrema vincentiana*	1	–	–	100	–	100	–	–	100	1
Sub-total	*Chondrichthyes*	898	42	30	25	3	67	33	72	28	1 675
Teleostei											
Southern drummer	*Kyphosus gibsoni*	33	100	–	–	–	100	–	100	–	62
Bight redfish	*Centroberyx gerrardi*	31	98	–	2	–	100	–	98	2	58
Long-snouted boarfish	*Pentaceropsis recurvirostris*	30	98	–	–	2	98	2	98	2	56
Queen snapper	*Nemadactylus valenciennesi*	23	98	–	2	–	100	–	98	2	42
Snapper	*Pagrus auratus*	19	100	–	–	–	100	–	100	–	35
Dusky morwong	*Dactylophora nigricans*	13	58	–	42	–	100	–	58	42	24
Western blue groper	*Achoerodus gouldii*	11	100	–	–	–	100	–	100	–	21
Red gurnard	*Chelidonichthys kumu*	10	56	–	22	22	78	22	56	44	18
Jewfish	*Argyrosomus japonicus*	5	90	–	–	10	90	10	90	10	10

TABLE 8B. (Cont'd). Breakdown of total catch by gillnet 6 inch and 6 1/2 inch mesh size as retained, discarded, live, and dead animals for each species in South Australia during 1998–2001.Catch-per-unit effort (CPUE) is measured as number of animals per 1 000 km-hr.

			Total catch (%)								
			Retained		Discarded		Total catch (%)		Total catch (%)		Number
Common name or effort	Scientiifc name	CPUE	Live	Dead	Live	Dead	Live	Dead	Retained	Discarded	caught
Magpie perch	*Cheilodactylus nigripes*	5	100	–	–	–	100	–	100	–	10
Yellow-spotted boarfish	*Paristiopterus gallipavo*	3	100	–	–	–	100	–	100	–	6
Leatherjacket	*Family Monacanthidae*	3	100	–	–	–	100	–	100	–	6
Latchet	*Pterygotrigla polyommata*	3	40	–	60	–	100	–	40	60	5
Sand flathead	*Platycephalus bassensis*	3	60	–	20	20	80	20	60	40	5
Tiger flathead	*Neoplatycephalus richardsoni*	2	100	–	–	–	100	–	100	–	3
Sergeant baker	*Aulopus purpurissatus*	1	–	–	100	–	100	–	–	100	2
Blue-throated wrasse	*Notolabrus tetricus*	1	100	–	–	–	100	–	100	–	2
Pink ling	*Genypterus blacodes*	1	100	–	–	–	100	–	100	–	1
Mirror dory	*Zenopsis nebulosus*	1	100	–	–	–	100	–	100	–	1
Jack mackerel	*Trachurus declivis*	1	100	–	–	–	100	–	100	–	1
Samsonfish	*Seriola hippos*	1	100	–	–	–	100	–	100	–	1
Bumpnose trevally	*Carangoides hedlandensis*	1	–	–	100	–	100	–	–	100	1
Sweep	*Family Scorpis lineolatus*	1	100	–	–	–	100	–	100	–	1
Old wife	*Family Enoplosus armatus*	1	–	–	100	–	100	–	–	100	1
Wrasse	*Family Labridae*	1	100	–	–	–	100	–	100	–	1
Greenback flounder	*Family Rhombosolea tapirina*	1	100	–	–	–	100	–	100	–	1
Toadfish	*Tetraodon erythrotaenia*	1	–	–	100	–	100	–	–	100	1
Sub-total	*Teleostei*	201	91	–	7	2	98	2	91	9	375
Other											
Swollen spider crab	*Leptomithrax gaimardii*	7	–	–	69	31	69	31	–	100	13
Southern rock lobster	*Jasus edwardsii*	2	100	–	–	–	100	–	100	–	4
Southern bay lobster	*Ibacus peronii*	1	–	–	100	–	100	–	–	100	1
Common dolphin	*Delphinus delphis*	1	–	–	–	100	–	100	–	100	1

3. Overall catch rates of chondrichthyan and teleost fishes by mesh size are very different. For chondrichthyans, the modal catch rate is by 4 inch mesh size with decreasing catch rates for both increasing and decreasing mesh size, whereas for teleosts the modal catch rate is by 2 inch mesh size with decreasing catch rates as mesh size increases.

4. For gillnets, there is linear increase in the ratio of the number of chondrichthyan fishes divided by the number of teleost fishes with increasing mesh size, whereas for hooks the ratio is approximately constant with increasing hook size.

5. For chondrichthyes, the top four species taken by gillnet across 8 mesh sizes (Experiment 1), *Squalus megalops*, *Mustelus antarcticus*, *Heterodontus portusjacksoni*, and *Galeorhinus galeus*, are similar to the top four species taken by longline across 8 hook sizes (Experiment 3), *Squalus megalops*, *M. antarcticus*, *Cephaloscyllium laticeps*, and *G. galeus*. The only difference is that *H. portusjacksoni* is more prevalent than *C. laticeps* in the gillnet catch, whereas the converse occurs for the longline catch.

6. For teleostei, *Platycephalus bassensis* is the most prevalent species caught by both gillnets across 8 mesh sizes (Experiment 1) and longlines across 8 hook sizes (Experiment 3). *Neosebastes scorpaenoides* is the second most prevalent species caught by longline and the third most prevalent species caught by gillnet. The second most prevalent species taken by gillnet, *Trachurus novaezelandiae*, is not caught by longline.

7. For chondrichthyes in Bass Strait, there has been about a one-third overall reduction in abundance across all species combined between 1973–76 and 1998–2001. About half of this reduction is attributable to an 87% reduction in the catch-per-unit effort (CPUE) of *Galeorhinus galeus* and a 54% reduction in the CPUE of *Cephaloscyllium laticeps*.

8. Only small proportions of the commercial catch of chondrichthyan (3%) and teleost (2%) animals taken by demersal gillnets of 6 inch and 6½ inch mesh size coming aboard dead are discarded. The discarded animals are mostly *Cephaloscyllium laticeps*, *Heterodontus portusjacksoni*, *Squalus megalops*, and *Myliobatis australis*, which come aboard live.

9. Fishery-wildlife interactions occur occasionally with Australian fur seals (*Arctocephalus pusillus dorfer*) and common dolphin (*Delphinus delphis*).

10. Of ten chondrichthyan species on the continental shelf and continental slope identified by the IUCN Shark Specialist Group as threatened, two are identified by the present study as caught by the fishery. White shark (*Carcharodon carcharius*) are taken occasionally and *Galeorhinus galeus*, once the primary target species, is presently taken as significant by-product (253 tons during 2000) (Walker *et al*., 2003).

In summary, most of the by-catch from the shark fishery of southern Australia consists of four chondrichthyan species that are discarded live. Only small quantities of teleost species are taken and these are mostly retained and marketed, and, with the exception of *Galeorhinus galeus*, interactions with protected or threatened species are minimal. The main challenge for management of the fishery is to allow sustainable use of the highly productive resource of *Mustelus antarcticus*, while rebuilding the depleted stocks of *G. galeus*. There is little spatial overlap between the shark fishery and other fisheries.

The 87% reduction in CPUE of *G. galeus*, detected by the present study in Bass Strait between 1973–76 and 1998–2001, is consistent with the reduction in CPUE reported by commercial fishers (Walker *et al*., 2003). The magnitude of the reduction is also consistent with the results of stock assessment for the species using independent data (Punt and Walker, 1998; Punt *et al.*, 2000).

The 54% reduction in the catch of *Cephaloscyllium laticeps* is more difficult to explain. Fishing mortality of these animals is not expected to be high, because they are highly robust animals; they are mostly alive when removed from gillnets. Part of the explanation for this observed reduction is that commercial fishers tend to avoid fishing grounds where these animals are known to be abundant. In addition, fishers often move away from fishing grounds where catch numbers of this species are high to avoid untangling large numbers of these animals from the gillnets. Some fishers claim that *M. antarcticus* tend not to aggregate in regions inhabited by large numbers of *C. laticeps*. In Bass Strait, no attempt was made to avoid *C. laticeps* during 1973–76 (172 fishing sites) or during the pilot fixed station fishery-independent survey in 1998 (24 fishing sites). However, some of the fishers operating under normal commercial conditions might have avoided such regions during 1999–2001 (67 fishing sites).

Ten chondrichthyan species occurring in the region of the shark fishery are listed as threatened by the IUCN Shark Specialist Group. The grey nurse shark (*Carcharias taurus*), Harrison's dogfish (*Centrophorus harrisoni*), and southern dogfish (*C. uyato*) are listed as critically endangered. Greeneye spurdog (*Squalus mitsukurii*) and endeavour dogfish (*C. moluccensis*) are listed as endangered. *Carcharodon carcharias*, *G. galeus*, Herbst's nurse shark (*Odontaspis ferox*), eastern angel shark (*Squatina* sp A), and Maugean skate (*Raja* sp L) are listed as vulnerable (Cavanagh *et al.*, 2003).

On the upper continental slope of southern Australia, several species of dogfish (*Squalidae*) and holocephalans (*Holocephali*), taken as by-product by demersal trawl, gillnet or longline, have been identified as severely depleted and requiring special management. Upper slope dogfish species are more vulnerable to capture than mid slope species, because they are targeted throughout their vertical distribution and most of their geographic distribution. Demersal trawl surveys off central and southern New South Wales during 1977 and 1997 indicate a reduction in catch rates of *Centrophorus* spp of 98.4–99.7% (Andrew *et al.*, 1997; Graham *et al.*, 2001). The shark fishery now only occasionally operates outside depths of 100 m, and therefore does not impact the severely depleted populations of *Centrophorus* spp or holocepahalans on the continental slope, which occur mainly in depths >200 m.

Reports by fishers indicate that a small by-catch of *Carcharodon carcharias* occurs, which is consistent with one animal caught by longline during 1973–76 as part of the present study (Experiment 4). The species is now totally protected in all Australian waters and the unintentional fishing mortality of the species is being reduced as various waters are closed to shark fishing. All Victorian waters (coastal waters out to 3 nm and all enclosed bays and inlets) have been closed to shark fishing since 1988. Area closures are presently under consideration in South Australia and Tasmania.

There are no reported catches of *Carcharias taurus* from the shark fishery of southern Australia. Although the distribution of *C. taurus* is reported to include Victoria, South Australia, and Tasmania (Last and Stevens, 1994), the species is extremely rare in these waters. The species occurs mainly in New South Wales and Western Australia (Pollard, 1996). Similarly there are no reported catches of *Odontapsis ferox*, *Squatina* sp A or *Raja* sp L from the shark fishery. *Odontapsis ferox* is distributed off New South Wales and *Squatina* sp A is distributed mainly in the coastal waters of New South Wales and Queensland (Last and Stevens, 1994) outside the range of the shark fishery. However, *Raja* sp L occurs inshore off southern Tasmania (Last and Stevens, 1994) where it can potentially interact with the shark fishery.

The small catch of marine mammals by gillnets during 1998–2001, two Australian fur seals (*Arctocephalus pusillus dorfer*) and one common dolphin (*Delphinus delphis*), is consistent with the anecdotal information of a small by-catch for these species. Several other species of seals (families *Otariidae* and *Phocidae*) and dolphins (family *Delphinidae*) that occur within the range of the fishery (Menkhorst, 1995) may be caught on rare occasions. The Victorian closure to shark fishing is likely to have reduced the unintentional fishing mortality of *Arctocephalus pusillus dorfer* within at least 3 naut. miles around four major seal breeding colonies (Lady Julia Percy Island, Seal Rock, Kanowa Island and The Skerries) and other haul out sites. Closure of other important seal habitat is under consideration in other States.

At a world level, based on limited data, 27 million tons of material are estimated to be discarded annually. Most of this is from industrial rather than artisanal fisheries. The highest number of records of discards is from trawl fisheries (966 records), followed by drift net and gillnet fisheries (232), line fisheries (150), pot fisheries (83), and purse seine fisheries (82) (Alverson *et al.*, 1994). Management of fishery-wildlife interactions, particularly with mammals, seabirds, and turtles, have become the key factors in the management strategies of some fisheries (Jennings *et al.*, 2001).

Most of the world's catch of chondrichthyan species is captured by demersal trawl, demersal gillnet, and pelagic and demersal longlines (Bonfil, 1994; Walker, 1998). Various studies have evaluated catches from demersal trawl (Van Der Molen *et al.*, 1998; Stobutzki *et al.*, 2001; Anderson and Clark, 2003) and longline fisheries (Bailey *et al.*, 1996; Marín *et al.*, 1998; Williams, 1999), but there has been little attempt to comprehensively evaluate catches in demersal gillnet fisheries.

The effects of mesh size in trawl codends on catch has been investigated extensively for prawns and teleosts (Sparr and Venema, 1992; Millar and Fryer, 1999; D'Onghia *et al.*, 2003), but not for chondrichthyans. Square mesh panels in demersal trawl codends has been shown to facilitate escapement of small teleost fish (Broadhurst *et al.*, 1997; Graham *et al*., 2003), but not yet for small chondrichthyan animals. Another approach is to fit a rigid grid in front of the codend to deflect large animals such as turtles, mammals and sharks through an escape panel; this by-catch reduction device (BRD) is often referred to as a turtle exclusion device or trawl efficiency device (TED) (Anon., 2000; Jennings *et al.*, 2001).

As demonstrated for sharks (Kirkwood and Walker, 1986; McLoughlin and Stevens, 1994; Simpfendorfer and Unsworth, 1998; Carlson and Cortés, 2003) and teleosts

(Millar and Fryer, 1999; Holgård and Lassen, 2002), the present study confirms that gillnets are highly length selective and mesh size markedly affects species composition of the catch and the length frequency composition of each species in the catch. The relative abundances of the various species taken in the 2–9 inch mesh sizes adopted were very different and there are distinct trends with mesh size. This means mesh size can be regulated to provide for the efficient catch of target species with escapement of pre-recruit and large breeding animals (Walker, 1998) and escapement of certain by-catch species (present study). In some fisheries, regulation of filament thickness has been suggested to facilitate escapement of particular by-catch species by allowing the filaments of gillnet webbing to break (Anon., 2000).

The effects of hook size on catch can be detected for some teleost species (Sparr and Venema, 1992; Sousa *et al.*, 1999; Holgård and Lassen, 2002) and hook type, hook shape, and bait can also have length selective effects on the catch (Woll *et al.*, 2001). Although not extensively investigated, it appears the effects of hook size are weak for demersal chondrichthyan species (present study). Increasing the distance for setting hooks above the seabed can markedly reduce the by-catch of deep water sharks (Coelho *et al.*, 2003). Anecdotal reports from observers on board vessels operating in the tropical and subtropical tuna longline fisheries indicate increasing the distance of hooks below the sea surface can reduce the by-catch of pelagic sharks. Also, preventing use of wire traces between the snoods and hooks can facilitate escapement of chondrichthyan species, particularly large sharks, by allowing snoods to be broken or bitten through (Anon., 2000).

Changes in the structure of demersal fish communities have been detected by studies with trawl gear, which is less size selective than gillnets. For example annual trawl surveys during 1970–2000, a time scale similar to the present study, demonstrated a change in community composition in an area following its closure in 1987 on the continental shelf of Nova Scotia, Canada. Fish from a total of 74 species were caught in either the area closed in 1987 (60 species) or the nearby Brown's Bank area (62 species). The change was demonstrated by multivariate analysis and a randomised pertubation test (Fischer and Frank, 2002). Another study, trawling regularly at 14 sites during 1970–75 and 1990/91 in Port Phillip Bay, Victoria, Australia, also provides evidence of detectable changes in the demersal fish communities (Hobday *et al.*, 1999). The present study shows that a gillnet fishery based on the narrow mesh size range of 6–7 inch mesh size can cause detectable changes in the relative abundance of particular species, providing evidence of a detectable change in demersal fish community composition. The observation from the present study of a linear increase in the ratio of the number of chondrichthyan fishes to the number of teleost fishes with increasing mesh size is consistent with the tendency for chondrichthyan animals to attain larger body size than teleost animals (Freedman and Noakes, 2002). The observation is also consistent with the tendency for teleost animals to be more abundant than chondricthyan animals in coastal demersal fish communities.

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