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THE VULNERABILITY OF FISH TO CAPTURE BY COMMERCIAL BEACH-SEINE NETS IN FALSE BAY, SOUTH AFRICA

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An experimental net was set behind a commercial beach-seine net to estimate the number of fish that escape from the latter. Escapement was high, 95% of the combined catch being caught in the cover net. Escapees were numerically dominated by the "baitfish" species *Engraulis capensis* (52%) and *Atherina breviceps* (36%). A relatively low proportion of "angling" species was lost from the commercial net. These species, namely *Lithognathus lithognathus*, *Rhabdosargus globiceps*, *Pomatomus saltatrix* and *Diplodus sargus capensis*, become vulnerable to capture by commercial beach-seines well before they reach two years of age and long before maturity. It is argued that the substantial increase in mesh size needed to reduce the by-catch of these juvenile "angling" species would drastically lower the total catch of *Liza richardsonii*, the principal target species of the commercial beach-seine fishery.

'n Eksperimentele net is agter 'n kommersiële strandseën gestel om te raam hoeveel vis uit lg. ontsnap. Ontsnapping was hoog en 95% van die gesamentlike vangs is in die deknet gevang. Die ontsnaptes is getalsgewys oorheers deur die "aasvis"-spesies *Engraulis capensis* (52%) en *Atherina breviceps* (36%). 'n Betreklik klein gedeelte van die "hengel"-spesies het uit die kommersiële net verlore geraak. Hierdie spesies, nl. *Lithognathus lithognathus*, *Rhabdosargus globiceps*, *Pomatomus saltatrix* en *Diplodus sargus capensis*, kan in kommersiële strandseënnette gevang word lank voor hul twee jaar oud is geslagsrypheid bereik. Daar word aangevoer dat die aansienlike vergroting van die maasgrootte wat nodig is om die newevangs van hierdie jong "hengel"-spesies te verminder, die totale vangs van *Liza richardsonii*, die vernaamste teikenspesie van die kommersiële strandseënvissery, drasties sal verlaag.

Since c. 1983, the official status of the commercial beach-seine fishery along the Cape coast of South Africa has been that of a single-species fishery targeting the southern mullet (harder) *Liza richardsonii*. St Joseph sharks *Callorhinchus capensis* are permitted as a by-catch, but the targeting and keeping of all other species is prohibited. However, beach-seine fishermen in False Bay are exempt from this restriction and are permitted to catch and retain species such as white steenbras *Lithognathus lithognathus*, white stumpnose *Rhabdosargus globiceps*, elf *Pomatomus saltatrix* and yellowtail *Seriola lalandi*, provided that they all exceed the legal minimum size.

This exemption has caused much chagrin among anglers and conservation groups, who claim that the small-meshed commercial nets allow no escape, and capture all fish in their paths (see Borden 1988, Kirsch 1993). In response to this concern, the minimum mesh size was increased from 44 to 50 mm (Theart *et al.* 1983, Stander 1991), but the decision was rescinded when seine fishermen claimed that the increased mesh size would result in too many fish being gilled, longer handling time and greater mortality of those released (McHugh 1960, Petty *et al.* 1984).

Several studies have investigated the mesh selectivity and capture efficiency of commercial and experimental nets (e.g. McHugh 1960, Botha *et al.* 1971, Hamley 1975, Jones 1982, Pierce *et al.* 1990). Investigations into the selective properties of commercial trawl, gill and beach-seine nets have, in most cases, determined that the optimum and ideal mesh size was that currently in use (Botha 1971, Grant 1981, Jones 1982, De Villiers 1987).

Escape from a beach-seine net will depend on the behavioural and morphological characteristics of the fish, on the dimensions and properties of the net and on the nature of the substratum over which the net is hauled. Important characteristics of the fish include fright response, typical position in the water column, girth and streamlining, all of which may vary temporally and with age (Hamley 1975, Trent and Pristas 1977, Lyons 1986, Parsley *et al.* 1989). Influential features of the net include mesh size, length, depth, elasticity, strength, visibility and the way it is hung (Hamley 1975, Parsley *et al.* 1989). Escape is generally more frequent over coarse, heterogenous substrata than over fine, snag-free substrata (Parsley *et al.* 1989, Pierce *et al.* 1990).

The aim of the present study was to describe and quantify escapement and vulnerability to capture of fish in commercial beach-seine nets in False Bay. Experimental and commercial catches in this and

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another study are compared and discussed.

METHODS

The study was conducted at Fish Hoek Beach (34°08'S, 18°27'E), on the western shore of False Bay. This beach is sheltered by steep rocky headlands on its northern and southern ends, is 1,3 km long, has a gentle gradient and an average wave height of 0,95 m (Bennett 1989). The outer breaker line varies between 50 and 200 m from the shore. This site was chosen because it is relatively sheltered in comparison to the exposed beaches on False Bay's northern shore and hence easier to sample. In addition, it was the only beach-seine area in which commercial hauls, set at approximately the same distance from the shore, were made consistently each morning at sunrise.

Two commercial beach-seine permit-holders operating from Fish Hoek Beach use nets 275 m long and 5 m deep, with a stretched mesh size of 44 mm, which they set between 400 and 600 m offshore. The commercial net was hauled by 14–20 crew. The experimental net was 30 m long and 2 m deep with a stretched mesh size of 12 mm. The experimental net was hauled by four persons, two on each 100 m hauling rope. As the bag of the commercial net approached 100 m from the shore, the experimental net (cover net) was rowed out on a dinghy and shot around the commercial net. The cover net was hauled up onto the beach behind the commercial net. Two other experimental hauls (control hauls) set at 100 m from the beach were made 100 m either side of, and before and after, each commercial haul.

Whenever possible, the entire catch of each net was counted and the total length of each fish was measured to the nearest millimetre. If more than 1 000 individuals of a species were caught, a representative subsample of at least 250 fish was measured. Body depth in a few selected species was measured. Length frequency distributions for each species were calculated from the combined cover and commercial net catches (excluding the control nets).

The selectivity of the commercial net was determined using both cover-net and alternate-haul techniques (Pope 1966). Using the cover-net method, the selectivity for a species was determined by plotting the proportion of the combined catch in the commercial net against total fish length (Pope 1966, Jones 1982). The length at which 50% of a size-class were retained was then read from the plot.

The alternate-haul method of Pope (1966) was applied to length frequency data collected from 311 commercial and 264 experimental net hauls monitored in False Bay between January 1991 and July 1993. Following the methodology of Pope (1966), the fish caught in the experimental net were, after being corrected for variations in catching efficiency between the two nets, assumed to be representative of the natural population, at least over the mesh selection range. The ratio of commercial to experimental catch in each size-class gave the proportion of fish retained by the commercial net. The number of fish retained was plotted by total length-class.

The results of the cover-net and alternate-haul methods were described by the logistic curve

$$P = 1/[1 + e^{-k(L - L_{50\%})}] ,$$

where P is the proportion retained by the commercial net, k is related to the length range over which the selectivity changes from 0 to values near 1, L is the length-class midpoint and $L_{50\%}$ is the length corresponding to 50% retention (Butterworth *et al.* 1989).

RESULTS

A total of 11 commercial beach-seine hauls was monitored and covered with the experimental net during February and March 1993. The combined catch of the commercial and cover nets totalled 70 727 fish, representing 43 species and 27 families (Table I). Of this total, 95% were caught in the cover net. Further, 17 species recorded in the cover net were not retained by the commercial net and 12 species caught by the commercial net did not escape into the cover net. Only 1% of the cartilaginous catch was recorded in the cover net. Horse mackerel *Trachurus trachurus capensis* and slender scad *Decapterus macrosoma* were the most abundant species in the commercial net. Anchovy *Engraulis capensis* and Cape silverside *Atherina breviceps* were the two most abundant species in the cover net. The largest specimens of leervis (garrick) *Lichia amia*, santer *Cheimerius nufar*, blacktail *Diplodus sargus capensis*, red tjor-tjor *Pagellus bellottii natalensis* and steentjie *Spondyliosoma emarginatum* in the cover net were all smaller than their smallest sizes in the commercial net (Table I). The size ranges of the 10 remaining species overlapped for both nets (Table I).

The control hauls netted a total of 8 248 fish of 15 species from 11 families. The catch per haul of 14 of these species was up to three orders of magnitude less than that of the cover net (Table I), even though the same net was used and the area swept was constant. The control catch per haul of *Liza richardsonii* was greater than that of the cover hauls (Table I).

Table I: Summary of information on the species composition, abundance and size of Osteichthyes and Chondrichthyes caught in 11 commercial and experimental cover beach-seine net hauls made at Fish Hoek Beach during February and March 1993. Control net catches are not included in the total catch

Taxon		Total catch	Size range of commercial haul (mm)	Size range of cover haul (mm)	Percentage of total catch in cover net	Number per haul of cover net	Number per haul of control net
OSTEICHTHYES							
Ariidae	*Galeichthys feliceps*	82	210–369				
Atherinidae	*Atherina breviceps*	24 431		84–118	100	2 221	88
Callionymidae	*Draculo celetus*	1		50	100	<1	<1
Carangidae	*Alectis ciliaris**	1		34	100	<1	
	Decapterus macrosoma	3 255	100–190	118–176	90	266	<1
	*Lichia amia**	3	220–240	172	33	<1	<1
	Trachurus trachurus capensis	5 254	50–230	25–202	65	308	<1
	Unidentified	5		32–112	100	<1	<1
Clupeidae	*Sardinops sagax*	1	230				
Cynoglossidae	*Cynoglossus capensis*	5	195–250				
Dactylopteridae	*Dactyloptena peterseni*	1		81	100	<1	
Engraulidae	*Engraulis capensis*	35 002	113–115	105–144	>99	3 182	
Gobiesocidae	*Psammogobius knysnaensis*	1		70	100	<1	
Monacanthidae	*Aluterus monoceros*	1	104			<1	
	Stephanolepis auratus	1		88	100	<1	
Mugilidae	*Liza richardsonii*	164		32–166	100	15	44
	Mugil cephalus	1		136	100	<1	<1
Mullidae	*Parupeneus rubescens*	19		57–78	100	2	
Ostraciidae	*Ostracion* spp.	2		7–14	100	<1	
Pomatomidae	*Pomatomus saltatrix**	15	130–135	49–166	87	1	<1
Sciaenidae	*Argyrosomus hololepidotus**	1	450				
	*Umbrina canariensis**	7		24–48	100	<1	<1
Soleidae	*Heteromycteris capensis*	55	110–152	32–148	87	4	
	Synaptura marginata	1	230				
Sparidae	*Cheimerius nufar**	8	112	50–92	88	<1	
	*Diplodus sargus capensis**	20	295	26–40	95	2	<1
	*Lithognathus lithognathus**	4	810–1 010				
	Lithognathus mormyrus	75		20–148	100	7	6
	Pagellus bellottii natalensis	13	160–164	41–159	54	<1	
	*Rhabdosargus globiceps**	1 303	40–320	22–105	87	103	45
	Sarpa salpa	1		100	100	<1	
	Spondyliosoma emarginatum	164	140–292	28–74	34	5	
Sphyraenidae	*Sphyraena acutipinnis*	13		125–154	100	1	
Synodontidae	*Trachinocephalus myops*	1		65	100	<1	
Tetraodontidae	*Amblyrhynchotes honckenii*	281	109–210	17–128	4	1	<1
	Pelagocephalus marki	1		26	100	<1	
Triglidae	*Chelidonichthys capensis*	193	130–350	35–189	27	5	<1
CHONDRICHTHYES							
Callorhinchidae	*Callorhinchus capensis*	76	190–950	175–190	5	<1	
Myliobatidae	*Myliobatis aquila*	58	230–440†				
Rajidae	*Raja* cf. *clavata*	18	115–600†				
Rhinobatidae	*Rhinobatos annulatus*	34	210–920†				
Scyliorhinidae	*Haploblepharus edwardsii*	11	300–570	450	9	<1	
	Haploblepharus pictus	1	290				
Triakidae	*Mustelus mustelus*	143	415–1 750				

* Angling species
† Disc width

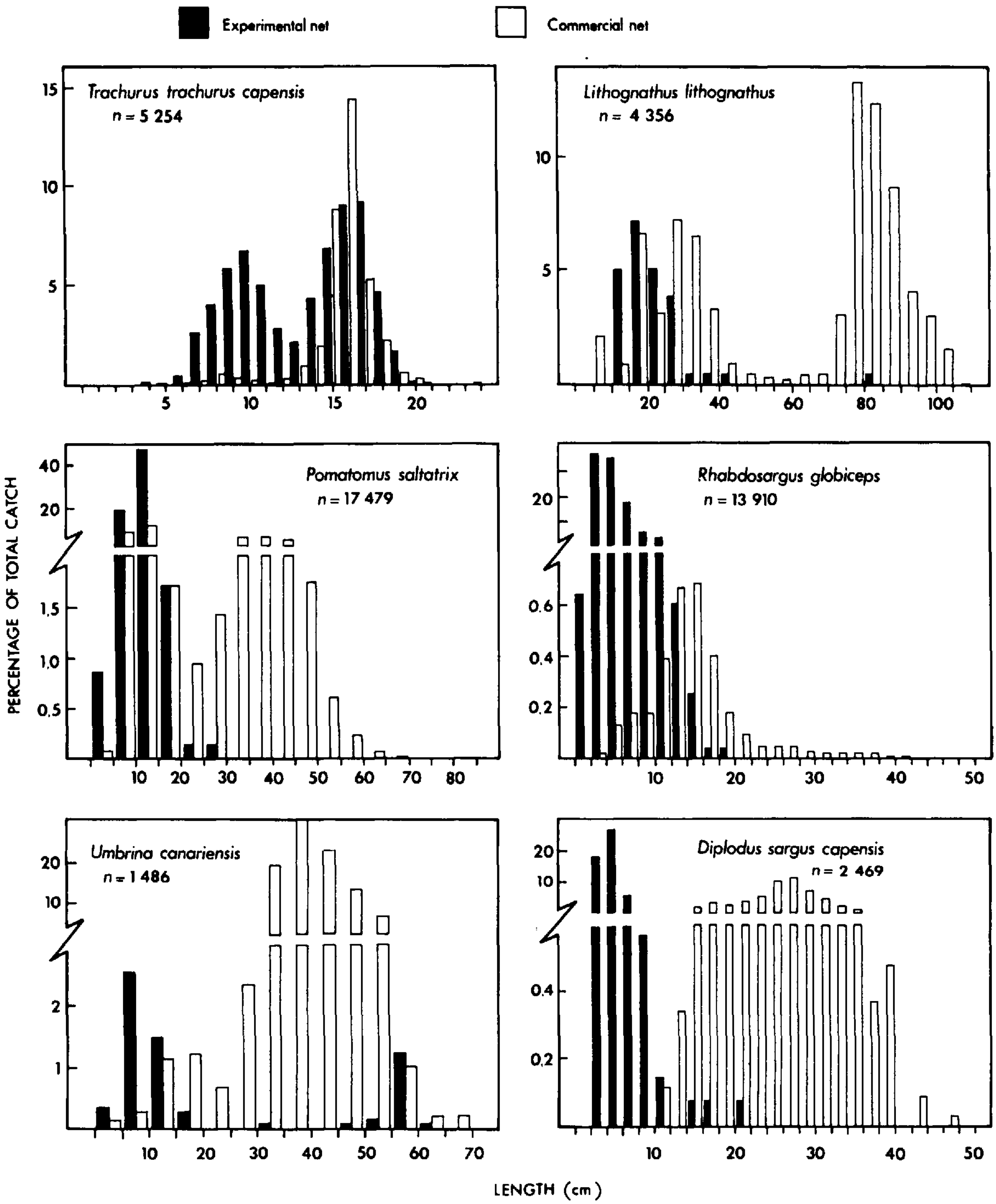

Fig. 1: Size frequency distributions of five "angling" species abundant in 311 commercial and 264 experimental net hauls made between January 1991 and July 1993. Included is the size frequency distribution of *Trachurus trachurus capensis* caught in 11 covered commercial hauls during February and March 1993

Table II: Summary of results conforming to the selectivity curve $P = 1/[1+e^{-k(L-L_{50\%})}]$ body depth to length ratios ± *SE*, body depth at 50% retention ($BD_{50\%}$) and lengths at 1 year old and maturity of species caught in commercial beach-seine nets in False Bay. Length and body depth are measured in mm. $L_{50\%}$ given as ±*SE*

Species	k	$L_{50\%}$	r^2	n	Ratio of body depth to length	$BD_{50\%}$	L_{1year}*	$L_{maturity}$*
Diplodus sargus capensis	0,073	105 ± 2,750	0,82	50	0,294 ± 0,007	31	105[a]	264[a]
Lithognathus lithognathus	0,120	166 ± 0,308	0,96	50	0,277 ± 0,002	46	160[b]	650[b]
Rhabdosargus globiceps	0,082	138 ± 0,183	0,98	50	0,238 ± 0,002	33	82[c]	310[c]
Umbrina canariensis	0,019	144 ± 10,840	0,61	60	0,296 ± 0,002	43		30[d]
Pomatomus saltatrix	0,021	160 ± 3,100	0,47	60	0,222 ± 0,004	36	170[e]	240[e]
Trachurus trachurus capensis	0,076	163 ± 0,651	0,82	50	0,193 ± 0,003	32	83[f]	200[f]

* a. Mann (1992); b. Bennett (1993); c. Talbot (1955); d. Unpublished data; e. Van der Elst (1976); f. Geldenhuys (1973)

The 50% retention length of *T. trachurus capensis* in the cover-net experiment was 163 mm (Table II). Insufficient catches within the selection ranges of the commercial and cover-net hauls prevented the use of the cover method being used to construct selectivity curves for any of the other species. Instead, the alternate-haul method was used to determine the selection curves of elf *Pomatomus saltatrix*, white stumpnose *Rhabdosargus globiceps*, white steenbras *Lithognathus lithognathus*, baardman *Umbrina canariensis* and *Diplodus sargus capensis* (Table II). Size frequency distributions of these species are shown in Figure 1.

The relationships between body depth and length for all species in this study were assumed to be linear owing to the limited size ranges over which measurements were made. These ratios were used to determine body depth at 50% retention (Table II). Excluding *L. lithognathus*, the body depth at 50% retention of all species was less than the 44 mm mesh size of the commercial net (Table II).

DISCUSSION

The 43 species caught in the 11 combined commercial/cover hauls during this study represent more than double the 20 species representing 12 families previously recorded at Fish Hoek by Bennett (1989). However, the 15 species from 11 families recorded in the control hauls are comparable with those of Bennett's (1989) study. Catch per haul of the control net, which averaged 187 fish per haul, was, however, considerably lower than the 1 550 fish per haul recorded by Bennett (1989).

Differences in gear, excluding personnel efficiency (Aneer and Nellbring 1977), cannot explain the difference in catch per haul of the control net and Bennett's (1989) study, because net lengths and mesh sizes were similar in both studies. As the area swept by the control net was twice that swept in Bennett's (1989) study, a larger catch would have been expected. Disturbance by the net and boat could have been a factor, and the doubled area through which the net was hauled could have allowed the fish more time to escape (Kuipers 1975, Aneer and Nellbring 1977). Hauls in this study were also conducted in the two hours spanning daybreak, as opposed to those of Bennett's (1989) study, which were made during daylight. The small catch per haul of the control net in this study could also be attributed to small and juvenile fish not having reoccupied the surf zone after their nocturnal absence (Romer 1986, Romer and McLachlan 1986). Bennett (1989) confined his hauls to the southern corner of Fish Hoek Beach and larval and post-larval fish abundance has been shown to vary laterally in the surf zone (Lyons 1986, Whitfield 1989). In addition, time of day, tides, wave height, wind speed, water temperature and wind direction are all known to influence fish abundance directly or indirectly (Lasiak 1984, Romer 1986, Ross *et al.* 1987, Bennett 1989). It is possible that the differences in catch size between this and Bennett's (1989) study reflect spatial and temporal changes in absolute abundance of the ichthyofaunal assemblage at Fish Hoek Beach. However, this statement cannot be substantiated because the capture efficiency of the nets (Lyons 1986, Parsley *et al.* 1989, Pierce *et al.* 1990), a parameter essential to the estimation of absolute abundance, was not determined in either of the two studies.

The 32 species recorded in the cover net included all of the 15 recorded in the control net. This suggests that the additional 17 species possibly originated from beyond the first 100 m of surf zone. The comparatively high catch per haul in the cover net was a result of fish being herded in front of the commercial net until they were within 100 m of the shore, whereupon fish escaped en masse through the mesh of the commercial net (pers. obs.).

In all, 12 species caught in the cover net during this experiment had not been recorded in 311 commercial hauls monitored during 1991 and 1992 in False Bay (Lamberth *et al.* 1994). At least one of them, *Draculo celetus*, was a new distribution record for the South-Western Cape (P. C. Heemstra, J. L. B. Smith Institute of Ichthyology, pers comm.). Therefore, the method of hauling a cover net behind a commercial net may be a viable way of sampling ichthyofauna (juveniles and adults) over a wider area of surf zone without a corresponding increase in labour intensity. In turn, the species composition of the cover-net catch, when compared to that of the control net, warns of the dangers of extrapolating the results of inshore experimental netting to include the outer surf zone.

The high proportion of fish (95%) that escaped from the commercial net during this study may have been atypical. A total of 286 fish caught in the 11 commercial hauls was of "edible size", and five of them (*L. lithognathus* and kob *A. hololepidotus*) were of commercial value. Catches of *L. richardsonii* were below average (approximately 2 019 per haul; Lamberth *et al.* 1994), and their smaller numbers may have allowed a greater proportion of escapees. In addition, there were no catches of detrital macrophytes, which frequently line the commercial nets (pers. obs.) and effectively reduce mesh size, so preventing the escape of small and juvenile fish, during this study. In turn, large quantities of macrophyte material in the surf zone would offer refugia to, and so increase the abundance of, certain species in the seine area and net (Pierce *et al.* 1990). However, large quantities of detrital material in the net cause it to roll up and lift off the sea floor, allowing fish to escape under the leadline (pers. obs., Pierce *et al.* 1990).

Based on gill-net selectivity experiments, *Liza richardsonii* is recruited into the gill and beach-seine fisheries at a length of 208 mm, just less than its length at 50% maturity (Ratte 1976, De Villiers 1987). However, gill nets are hung to the full extent of their mesh size, whereas the 44-mm meshes of the commercial seine nets in this study were observed to be vertically reduced by the tension on the hauling ropes. As a result, the mean girth of fish at the 50% retention level is slightly above and slightly below the mesh size for gill and beach-seine nets respectively (Hamley 1975, Table II).

The 50% retention lengths of the "angling" species *L. lithognathus*, *D. sargus capensis* and *P. saltatrix* are below or approximately at their lengths at one year of age (Van der Elst 1976, Mann 1992, Bennett 1993). The 50% retention length of *Rhabdosargus globiceps* was before two years of age (Talbot 1955). Although these estimates of 50% retention are crude, they suggest that most of the "angling" fish component of beach-seine catches become vulnerable to capture within their first two years of life, well before they are sexually mature. Moreover, as they are well below minimum legal size, most of these fish are released.

The Theart Committee (Theart *et al.* 1983) recommended that the minimum mesh size of commercial beach-seine nets be raised from 44 to 50 mm to reduce the catch of juvenile "angling" fish (J. V. Petty, False Bay Trek-Fishermens' Association, pers. comm.). Assuming that the ratio of body depth to mesh size remains more or less constant, it is likely that "angling" species such as *L. lithognathus* and *P. saltatrix* would still be recruited into the beach-seine fishery well before they reached two years of age. The 50% retention length for *Liza richardsonii* by 44-mm mesh is ideal in that it corresponds to the species' length at 50% maturity (De Villiers 1987). The low ratio of body depth to length of *L. richardsonii* would ensure that its 50% retention length would be raised by at least 30 mm if a 50 mm mesh size were to be implemented, the likely result being a substantial reduction in the commercial catch of this species. It is also likely that there would be a decrease in the catch of juvenile "angling" fish. However, the fishermen could attempt to compensate for their smaller catches of *L. richardsonii* by increasing their targeting of adult "angling" species to make up for the reduction in the *L. richardsonii* catch. The overall result might well be an increase, as opposed to the intended reduction, of the landed catch of "angling" species.

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