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BYCATCH IN THE GILLNET AND BEACH-SEINE FISHERIES IN THE WESTERN CAPE, SOUTH AFRICA, WITH IMPLICATIONS FOR MANAGEMENT

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Interview questionnaires and access point surveys were conducted in order to describe and quantify the catch composition of the inshore net-fisheries in the Western Cape, South Africa. A total of 138 562 fish, representing 29 species from 20 families, was recorded in 141 monitored commercial gillnet fishing operations between February 1998 and October 1999. Numerically, the legal target species, harders *Liza richardsonii,* dominated the catches, contributing 94.87% of the total gillnet catch. Elf, *Pomatomus saltatrix,* horse mackerel *Trachurus trachurus capensis,* gurnard *Chelidonichthys capensis* and barbel *Galeichthys feliceps* were the most common bycatch species, and contributed 4.2% to the total catch numerically and occurred in 12–47% of the marine 44–64-mm gillnet catches that were monitored. Five species most frequently targeted by shore-anglers on the West Coast: galjoen *Dichistius capensis,* white stumpnose *Rhabdosargus globiceps,* hottentot *Pachymetopon blochii,* silver kob *Argyrosomus inodorus* and white steenbras *Lithognathus lithognathus*, also occurred in gillnet catches. Most of the bycatch consisting of immature, undersized fish that were often injured during entanglement and were not released alive. *L. richardsonii* also numerically dominated the beach-seine hauls that were monitored (>99%) with only four bycatch species being recorded in low numbers. Beach-seine questionnaire respondents, however, reported sporadic catches of at least 17 bycatch species, including occasional appreciable catches of the important linefish species *L. lithognathus* and *A. inodorus*.

Key words: beach-seine, bycatch, catch composition, gillnets, fishery management, inshore netfishing

Bycatch in net-fisheries, particularly gillnet fisheries, is a global concern. Many recent international studies have focussed on identifying and quantifying catches by these fisheries, for example in Australia (Russell 1988), Ireland (Berrow 1994), Japan (Akiyama 1997), Korea (Han *et al*. 1997) and the United States (Bronte and Johnson 1983, Quinn 1988, Hale *et al*. 1996, Julian and Beeson 1998). In South Africa, limited subsistence gillnet fishing is permitted in the Kosi Lakes (Kyle 1999) and St Lucia (Mann 1995, 1997) estuarine systems in northern KwaZulu-Natal and to a lesser degree in the Eastern Cape (Lamberth *et al.* 1997). The Natal Sharks Board seasonally deploys large-mesh gillnets as a measure to reduce the risk of shark attacks along the KwaZulu-Natal coast (Compagno *et al*. 1989). Commercial-scale gill- and beach-seine netting is, however, largely confined to the Western Cape Province of South Africa. Catches by the inshore net-fisheries in this region have only been quantified for the beach-seine fishery in False Bay (Lamberth *et al.* 1994) and gillnet catch composition is largely unknown.

Conflict between net-fishers and other users of inshore fish resources, particularly recreational and commercial linefishers, is not a recent phenomenon in the Western Cape. As early as 1895, political pressure by linefishers, who felt that gillnets were decimating linefish stocks, particularly geelbek *Atractoscion aequidens*, resulted in action been taken against gillnet fishers in Table Bay (Thompson 1913). As recreational angling grew in popularity, there was increasing public concern over large net catches of what were perceived to be "angling" fish species, such as galjoen *Dichistius capensis* (Anon. 1949, De Villiers 1987, Penney 1991, Lamberth 1994). Concern about inshore net-fishing was addressed in several reports (Yeats *et al.* 1966, Treurnicht *et al.* 1980, Theart *et al.* 1983, Stander 1991) and scientific studies (De Villiers 1987, Penney 1991, Clark *et al.* 1994a, b, Lamberth *et al.* 1994, 1995a, b, c). As a result, by the early 1980s, numerous management measures had been implemented. These included a reduction in overall netting effort, a restriction of gillnetting to the West Coast north of Melkbos Point, a permit system that required permit holders to submit daily catch returns, and numerous gear restrictions (De Villiers 1987, Stander 1991, Lamberth *et al.* 1997). Furthermore, gillnet and beach-seine permits in the Western Cape, with the exception of False Bay, were awarded solely for the capture of harders *Liza richardsonii* and St

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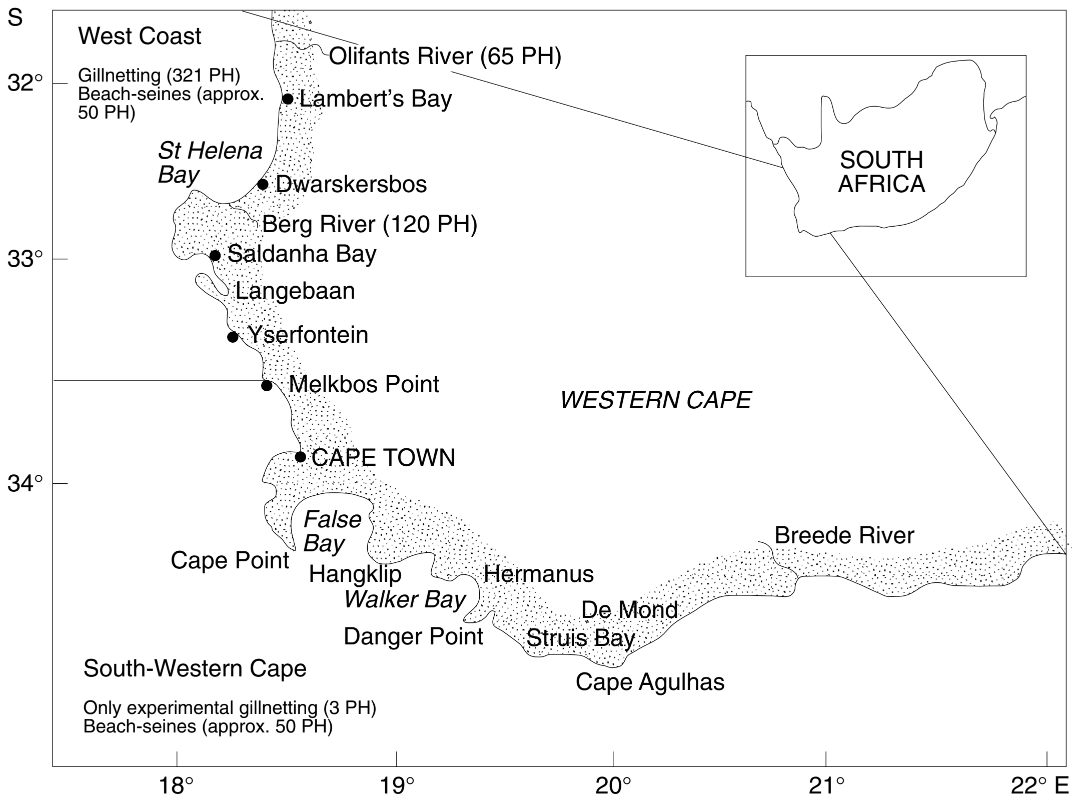

Fig. 1: Map of the Western Cape showing current location of the net-fisheries and other places mentioned in the text. PH = permit-holders

Joseph sharks *Callorhinchus capensis*. The targeting or catching of linefish species was prohibited.

In spite of these regulations, conflict between recreational anglers and the net-fishers is likely to continue to increase in the Western Cape. As angler numbers are increasing, linefish stocks targeted by these fishers are decreasing, and they are also caught as bycatch in the net-fisheries (Bennett 1991, van der Elst and Adkin 1991, Lamberth 1994, Attwood and Farquhar 1999). However, recent studies have shown catch returns submitted by net-fishers to be inaccurate, with up to 90% of the effort and catch, particularly of bycatch species, not reported (Lamberth *et al.* 1994, 1997). Lamberth *et al.* (1997) concluded that knowledge of the South African beach-seine and gillnet fisheries was poor and stressed the importance of quantifying the catch composition and catch rates in the fishery before any future management decisions were made, particularly with respect to any expansion of the fishery.

This study was conducted with the overall objective of providing scientific information relevant to the management of the gillnet and beach-seine fisheries in the Western Cape. Its primary aims were to provide quantitative estimates of total catch and effort, to assess the current and potential future importance of bycatch in the fisheries, to describe the socio-economic status of participants and to evaluate the management measures currently in effect. This paper describes the catch composition of the inshore net-fisheries during 1998 and 1999 and assesses the importance of bycatch in the fisheries. Estimates of total catch and effort for the fisheries are provided in Hutchings and Lamberth (2002a) and the socio-economic characteristics of net-fishers are described in Hutchings and Lamberth (2002b). The possible impacts of an eastward expansion of the gillnet fishery in the Western Cape, a likely scenario with political pressure encouraging increased access to marine resources, are investigated in Hutchings and Lamberth (in press).

MATERIAL AND METHODS

Fishing methods

Beach-seine fishing has remained essentially unchanged since the technique was introduced to South Africa during the mid 1600s. The only technological improvements in the fishing gear relate to the use of woven nylon rather than cotton nets, glass-fibre dinghies and four-wheel drive vehicles to transport the rigs on sandy beaches. Beach-seines are mobile fishing gears that are usually rowed out, under the directions of a spotter, into the surf zone to encircle a shoal of fish. A crew of 6–30 persons, depending on the size of the net (up to 275 m long) and the length of the haul, then hauls the net, attached to head ropes, shorewards. As the net approaches the shore, the ends or wings of the net are bought together, and the trapped fish are driven into the bag or "kuil" in the middle of the net. Occasionally, nets are not deployed under the guidance of a spotter and a "blinde trek" or "blind seine" is made in areas or at times when fish are likely to occur. Smaller 50–100 m beach-seine nets may also be deployed without the use of a rowing boat, by walking them out into the surf to encircle fish. A beach-seine net used in this manner is locally referred to as a "voetseën" or "foot net".

Gillnetting is normally a passive form of fishing in which nets are deployed (usually from a boat) in the water in the hope that fish will swim into them and become entangled. Gillnets used for catching *L. richardsonii* in the Western Cape are positively buoyant, may not be anchored at both ends or left unattended, and are referred to as drift nets. Gillnets used to target *Callorhinchus capensis* are negatively buoyant, are set along the seabed and are buoyed and anchored at both ends. Gillnets illegally used by fishers to target linefish, e.g. *D. capensis*, are also negatively buoyant, but are often staked overnight or set without marker buoys to avoid detection.

Although cotton and multifilament braided nylon mesh was used in the past, all the gillnets observed during this study were made of monofilament mesh. Monofilament mesh takes up more space in the fishing boat, is not as durable and hence requires more frequent repair than multifilament mesh but, because of its low visibility in the water, is widely accepted to be more efficient at catching fish (Hylen and Jakobsen 1979, Collins 1979, 1987, Grant 1981). Many commercial gillnet fishers have learnt to locate shoals of fish, using echosounders or spotlights at night, and employ a more active type of gill netting. Shoals may be completely encircled, or the nets are set in a semicircle in the path of the shoal. The fisher then scares the fish into the net by increasing the revolutions of the outboard motor and completing the circle behind the shoal.

Study area and current location of the netfisheries in the Western Cape

Netfish catch composition was assessed along the Western Cape coast between the Olifants and the Breede rivers (Fig. 1). Approximately 321 gillnet permit-holders are licensed to operate in the sea (marine permits) on the West Coast to the north of Melkbos Point, and an additional 185 permits are issued for the Olifants and Berg River estuaries (Fig. 1). In all, 73% of all marine gillnet permit-holders operate in St Helena Bay and may legally use a maximum of four 75-m floating "harder" (44–64 mm stretch mesh) or sinking "St Joseph" (178 mm stretch mesh) nets, although each net must be licensed. Fishers north of St Helena Bay may obtain permits for up to four "harder" nets, but most (78%) use only one, whereas the 10 Saldanha Bay permit holders may use two 75-m "harder" nets. Permit holders for Langebaan Lagoon, the Berg River and Ysterfontein are only allowed to operate one 75-m "harder" net, and Olifants River permit-holders are restricted to one "harder" net 35 m long. In areas where the number or length of nets is restricted, many permit-holders exceed these limits. There are approximately 100 beach-seine permit-holders within the study area, more or less equally distributed along the West and South-West coasts. Beach-seine nets are restricted to 137 m long to the east of Walker Bay and to 275 m to the west of it.

Survey methods

Information pertinent to the current legislation of netfishing activity was obtained from officials of Marine & Coastal Management (MCM), the South African National Parks (SANP) and Cape Nature Conservation (CNP). A list of all marine net permit-holders was obtained from MCM and a similar list for Langebaan Lagoon permit holders from the SANP. These lists were used as the sampling frame for the questionnaire survey (see Appendix 1 of Hutchings and Lamberth 2002b). The questionnaire survey was conducted both on-site, i.e. during monitoring of commercial netfishing operations, off-site at permit-holders' places of residence or work, and at the Annual General Meeting of the Berg River Net-fish Association. During interviews, fishers were asked to provide information on the number of trips they had undertaken in the previous week, month and 12 months,

Table I: Results of the bycatch component of interviews with gillnet fishers in the Western Cape, February 1998–October 1999. Results are presented as a percentage of respondents who acknowledged catching a particular species

Species	Respondents (%)			
	Doring–Elands Bay	St Helena Bay	Saldanha–Langebaan	Berg River
Pomatomus saltatrix	24	22	11	67
Trachurus trachurus capensis	18	18	9	3
Callorhinchus capensis	12	20	11	
Galeichthys feliceps	4	5	3	18
Mustelus mustelus				24
Dichistius capensis	13	9		
Rhabdosargus globiceps			16	
Chelidonichthys capensis	3	7	5	
Argyrosomus inodorus	4	3	5	
Lithognathus lithognathus	2	2	3	6
Thyrsites atun	7			
Pachymetopon blochii	6			
Spondyliosoma emarginatum			5	
Mugil cephalus				3
Cyprinus carpio				3
Sardinops sagax		3		
Diplodus sargus	3			
Others	4	7	8	
sharks		5		
Number of interviews	41	61	16	42

the species of fish caught and the average daily catch rates for these species.

An Access Point Survey (APS) was undertaken during the period February 1998–October 1999. Sampling effort was concentrated at accessible landing sites and during times of high netfishing activity in order to obtain sufficient samples, within the limited manpower and budget available. Any netfishing activity encountered fortuitously during the 16 two-week field trips and 10 two-day trips was also monitored. For all monitored landings, the total mass of the legal target species, *L. richardsonii* and *Callorhinchus capensis*, was estimated by counting the number of bins or individual fish. The total number of any bycatch individuals was also counted at the same time. The mass of fish contained in the different types of bins (mainly two types) was estimated by observing the weighing of bins of fish at factories. For *L. richardsonii*, conversions of mass to number and vice versa were made using a ratio based on the average number of fish per kilogramme landed in that area (the ratio varied from 5.7 to 7.8 fish kg^{-1} in the different areas). Where possible, all fish were measured to the nearest mm total length. If the size of the catch was very large, a representative sample (minimum 100 individuals) was measured. Differences in the average lengths of *L. richardsonii* landed by gillnet fishers in the different areas were tested by ANOVA and post-hoc Tukey HSD tests, using the STATISTICA software package (STATSOFT 1999). The boat registration number, number of crew, number of nets used and the hours fished were also recorded.

Data from the APS were converted to catch per unit effort (*cpue*) by the method recommended by Pollock *et al*. (1994) for complete trips:

$$Cpue = \frac{\left(\sum_{i=1}^{n} c_i\right)}{\left(\sum_{i=1}^{n} e_i\right)} \quad ,$$

where c_i is the number or mass (kg) of fish retained by the *i*th netfisher, e_i the effort expended by the *i*th netfisher and n is the number of landings sampled. In both cases the measure of effort was one trip or fisher-day^{-1}.

RESULTS

Gillnets

CATCH RATES AND COMPOSITION

In all areas, respondents to the questionnaire survey claimed that *L. richardsonii* was the most common species caught. Many respondents insisted that it was the only species caught, but others admitted to catching between six (Berg River) and 17 (St Helena Bay) bycatch species (Table I). Marine gillnetters, when targeting *L. richardsonii*, reported catching similar bycatch species in all regions, i.e. elf *Pomatomus saltatrix*, horse mackerel *Trachurus trachurus capensis,* St Joseph shark *Callorhinchus capensis* and gurnard *Chelidonichthys capensis*. However, Saldanha Bay and Langebaan Lagoon fishers claimed a fairly distinctive catch composition, with species such as houndshark *Mustelus mustelus*, white stumpnose *Rhabdosargus globiceps* and steentjie *Spondyliosoma emarginatum* being caught frequently. Estuarine permit-holders also claimed a very different bycatch, with all species except *T. t. capensis* having some degree of estuarine association. The claimed estuarine bycatch was dominated by *P. saltatrix* and included the alien freshwater carp *Cyprinius carpio*.

These data do not represent quantification of the abundance of different species caught, but rather the proportion of permit-holders who recall catching them, and is a measure of the occurrence of different species in net catches. As such, these lists are subject to recall bias, with permit-holders only naming the more memorable species they had caught. Furthermore, species may be have been incorrectly identified. For example, fishers often group elasmobranchs (sharks, skates and rays). Permit-holders also certainly deliberately refrained from mentioning catches of linefish, which are prohibited. Respondents were asked to estimate an average daily catch of these species, but they

Table II: Summary of information on species composition and abundance of all fish caught in 141 monitored gillnet fishing operations in the Western Cape during the period February 1998–October 1999. Percentage occurrence is the proportion of monitored landings where a particular species was recorded

Species	Number of fish landed	% of total	*Cpue* (number of fish day^{-1}) and (% occurence)			
			West Coast estuarine	West Coast marine		
			44–51 mm net	44–51 mm net	178 mm net	44–145-mm net†
Osteichthyes						
Ariidae						
Galeichthys feliceps	41	0.039	0.5 (12)	0.36 (12)		0.63 (25)
Galeichthys ater	1	<0.001			0.33 (33)	
Carangidae						
Trachurus trachurus capensis	3 259	3.111		33.59 (33)		0.13 (12)
Clupeidae						
Sardinops sagax	1	<0.001	0.13 (12)			
Coracinidae						
*Dichistius capensis**	137	0.131		0.32 (4)		13.25 (75)
Cyprinidae						
Cyprinus carpio	1	<0.001	0.13 (12)			
Gempylidae						
*Thyrsites atun**	1	<0.001		0.01 (1)		
Merluccidae						
Merluccius capensis	12	0.011		0.10 (3)	0.67 (66)	
Mugilidae						
Liza richardsonii	131 723	94.87	285 (100)	1 096 (96)		12.5 (12)
Mugil cephalus	3	0.003	0.38 (25)			
Pomatomidae						
*Pomatomus saltatrix**	1 009	0.963	27.4 (50)	8.14 (47)		
Sciaenidae						
*Argyrosomus inodorus**	26	0.025		0.20 (93)	0.33 (33)	1.89 (12)
Sparidae						
Lithognathus aureti	1	<0.001	0.13 (12)			
*Lithognathus lithognathus**	2	0.002		0.02 (2)		
*Pachymetopon blochii**	5	0.005		0.05 (1)		
*Rhabdosargus globiceps**	23	0.022		0.24 (8)		
Sarpa salpa	1	<0.001		0.01 (1)		
Spondyliosoma emarginatum	25	0.024		0.26 (4)		
Soleidae						
Austroglossus microlepis	4	0.004		0.04 (3)		
Triglidae						
Chelidonichthys capensis	87	0.083		0.73 (13)	5 (33)	0.13 (12)
Subtotal	133 987	99.29	313	1 140	6.33	28.53
Number of species	20		7	15	4	6

(continued)

Table II: *(continued)*

Species	Number of fish landed	% of total	*Cpue* (number of fish day^{-1}) and (% occurence)			
			West Coast estuarine	West Coast marine		
			44–51 mm net	44–51 mm net	178 mm net	44–145-mm net†
Chondrichthyes						
Callorhinchidae						
Callorhinchus capensis	2 169	0.674		1.46 (16)	252 (100)	1.75 (12)
Hexanchidae						
Notorynchus cepedianus	2	0.002			0.67 (33)	
Rajidae						
Raja alba	4	0.004			1.33 (66)	
Raja straeleni	1	<0.001			0.33 (33)	
Rhinobatidae						
Rhinobatos annulatus	6	0.006				0.75 (12)
Scyliorhinidae						
Haploblepharus edwardsii	1	<0.001		0.01 (1)		
Haploblepharus pictus	2	0.002				0.25 (12)
Squalidae						
Squalus megalops	2	0.002		0.02 (1)		
Triakidae						
*Mustelus mustelus**	13	0.012		0.09 (3)	1.33 (33)	
Subtotal	2 200	0.704	0	1.58	255.29	2.75
Number of species	9		0	4	5	3
Number of landings monitored	141		8	117	8	8
Total	138 562		313	1 141.58	261.62	31.28

* Linefish species
† Illegal nets confiscated by MCM inspectors

insisted that such catches were small and sporadic and that they could not supply any figures.

Accurate data on bycatch composition and catch rates could only be obtained by monitoring commercial landings. A total of 138 562 fish, representing 20 different families and 29 species (12 more than claimed by respondents), was recorded in 141 monitored, commercial gillnet fishing operations (Table II). The number of species caught (19) and overall *cpue* (1 142 fish day^{-1}) was greatest for 44–64 mm nets used in the sea. Only seven species, all teleosts, were recorded in the estuarine operations monitored, whereas nine species were recorded in both the 178 mm and "illegal" 44–145 mm (nets used without permits, or mesh sizes that were illegal) net catches monitored. Daily catch rates for estuarine 44–64 mm nets (313 fish day^{-1}) were much lower than for marine operations (1 142 fish day^{-1}, Table II). It must, however, be noted that the fishers in estuaries typically use only one 35–75 m gillnet as compared to the two to four 75-m nets used by legal marine operators, which means that the catch per net is similar. "Illegal" (44–145mm) net catches of teleosts were considerably greater than those made in the legal, larger mesh 178-mm nets, but more elasmobranchs are caught in 178-mm nets.

Numerically, *L. richardsonii* dominated the catches, contributing 94.87% of the total catch, occurring in all estuarine and 96% of the marine 44–64 mm net landings monitored (Table II). The other target species, *Callorhinchus capensis*, only contributed 0.67% numerically of the total catch, but occurred in all the 178-mm net, 16% of the 44–64 mm net and 12.5% of the "illegal" net landings monitored (Table II). *P. saltatrix* occurred in half the 44–64 mm net landings in estuarine and marine environments, whereas *T. t. capensis, Chelidonichthys capensis* and barbel *Galeichthys feliceps* occurred in more than 10% of the marine 44–64 mm net landings (Table II). *D. capensis* occurred in only 4% of the legal 44–64 mm net landings, but in 75% of the illegal nets monitored, showing the extensive illegal targeting of that species.

SIZE DISTRIBUTION OF GILLNET CATCHES

The size frequency distributions of *L. richardsonii* caught in commercial gillnet operations at different areas along the West Coast are shown in Figure 2. Significant differences were found between the average lengths of fish landed in the different areas ($F_{0.5, 5, 47}$ = 21.63, $p < 0.05$). Fishers in Langebaan Lagoon caught fish that were significantly larger on average than those

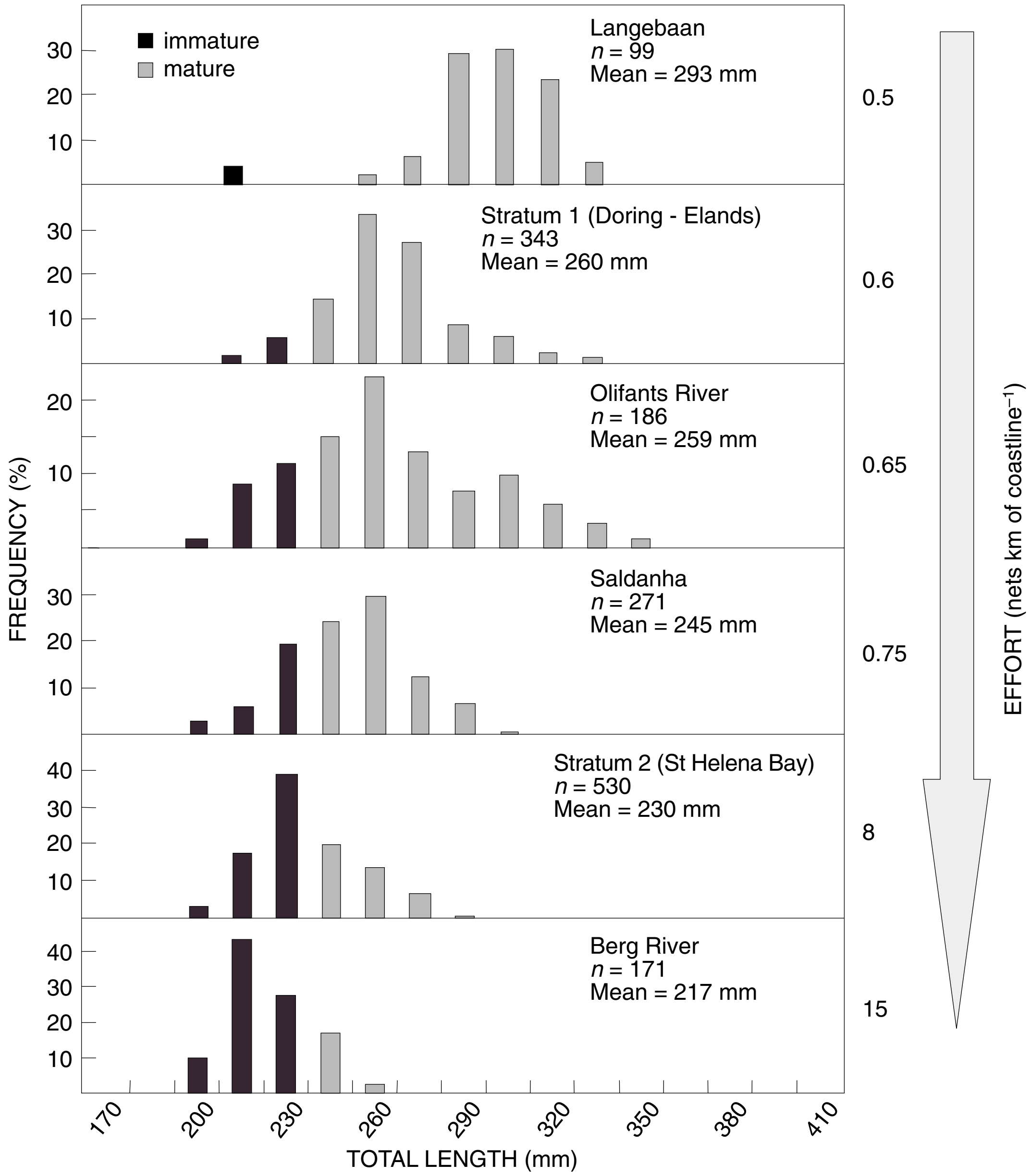

Fig. 2: Length frequency distributions of *Liza richardsonii* landed by commercial gillnetters in different regions. Potential effort levels are included for illustration

caught in any other area ($p < 0.05$). Size frequency distributions of *L. richardsonii* caught to the north of Dwarskersbos (Doring–Elands Bay) and the Olifants River were similar. The mean lengths of fish landed in those areas were not significantly different ($p > 0.05$), but were significantly larger than the average size fish landed in the heavily fished St Helena Bay and Berg River ($p < 0.001$). Generally, the mean lengths

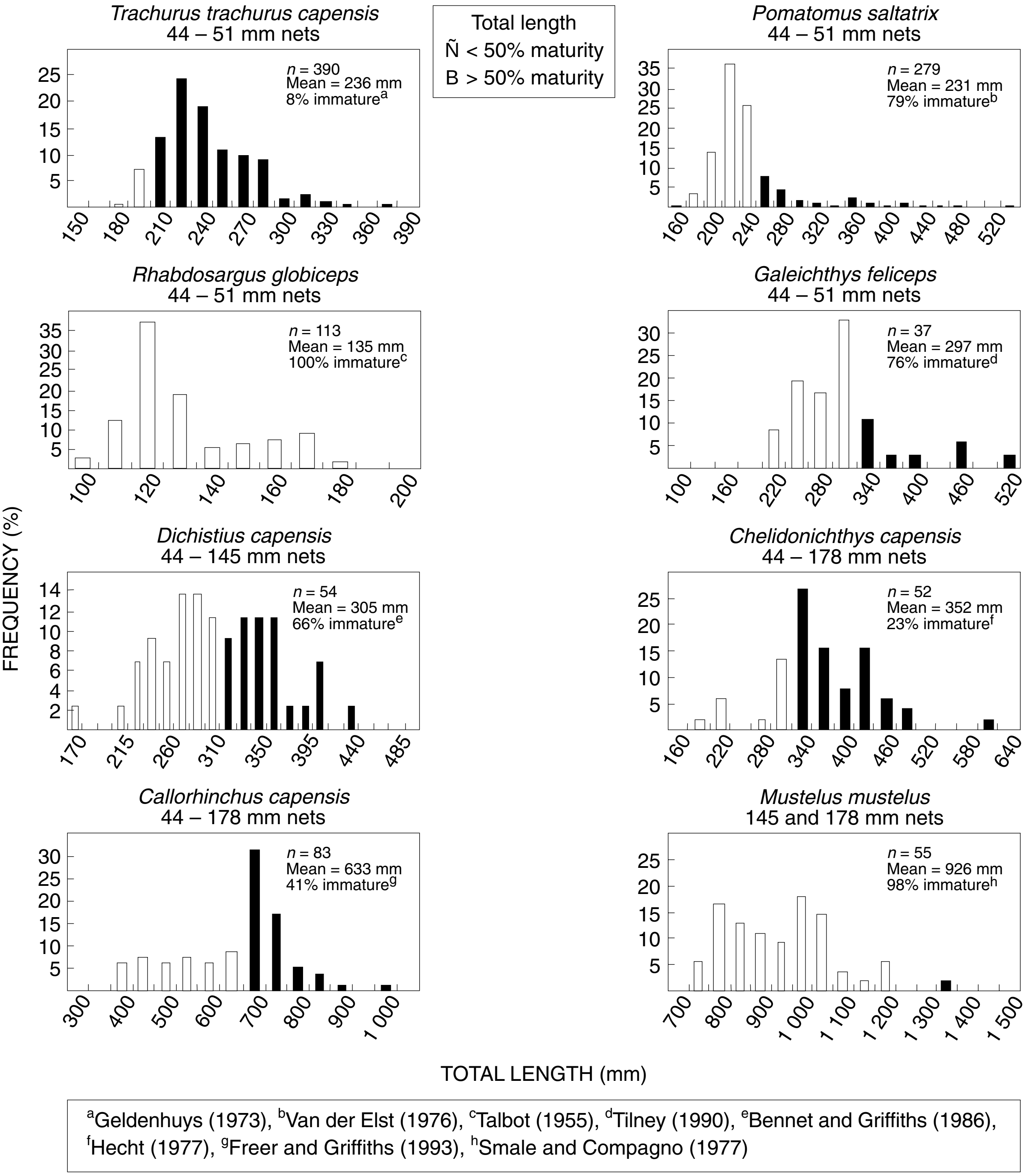

Fig. 3: Length frequency distributions of common gillnet bycatch species from the Western Cape (February 1998–October 1999)

of landed fish decreased, and the proportion of the catch that was immature increased, as gillnetting effort increased (Fig. 2).

Length frequency distributions of some of the more common bycatch species landed in commercial gillnets on the West Coast are shown in Figure 3. With the exception of *T. t. capensis*, catches of the most common bycatch species (*P. saltatrix*, *R. globiceps* and *G. feliceps*) in legal 44–64 mm "harder" nets consisted predominantly (76–100%) of immature fish. The catch of species that were caught in both the "harder" nets and the larger-mesh illegal (44–145 mm) and "St Joseph" (178 mm) nets consisted of both mature and immature individuals. The nets traditionally used to illegally target *D. capensis*, (with a stretched mesh of 145 mm) seldom retained them <350 mm total length (KH, pers. obs.). The high proportion (66%) of immature *D. capensis* in gillnet catches was partly because of the incidental capture of a few fish in legal 44–64 mm nets, but was mostly due to the increased use of smaller (75 and 100 mm stretch mesh) nets by illegal fishers. Although 73% of the *Chelidonichthys capensis* measured were caught in small mesh (44–64 mm) nets, nearly 80% of the individuals were mature. These fish were not usually "gilled" properly in the nets and were frequently entangled by their spiny head parts. Slightly more than half the *Chelidonichthys capensis* caught were mature. Mesh size has little size selective effect on these fish, the majority becoming entangled by the dorsal spine or the tentaculum of mature males. Some 98% of the *M. mustelus* landed were immature.

Beach-seine

Beach-seine permit-holders who were interviewed reported catching 17 different species in addition to *L. richardsonii* (Fig. 4). This list is subject to the same recall bias, possible misidentification of species and intentional deception as the species lists obtained for gillnets. Some respondents admitted to substantial landings of bycatch species; up to 500 kg of silver kob *Argyrosomus inodorus* and 3 tons of white steenbras *Lithognathus lithognathus* in individual hauls, and up to 8 tons of sardine *Sardinops sagax* and 10 tons of sandshark *Rhinobatos annulatus* per year. It was insisted, however, that large catches were rare and usual catches were in the range of 0–100 bycatch fish per day. Fishers reported very low or non-existent bycatch when they deployed their nets on shoals of *L. richardsonii* that had been spotted. However, bycatch was substantial when "blind" seines were made in the dark or made through patches of dirty water, or when valuable linefish species were intentionally and illegally targeted (KH pers. obs.).

Despite the fact that more than 170 days were spent in the field by researchers during the project, only nine beach-seine operations were monitored. Beach-seine fishers were simply operating too infrequently and for too short a time to be encountered. During these nine landings, nearly 7 tons of *L. richardsonii* were landed, but in most cases either no bycatch was landed or researchers arrived too late to assess the bycatch accurately. In the three hauls where the entire operation was observed, one haul had zero bycatch, the second landed one striped mullet *Liza tricuspidens* and one garrick *Lichia amia*, and the third landed 44 juvenile *R. globiceps* and one *P. saltatrix*. In all three cases, the bycatch was numerically <5% of the *L. richardsonii* catch. Because of the paucity of beach-seine monitoring, these figures are not considered representative of the fishery as a whole.

DISCUSSION

Four previous studies have dealt with the gillnet fishery in the Western Cape, but these were limited in scope, being restricted spatially to certain regions, or there was lack of accurate data on catches. De Villiers (1987) provided a broad overview of the fishery, but the study was based on reported catches of target species, *L. richardsonii* and *Callorhinchus capensis*, and did not provide a complete catch composition. Freer and Griffiths (1993) described the gillnet fishery for *Callorhinchus capensis* and observed a similar elasmobranch bycatch to that recorded during this study, but only reported *Chelidonichthys capensis* and Cape hake *Merluccius capensis* as teleost bycatch. Sowman *et al*. (1997) investigated the Olifants River fishery with the intention of developing a co-management arrangement between fishers and the management authority. Catch rates of *L. richardsonii* were provided, but mention was only made of three bycatch species that used to occur in catches and that "fairly large numbers" of *P. saltatrix* are still landed. Lamberth *et al*. (1997) described the status of South African beach-seine and gillnet fisheries on a national scale and attempted to validate reported catches of West Coast permit-holders, based on observed catches in 383 hauls by gillnets and beach-seine nets combined. Overall, only 3.6% of the observed catch of at least 10 different species were reported in that study. The current study has therefore provided the first complete description of catch composition and catch rates for the marine gillnet fishery.

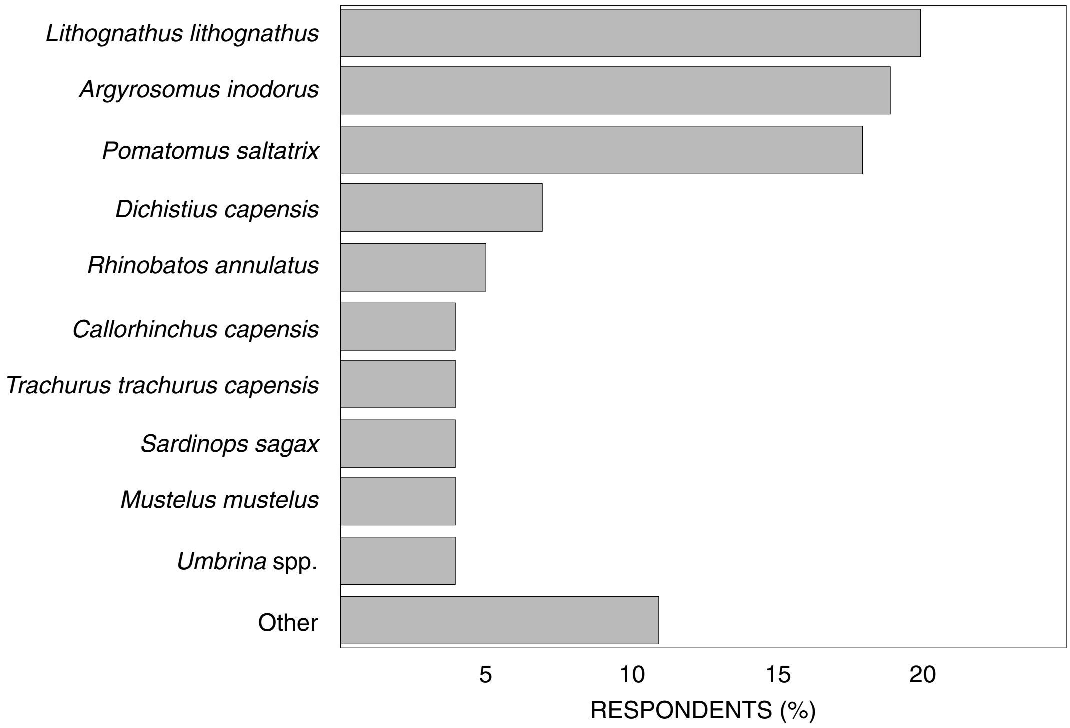

Fig. 4: Results of the bycatch component of interviews with 40 beach-seine permit-holders (excluding False Bay permit-holders) from February 1998 to October 1999. Results are presented as a percentage of respondents who acknowledged catching a particular species

Gillnet catch composition

For all net types monitored, the target species, i.e. *L. richardsonii* for 44–64 mm nets, *Callorhinchus capensis* for 178 mm nets and *D. capensis* for illegal 145 mm nets, were caught at much greater rates than any bycatch species (Table II). With the exception of *P. saltatrix,* the most commonly caught bycatch species in legal netfish landings, *T. t. capensis*, *Chelidonichthys capensis* and *G. feliceps*, are not usually targeted by shore-anglers. *Trachurus t. capensis* is the main target species of the midwater trawl fishery (Payne 1989) and an experimental inshore trawl fishery (3–5 boats) for *Chelidonichthys capensis* was attempted during the early 1990s in St Helena Bay (J. E. van Zyl, West Coast Netfish Association, pers. comm.). Cape hake *Merluccius* spp. and snoek *Thyrsites atun* are principal catch components of the demersal trawl fishery (Payne 1989, Payne and Badenhorst 1989), whereas *S. sagax* is one of the most important purse-seine target species (Armstrong and Thomas 1989). *T. atun* and hottentot *Pachymetopon blochii* are the two most important species in the commercial boat-based linefishery on the West Coast (Sauer *et al.* 1997). Although all these species occurred in monitored gillnet landings, their catch rates were very low and can be regarded as insignificant when compared to the catches made by the larger industrial fisheries.

The legal target species *L. richardsonii* (94.87%) and *Callorhinchus capensis* (0.67%) as well as *T. t. capensis* (3.1%), which are classified as bait species, contributed 98.65% numerically to the total gillnet catch (138 562 fish) monitored during this study. Of the remaining 26 species, eight species (see Table II) that can be considered important to the recreational and commercial linefisheries (Penney *et al.* 1989, Brouwer *et al.* 1997, Sauer *et al.* 1997) made up only 1.15% numerically of the total catch. Hale *et al*. (1996) concluded that the extremely low bycatch (<1%) in the striped mullet *Mugil cephalus* gillnet fishery (Florida, USA) would "obviously have no impact on the game fish populations in a system as large as the St Johns River". Total annual effort in the St Johns River fishery, however, was 1 554 days, and it would be incorrect to draw a similar conclusion for the South African west coast gillnet fishery, which has a total annual effort of approximately 25 000 days (Hutchings and Lamberth 2002a).

Catch rates of "shore-angling" species in legal gillnets were very low relative to catch rates of target species. However, these catch rates are appreciable when compared to the West Coast shore-angler *cpue* of 0.94 fish angler^{-1}day^{-1}, as estimated by Sauer and Erasmus (1996). The five species (*D. capensis*, *R. globiceps, P. blochii*, *A. inodorus* and *L. lithognathus*) most often targeted by shore-anglers on the West Coast (Brouwer *et al.* 1997) are bycatch species in the commercial and predominantly illegal netfish catch. The combined catch rate of these species in legal gillnets (1.16 fish day^{-1}) is similar to the shore-angler catch rate, but the illegal net catch rate (15.14 fish day^{-1}) is much greater than that achieved by shore-anglers. Although not extensively targeted by shore-anglers on the West Coast, *P. saltatrix* is a popular angling fish along the South and East coasts. West Coast gillnet catch rates of this species (8.14–27.4 fish day^{-1}) exceed shore-angler *cpue* for all species combined (1.18–2.06 fish angler^{-1} day^{-1}, Brouwer *et al.* 1997). The implication of the much greater catch rates of linefish species by gillnetters compared to recreational shore-anglers is that the total estimated linefish catch by netfishers potentially exceeds that made by shore-anglers, despite the much lower total effort estimate for the former (see Hutchings and Lamberth 2002a).

Conflict between commercial netfishers and recreational shore-anglers is not unique to South Africa. In the United States of America, as long ago as 20 years, such conflict was escalating in freshwater (Quinn 1988) and the marine environment (Moore 1980). Local or state legislation was adopted with the aim of reducing such conflicts, primarily by restricting the use of gillnets both in time (closed seasons) and space (closed areas; Moore 1980). Restricted areas were particularly effective in reducing gamefish bycatch in Lake Seminole, Georgia (Quinn 1980). In the Papua New Guinea, gillnet fishery for barramundi *Lates calcarifer*, the use of certain mesh sizes is banned during peak periods of juvenile migration (Milton *et al.* 1998). This management measure is aimed at reducing fishing pressure on the juvenile population of the target species, in the hope that it will lead to an increase in the adult spawning population. The commercial gillnet fishery for *L. calcarifer* in Australian estuaries appears to have little impact on non-target estuarine icthyofauna, which is mostly small juvenile fish (Ley *et al.* 1999). This is possibly owing to the selection effect of the large (150 mm) mesh sizes used in the fishery (Ley *et al.* 1999). The Kosi Lakes gillnet fishery in northern KwaZulu Natal, South Africa, is also managed by a combination of gear restrictions and closed areas. These measures aim to decrease the proportion of non-target species in gillnet catches, decrease conflict with recreational anglers and traditional trap-fishers and limit interference with fish migrations (Kyle 1999).

In the Western Cape, most legal netfishers understandably believe that their bycatch of "linefish" is negligible when compared to their *L. richardsonii* catches or the collective catches made by the more numerous shore-anglers. Furthermore, they argue correctly that the catch is unintentional and mortality of the bycatch is often unavoidable, given the nature of the fishing operation. Mesh size regulations currently in force are aimed largely at reducing mortality of adult "linefish" and maximizing catch rates of the target species. An attempt is made to limit juvenile bycatch by means of size limits, closed seasons, bag limits and sales bans. Enforcement of these regulations relevant to "linefish" bycatch in netting operations is, however, almost non-existent (KH pers. obs.). An increase in enforcement would certainly encourage fishers to reduce bycatch levels, either by moving from areas where bycatch is high or by returning more non-target and undersized fish to the water. Historical and anecdotal evidence suggests that net catches of "linefish" were much greater in the past (Thompson 1913, Biden 1954, Bennett 1988, 1993) and that the current low catch rates are a reflection of the current overexploited status of most South African "linefish" (Attwood and Farquhar 1999, Griffiths 1999). The gillnet fishery in the Western Cape is subject to a closed area restriction (limited to the West Coast) and this is probably the most effective management measure for reducing the impact of gillnetting on "linefish" stocks (Hutchings and Lamberth in press).

Size frequency distributions of net catches

Gillnets actively select fish of a certain size, as a function of mesh size and fish morphometrics, whereas the thickness, composition and colour of net twine, hanging ratio and method of fishing may also affect selectivity (Dalzell 1996). A theoretical catch frequency distribution should follow a normal bell-shaped curve (Holt 1963), with the left slope of the selectivity curve representing small fish wedged bodily in the mesh and the right slope representing larger fish mainly tangled by head parts. A result of this is that, in small mesh 44–57 mm gillnets, much of the bycatch (which often have deeper body profiles than the elongate target species *L. richardsonii*) is undersized, immature fish. These small bycatch fish have little financial value to the fishers themselves, but are usually dead in the nets by the time the boat docks and are taken as food by impoverished helpers ("stropers") who clean the nets. Legal large-mesh (178 mm) and "illegal" (70–145 mm) nets, however, catch much larger fish, particularly sharks. These more valuable fish are retained by the fishers either for their own consumption or for sale.

The concern surrounding the capture of juvenile fish is that potential yields are reduced by growth overfishing, or if insufficient fish in the affected population survive to maturity, recruitment overfishing may occur (Bohnsack and Ault 1996). Clark *et al*. (1994b) showed that the beach-seine fishing mortality on juvenile teleosts in False Bay was insignificant when compared to the rates of natural mortality the size-classes captured. In the current study, although much of the 44–64 mm gillnet bycatch was immature, the average size of fish was greater than that in the False Bay study. Most of these fish had already survived the early, highly vulnerable juvenile stage by the time they were captured in 44–64 mm gillnets, so it is likely that the fishing mortality is significant relative to natural mortality for these size-classes. Bycatch in the larger mesh "illegal" gillnets and 178 mm "St Joseph" gillnets often consists of large, mature fish, and such catches certainly affect adult mortality rates for these species. Beach-seine operators in certain areas on the West and South-West coasts suggested that the intentional targeting of aggregations of valuable, over-exploited species such as *L. lithognathus* and *A. inodorus* (Bennett 1993, Griffiths 1997) does occur. The large illegal catches of these species in beach-seine hauls, although sporadic and by just a few operators, would contribute substantially to the total fishing mortality for these species (Bennett 1993).

Analysis of size frequency distributions of *L. richardsonii* caught in commercial netting operations suggests that the stock is regionally overexploited. In St Helena Bay, Saldanha Bay and the Berg River, areas with high netfishing effort, the average size of fish caught is significantly smaller than elsewhere on the West Coast, where netfishing effort is less (Fig. 2). This suggests that fishing mortality in the intensively fished areas is currently high relative to recruitment, with very few fish at liberty above the minimum size selected for by the nets. Such reductions in numerical abundance and decreases in mean size of species selectively targeted by a fishery are often documented effects of intensive fishing pressure (Law 1991, Boehlert 1996, Jennings and Lock 1996). However, the evidence is not conclusive, because size-specific spatial variations may simply be related to natural distribution patterns (Jennings and Lock 1996). Furthermore, fishers who operate in St Helena Bay and the Berg River use nets of smaller (44–48 mm) mesh more regularly than do fishers elsewhere, and net selectivity must be at least partly responsible for the observed size frequency distributions. Fishers obviously select mesh sizes to maximize their catches, but it is not known if small-mesh nets have always been used in these areas, or if fishers have reacted to declining catch rates. There have been attempts by the Berg River Net-fish Association to encourage members to use larger mesh sizes and thus decrease the current catch of juvenile *L. richardsonii*, which they perceive to be a threat to the resource (J. V. F. Heydenreich, Berg River Netfish Association, pers. com.).

The occurrence of particularly large *L. richardsonii* in Langebaan Lagoon is not a recent phenomenon. Using otoliths found in archeological digs, Poggenpoel (1996) determined the length frequency composition of *L. richardsonii* catches made by the Dutch at Langebaan Lagoon and Table Bay (Cape Town). Even 200 years ago, the fish caught at Langebaan Lagoon were considerably larger than those caught elsewhere. The reasons for the occurrence of large *L. richardsonii* in Langebaan Lagoon could be related to the availability of food and the relatively high water temperature, allowing faster growth. In order to maximize their catch rates, gillnet fishers in Langebaan Lagoon use nets with large mesh (57–64 mm), so it could be argued that the larger meshes explain the observed greater size of fish caught. However, experimental gillnetting conducted during this study, using smaller (48 mm) mesh nets, landed fish of a similar size (mean length 27 cm) to those landed in commercial operations (mean length 29 cm), although catch rates were lower because the fish were too large to "mesh" properly.

Beach-seine catch composition

Lamberth (1994) recorded 66 species from 34 families in 311 beach-seine hauls that he monitored in False Bay. Although False Bay permit-holders have an exemption to catch "linefish", only three species are intentionally targeted, *L. richardsonii*, *L. lithognathus* and yellowtail *Seriola lalandi* (Lamberth 1994). Given that the remaining 63 species caught in False Bay are unintentional bycatch, it is reasonable to assume that beach-seine nets in other regions east of False Bay, although not permitted to target "linefish", will have a similar catch composition. Species richness of fish along the West Coast is, however, much lower than east of Cape Point (Turpie *et al*. 1999), and beach-seines along the West Coast should therefore land correspondingly fewer species.

Historical catch composition

Archeological evidence from the historical site Oudepost on the shores of Langebaan Lagoon, which was occupied by the Dutch during the 17th and early 18th centuries (Poggenpoel 1996), suggests that there have been considerable changes in the relative abundance of different fish species in catches there. Such changes are widely accepted as being some of the most likely detectable effects of fishing pressure (Jennings and Lock 1996). During an archeological dig at that West Coast site, Poggenpoel (1996) identified 20 taxa according to characteristic body parts. Numerically, >75% of the fish found at the site were linefish species, including *R. globiceps* (63%), *L. lithognathus* (8%), *A. inodorus* (3%) and *P. saltatrix* (1%). On the other hand, *L. richardsonii,* which currently makes up >90% numerically of the fish caught in the Lagoon, only contributed 21% of the catch 200 years ago. The well-documented "groot trek" that was made at Kleinbaai in December 1925 netted more fish than the Cape Town market could absorb (Krynauw and Moller 1994). That catch was not just a single species, but consisted of all types of fish, including many linefish. Biden (1954) also documents substantial net catches of "linefish" along the West Coast, including *L. lithognathus*, *R. globiceps*, *D. capensis*, *P. saltatrix* and *A. inodorus*. Although possible, it is unlikely that operators there were intentionally targeting linefish by using large-mesh seine nets. Historical records, for example the diary of Jan van Riebeck, always contain references to catches of *L. richardsonii* (Muller 1938), which would not have been made with large mesh nets. Many of the older netfishers who were interviewed also recalled making large catches of linefish as recently as 30 years ago.

CONCLUSION

In theory, net permits are issued solely for the capture of *L. richardsonii* and *Callorhinchus capensis*, and the landing of other species in nets is technically limited to 10 fish per day. However, these permit conditions are unrealistic and are often ignored. Bycatch species in excess of the limit often die in gillnets before fishers even notice them, and the financial rewards of keeping large linefish that are caught far outweigh the low risk of a fine. The number of species vulnerable to capture in gillnets and beach-seines, even along the West Coast where diversity is low, is far greater than reported. Individual gillnet and beach-seine net fishers can on occasion make much larger catches than linefishers. If management strategies aimed at rebuilding linefish stocks are to be successful, gillnet and beach-seine net bycatch and, more urgently, illegal gillnet catches, will have to be controlled through increased enforcement and education of fishers. Any management action that is likely to limit netfishers' access to fish in favour of other sectors must, however, take cognizance of the fact that the netfisheries have historically targeted a variety of species and have dominated the inshore fisheries on the West Coast since the turn of the century (Thompson 1913). Netfishers can therefore claim a traditional right to fish commercially with nets, and co-management initiatives to reduce bycatch are clearly therefore going to be better than confrontation.

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