S. Afr. J. mar. Sci. 24: 205–225
2002

CATCH-AND-EFFORT ESTIMATES FOR THE GILLNET AND BEACH-SEINE FISHERIES IN THE WESTERN CAPE, SOUTH AFRICA

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Total catch and effort for the inshore net-fisheries in the Western Cape, South Africa, were estimated by means of face-to-face questionnaire, telephone and access point surveys, analysis of factory records and compulsory catch returns. In most areas, gillnet fishing effort was confined to summer, with highest average catch per unit effort during months of low effort. Records of monofilament gillnet sales show that approximately 180 illegal nets are sold annually (20% of all sales). During the period 1994–1999, only 26 illegal mesh size nets were confiscated annually (14% of those sold) on average, indicating that few illegal fishers are apprehended. Beach-seine fishers appeared to operate opportunistically throughout the year along the West Coast, whereas South-West Coast permit-holders concentrate their activity during summer. Sources of survey error in effort and catch-rate estimation are discussed. Approximately 25 000 gillnet days and 3 200 beach-seine hauls made annually land around 6 000 tons of fish, substantially more than the mean annual reported catch of 1 369 tons. Comparison of observed or documented catches with compulsory catch returns confirmed that as little as 21% of the actual effort and only 8% of the fish caught are reported. Despite the fact that catches are much greater than those reported, the lower catch rates, smaller average size of fish caught and historical and anecdotal evidence suggest that the harder *Liza richardsonii* stock is regionally overexploited in areas with high fishing effort. It is concluded that the inshore net fishery in the Western Cape is oversubscribed in most regions and a reduction in latent and "recreational" effort is therefore recommended. A suitable reduction in total effort may allow the *L. richardsonii* stock to recover, reduce the ecosystem effects of the fishery by reducing the amount of bycatch and improve catch rates for *bona fide* commercial fishers. It would also facilitate improved monitoring and policing of the fishery and hopefully improve compliance with regulations.

Key words: beach-seine, catch-and-effort estimates, catch returns, gillnets, *Liza richardsonii*

Throughout the history of the inshore net-fisheries in the Western Cape, management has focused on resolving conflict among the net-fishers themselves and with other sectors, namely the pelagic, commercial and recreational line-fisheries (Thompson 1913, Penney 1991, van Sittert 1992, Lamberth 1994). Most management regulations were implemented in response to political pressure from other user groups and were based on the assumption that catch and effort were correctly reported (Lamberth *et al*. 1994, 1997). The average annual reported southern mullet (or harder) *Liza richardsonii* catch for the period 1974–1984 was 1 745 tons (De Villiers 1987), substantially more than the 1 368 tons reported for 1996–1997 (Lamberth *et al.* 1997), or the 778 tons reported for 1998–1999 (Marine & Coastal Management, unpublished data). This 65% reduction in the reported catch either reflects an increasing trend in under-reporting or indicates that the fishery is in decline or even has collapsed.

Recent studies, however, have shown catch returns to be inaccurate, with up to 90% of the catch and effort, particularly of bycatch species, not reported (Lamberth *et al.* 1994, 1997). Furthermore, permit-holders who operate in estuaries and in Langebaan Lagoon submit returns to different licensing authorities, and their accuracy has never been assessed. With the failure of the compulsory catch return system, and hence the sole means of monitoring catch and effort in the inshore net-fisheries, it was concluded that true catch and effort in the fishery were unknown and certainly exceed those reported (Lamberth *et al.* 1997). Opposition to net-fishing by the increasing population of recreational anglers continues to grow. In a recent questionnaire survey, 17% of the shore-anglers interviewed in the Western Cape felt that gill and beach-seine nets were the primary reason for the decline in shore-angling catches (Brouwer *et al*. 1997).

Scientific management of both the line- and net-fisheries requires accurate estimates of current catch and effort for both sectors. Recent nationwide surveys provided catch-and-effort estimates for both the boat-based linefishery and recreational shore-angling sectors (Sauer *et al*. 1997, Brouwer *et al*. 1997). This study aims to complement these surveys by providing similar

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Manuscript received August 2000; accepted August 2001

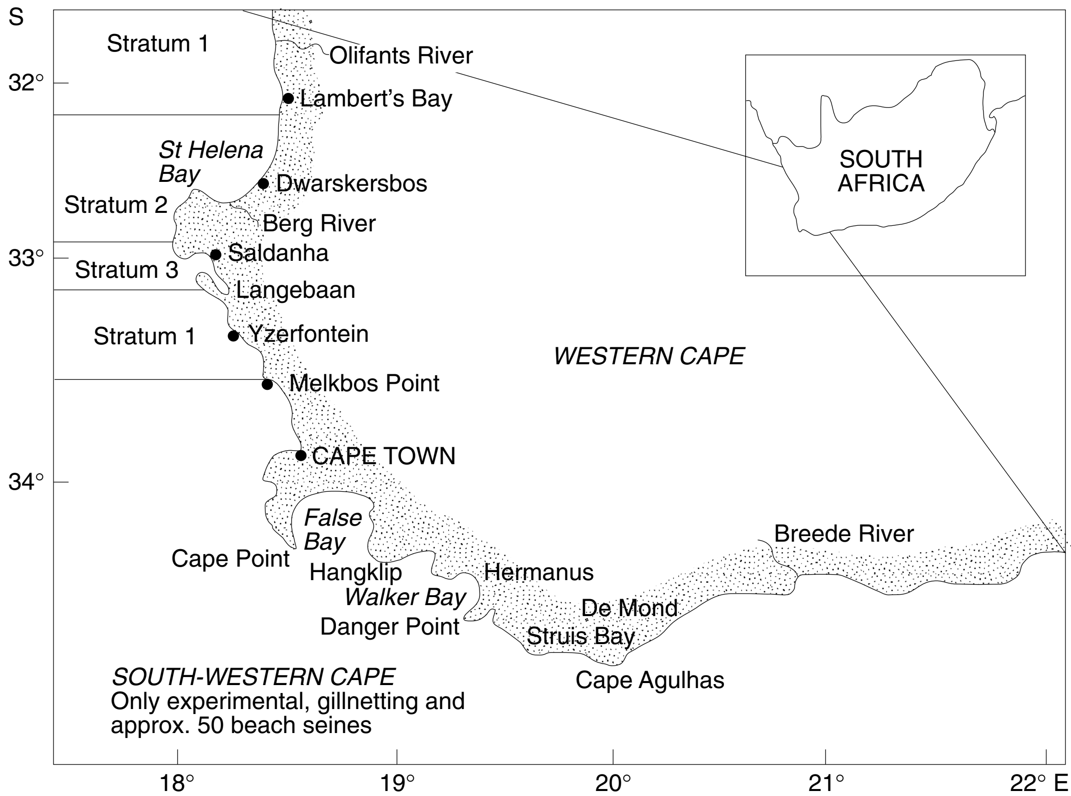

Fig. 1: Map of the Western Cape showing the areas for which catch and effort were assessed. Note that Stratum 1 includes the area north of St Helena Bay as well as south of Langebaan Lagoon

information on the commercial net fishery. In this study, a combination of on- and off-site survey methods and analysis of factory purchases were used to provide the first independent (of catch returns) estimates of total annual catch and effort for the net-fishery in the Western Cape. Spatial and temporal trends in catch and effort, the biases inherent in the different survey methods and the accuracy of these estimates are discussed.

MATERIAL AND METHODS

Study area

The stretch of the South African coast for which net-fish catch and effort were assessed is shown in Figure 1. The nature of catch and effort in the West Coast gillnet fishery was found to vary greatly over the region. Therefore, in order to improve the overall precision of the estimates, the marine fishery was divided into three strata and the estuarine fishery was assessed separately (Fig. 1). The beach-seine fishery within the study area was treated as homogeneous, with the exception of False Bay, where the fishery operates under unique permit conditions. Estimates of catch and effort for False Bay and the Olifants River were extracted from Lamberth (1994) and Sowman *et al.* (1997) respectively. The net-fishing methods and the current location of the fisheries in the Western Cape are described in Hutchings and Lamberth (2002a).

Survey methods

A list of all marine net permit-holders was obtained from Marine & Coastal Management (MCM), and a similar list for Langebaan Lagoon permit-holders from the South African National Parks, who manage the net fishery in the lagoon. These lists were used as the sampling frames for questionnaire and telephone surveys.

A detailed description of the questionnaire and access point surveys that were conducted is provided in Hutchings and Lamberth (2002a). Data on the gillnet fishery from these surveys were stratified after sampling. In the case of the telephone survey, the sampling frame was stratified prior to the survey with sampling effort proportionally allocated to each stratum. Permit numbers were randomly selected (computer generated random numbers) and each selected permit-holder was called back a maximum of three times. If no response was forthcoming, another permit holder was randomly selected. During the telephone interview, respondents were asked for the number of trips made and the total mass of fish of each species caught in the previous 12 months.

The average number of days fished annually claimed by telephone and questionnaire survey respondents were compared by means of *t*-tests (Zar 1996). The average daily catch rates claimed by questionnaire survey respondents, observed during monitoring and documented in factory sales books, were compared by means of a Kruskal-Wallis ANOVA by ranks using the STATISTICA software program (Statsoft 1999).

Vessel owners whose boat registration numbers were recorded during monitoring of commercial net-fish operations were identified. Positive matches of vessel owners with the names of net permit-holders allowed for comparisons of observed versus reported catches. Catches reported within one week of the observed landing were taken as correctly reported. To allow for observer error in the estimate of the quantity of fish landed, any weight reported within 33% of the observed catch was accepted as correct.

Factory records from two large buyers of net-fish in the Saldanha and St Helena Bay areas, containing the names of fishers, date of sale and quantity of fish sold, provided further accurate data for the estimation of catch per unit effort (*cpue*) and the validation of catch returns. Although these factory books mostly only documented purchases of *L. richardsonii*, several purchases of bycatch species were recorded and could be checked against reported catches. This method of validating catch returns is potentially very accurate in that the fisher, and not the boat owner, is identified. Also, because the quantity of fish is weighed accurately, only reporting of more, not less, fish than the weight sold is possible (if some fish were retained for own consumption or sold elsewhere).

To account for the possibility that a relative of the boat owner may have been using the vessel, or that the permit-holder or seller was misidentified, the catch returns submitted by all permit-holders with the same surname as the boat owner in the region were checked for matches. When permit-holders submitted returns, the reported *L. richardsonii* catch was compared to the monitored landing or the mass sold by means of a paired *t*-test (Zar 1996). A rough estimate of illegal net-fishing effort was obtained from sales of illegal mesh size (76–145 mm) nets and catch rates estimated from fish caught in confiscated nets.

Catch-and-effort calculation

Catch-and-effort estimates were calculated using the methods developed by Pollock *et al.* (1994). Net-fishing effort was estimated from the activity rates, claimed by respondents, to the questionnaire and telephone surveys. Total annual effort for each stratum was calculated as

$$\hat{E}_i = N_i \bar{e} i \quad ,$$

where $\hat{E}_i$ is the total annual effort for the *i*th stratum, N_i the number of permit holders in the *i*th stratum and $\bar{e}_i$ is the mean effort claimed by respondents in stratum *i*.

The effort variance for each stratum was calculated as

$$\mathrm{Var}\left(\hat{E}_i\right) = N_i^2 \,\mathrm{Var}\left(\bar{e}_i\right)$$

where

$$\mathrm{Var}\left(\bar{e}_i\right) = \left(\frac{N_i - n_i}{N_i}\right)\frac{s_i^2}{n_i} \quad ,$$

where n_i is the number of permit-holders interviewed in the *i*th stratum and s_i^2 is the sample variance.

Total annual effort and effort variance was obtained by summation of the values for each stratum:

$$\hat{E} = \hat{E}_1 + \hat{E}_2 + \hat{E}_3$$

$$\mathrm{Var}\left(\hat{E}\right) = \mathrm{Var}\left(\hat{E}_1\right) + \mathrm{Var}\left(\hat{E}_2\right) + \mathrm{Var}\left(\hat{E}_3\right) \quad .$$

In the case of the telephone survey, where respondents were asked for the total mass of fish captured in the previous 12 months, total catch and catch variance was calculated using the same method.

In the questionnaire survey, respondents were asked for their usual catch per trip, and the average of these values was used as the measure of *cpue*:

$$cpue = \frac{\sum_{i=1}^{n} c_i}{n} \quad ,$$

Table I: Marine gillnet catch and effort of *Liza richardsonii* and *Callorhinchus capensis* estimated by different survey methods

Parameter	Stratum 1: Doring–Elands + Yzerfontein (±*SE*)	Stratum 2: South of Elands – North Head (±*SE*)	Stratum 3: Saldanha–Langebaan (±*SE*)		Total (±*SE*)
Questionnaire survey					
Number of permit-holders	58	235	28		321
Sample (interviews)	37	46	16		99
Average annual effort (number of trips)	60 (±7)	77 (±9)	195 (±19)		
Total annual effort (number of trips)	3 494 (±235)	18 110 (±4 182)	5 470 (±342)		27 075 (±4 202)
Cpue of *L. richardsonii* (kg trip^{-1})	34 (±7)	112 (±21)	78 (±16)		
Annual catch of *L. richardsonii* (tons)	119 (±8)	2 023 (±402)	425 (±19)		2 567 (±403)
Telephone survey					
Sample (number of interviews)	12	48	10		70
Average annual effort (number of trips)	33 (±10)	52 (±8)	142 (±20)		
Total annual effort (number of trips)	1 900 (±500)	12 300 (±1 670)	4 000 (±458)		18 270 (±1 800)
Average catch (kg y^{-1} claimed)	858 (±296)	2 312 (±471)	15 925 (±4 793)		
Annual catch of *L. richardsonii* (tons)	50 (±15)	543 (±98)	446 (±108)		1 040 (±146)
Cpue of *L. richardsonii* (kg trip^{-1})	26	44	112		
Annual catch of *C. capensis* (tons)		290			290
Access point survey					
Telephone survey effort					
Sample (number of landings)	8	95	14		117
Cpue of *L. richardsonii* ((kg trip^{-1})	9.8 (±4.9)	159 (±18)	136 (±39)		
Range (kg trip^{-1})	0–40	0–1 008	0–550		
Annual catch of *L. richardsonii* (tons)	19 (±7)	1 949 (±284)	542 (±67)		2 510 (±292)
Annual effort of *C. capensis**		2 570			
Cpue of *C. capensis* (kg trip^{-1})		252 (±58)			
Annual catch of *C. capensis* (tons)		647			647
*Factory records***			Saldanha	Langebaan	
Telephone survey effort					
Sample (number of permit-holders)		30	3	6	39
Sample (number of sales)		312	48	354	714
Cpue of *L. richardsonii* (kg sale^{-1})		183 (±11)	280 (±48)	99 (±5)	
Range (kg sale^{-1})		3–1 149	17–2 198	5–693	
Annual effort (number of trips)	1 900 (±500)	12 300 (±1 670)	1 117 (±173)	2 808 (±309)	18 125 (±1 800)
Annual catch of *L. richardsonii* (tons)	19 (±7)	2 251 (±327)	313 (±57)	278 (±31)	2 861 (±334)

**C. capensis* gillnet effort estimated as 20% of *L. richardsonii* net effort, based on responses to telephone survey – catch rate based on eight monitored landings

** No factory records available, values from monitored landings. Only applicable to Stratum 1

where c_i is the average catch per trip claimed by the ith respondent and n is the number of net-fishers interviewed.

Data from the access point survey and factory records were used to calculate *cpue*:

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

where c_i is the number or weight (kg) of fish retained or sold by the ith net-fisher, e_i the effort expended by the ith net-fisher and n is the number of landings or sales sampled. In both cases the measure of effort was one trip or fisher-day.

Catch-rate variance for each stratum was calculated as the variance of the individual landings monitored or average catches claimed by questionnaire respondents using the standard formula for sample variance (Zar 1996):

$$\mathrm{Var}\left(cpue_i\right) = \frac{\sum_{i=1}^{n} c_i^2 - \frac{\left(\sum_{i=1}^{n} c_i\right)^2}{n}}{n-1} \quad ,$$

where c_i is the average catch of fish claimed by the *i*th respondent or the mass (kg) retained by the *i*th net-fisher and *n* is the number of net-fishers interviewed or landings monitored.

Total catch for each stratum was estimated by multiplying the total estimated effort by the *cpue*:

$$C_i = cpue_i \times E_i \quad ,$$

and the total catch variance as the product of the effort and catch variance:

$$\text{Var}\,(C_i) = \text{Var}(cpue_i) \times \text{Var}(E_i) \quad .$$

RESULTS

Catch-and-effort estimates

MARINE GILLNETS

The average number of fishing days per year claimed by gillnet permit-holders in all strata responding to the questionnaire survey was significantly greater than that claimed by respondents to the telephone survey (*t*-test, $p < 0.05$). Because of this, the total marine gillnet effort calculated from the questionnaire survey data (27 075 fisher-days) was substantially more than that calculated from the telephone survey data (18 270 fisher days; Table I). The telephone survey effort estimate was less clearly affected by survey error and bias (see discussion), and the data were used in conjunction with catch rates obtained from monitoring and factory records to estimate total catch (Table I).

Permit-holders from Stratum 2, contacted during the telephone survey, claimed to make an average of 52 trips in a year and catch in the region of 2.0–2.5 tons of *L. richardsonii* (Table I). This is equivalent to a daily catch rate of only 44 kg, substantially less than that claimed in the questionnaire survey (112 kg), observed during monitoring (158 kg) or calculated from factory sales (183 kg; Table I). Therefore, despite use of the same effort values obtained from the telephone survey, total catch estimated from catch rates on the basis of monitoring or factory sales are 2.5–3.0 times greater than the total catch estimated by the telephone survey (Fig. 2).

Average daily catches claimed by questionnaire survey respondents from Strata 2 and 3 were 30–70% less than the *cpue* calculated from monitored landings or factory sales, but the difference was not significant (Kruskal-Wallis ANOVA by ranks, $p > 0.05$). The lower catch rate, but higher effort, claimed by fishers in the questionnaire survey resulted in total catch estimates similar to those calculated with catch rates based on monitoring or factory sales and telephone survey effort (Fig. 2).

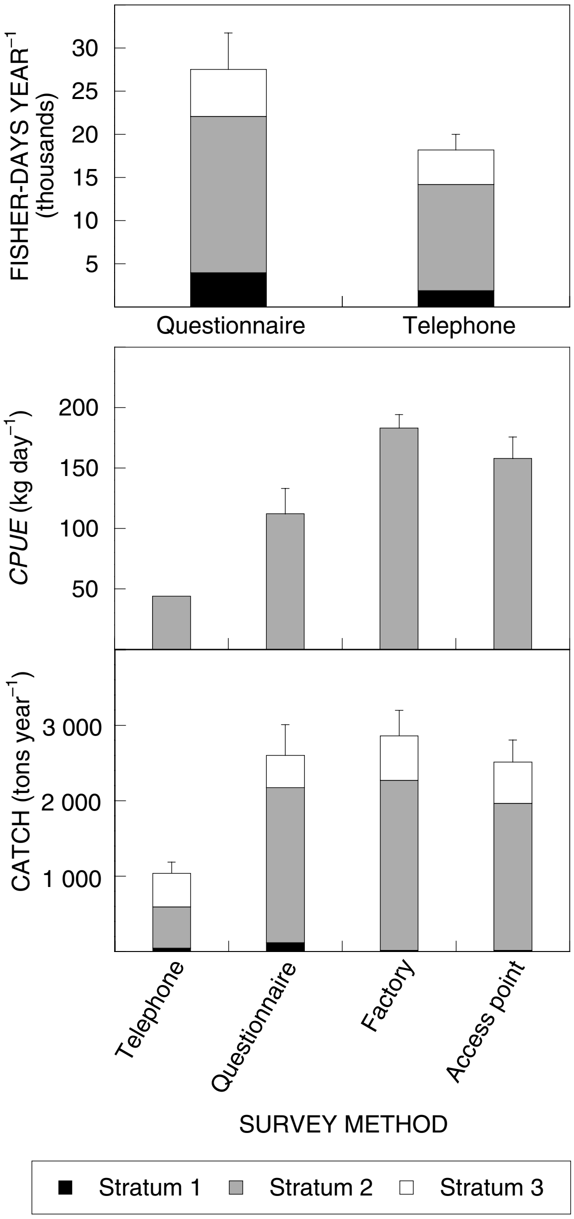

Fig. 2: Comparison of marine gillnet catch-and-effort of *L. richardsonii* estimated by different survey methods

Estimates of the total annual marine 44–64 mm gillnet landings of the more common bycatch species are shown in Table II. These estimates are based on ob-

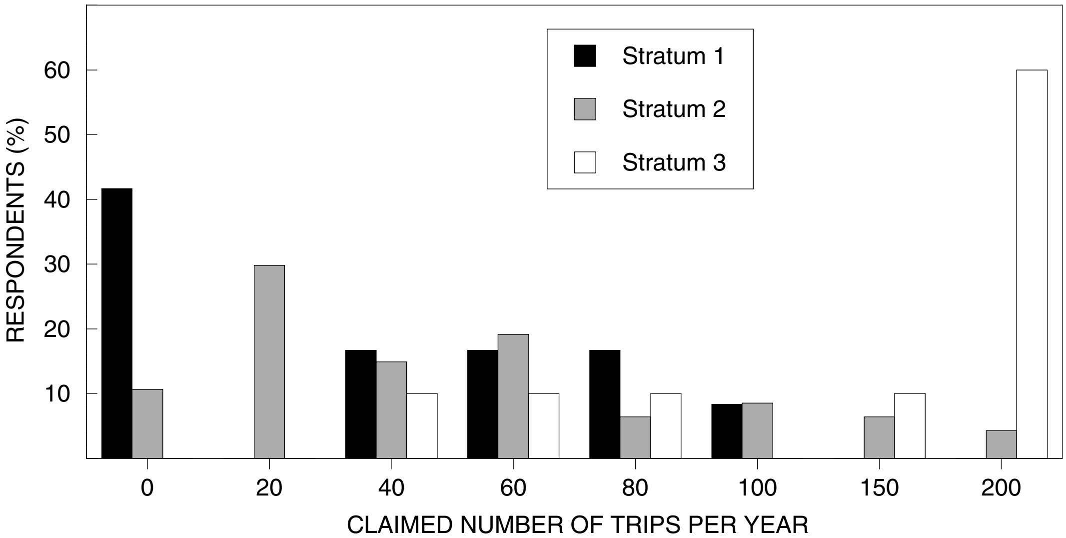

Fig. 3: Frequency distribution of annual effort claimed by gillnet respondents in the telephone survey

served catch rates in monitored landings and the effort levels claimed by net-fishers in the telephone survey.

The majority of permit-holders operate opportunistically in a small-scale commercial or recreational fashion, and a fair number have not been active at all (Fig. 3). Permit-holders fishing between Doring Bay and Elands Bay (Stratum 1) are the least active, whereas those operating between Saldanha and Langebaan (Stratum 3) claim to make the most trips. The widely varying activity rates of net permit-holders, some making no trips in a year and others claiming to make more than 200 (Fig. 3), is the cause of the high variances associated with effort estimates.

ESTUARINE GILLNETS

Olifants River permit-holders were not interviewed in the questionnaire or telephone surveys. Catch-and-effort estimates for this estuary were extracted from an earlier study by Sowman *et al*. (1997). In the Olifants River study, catch and effort were assessed as part of a co-management exercise and fishers were required to fill in catch cards with the assistance of a paid "shore skipper". Sowman *et al.* (1997) estimated that approximately 100 tons of *L. richardsonii* and 6–8 tons of bycatch, predominately juvenile elf *Pomatomus saltatrix*, were landed annually.

In all, 59 of the 120 fishers who received permits for the Berg River in September 1998 responded to the questionnaire survey conducted at the AGM of the Berg River Net-fish Association. However, only 27 respondents provided information on their anticipated fishing activity on the river. Those fishers anticipated making an average of 110 trips on the river during

Table II: Annual marine 44-64-mm gillnet bycatch estimated by access point survey and effort estimate from the telephone survey

Species	Common name	Percentage occurrence	Estimated number caught (*cpue*: number trip^{-1})			
			Doring–Elands + Yzerfontein	South of Elands – North Head	Saldanha–Langebaan	Total
Trachurus trachurus capensis	Horse mackerel	8.3–39	2 850 (1.5)	516 920 (42)	3 300 (0.83)	523 070
Pomatomus saltatrix	Elf	8.3–58		124 597 (10)	3 333 (0.83)	127 930
Chelidonichthys capensis	Gurnard	8.3–19.5		9 744 (0.79)	3 333 (0.83)	13 077
Galeichthyes feliceps	Barbel	13–17		5 271 (0.43)	1 125 (0.63)	6 396
Dichistius capensis	Galjoen	5.6		4 952 (0.40)		4 952
Rhabdosargus globiceps	White stumpnose	8–17		3 035 (0.25)	1 333 (0.83)	4 378
Spondyliosoma emarginatum	Steentjie	33			8 333 (2.08)	8 333
Mustelus mustelus	Houndshark	17		1 230 (0.5)	2 333 (0.58)	3 563
Pachymetopon blochii	Hottentot	12.5	1 188 (0.63)			1 188

Table III: West Coast estuarine catch-and-effort estimates of *L. richardsonii*

Parameter	Berg River		Olifants River
	Factory data (±*SE*)	Questionnaire data (±*SE*)	Sowman *et al*. 1997
Number of permit-holders	120	120	65 (+ 30 illegal)
Sample (permit-holders)	6	27	No data
Mean annual effort (trips fisher^{-1})	21.5 (±10.5)	110.2 (±6.2)	No data
Total annual effort (net-days)	2 580 (±1 205)	13 227 (±747)	No data
Sample (Number of sales)	136		No data
Mean *cpue* (kg trip^{-1})	37 (±3)		20–50 fish net-h^{-1}
Annual catch (tons)	95 (±44)	489 (±27)	100

the next six months, substantially more than the average number of factory sales (22) made by six of the river fishers for the season (Table III).

This huge discrepancy between the number of trips fishers anticipate making in a season and the number of sales documented means that the actual *L. richardsonii* catch from the Berg River could range between 100 and 500 tons (Table III). The most common by-catch in the Berg River, *P. saltatrix*, was in 50% of the landings monitored, at a catch rate of 27 fish per day; this translates into an annual catch of 70 692–362 420 fish (approximately 14–72 tons), depending on the effort estimate used. Given the greater number of permit-holders operating (120 v. 65) and the longer nets permitted (75 v. 35 m) in the Berg River compared with the Olifants River, it is reasonable to expect a greater annual catch in the former. On the other hand, a total annual catch in the Berg River, which is nearly five-fold the estimated annual catch for the similar-sized and apparently maximally exploited Olifants River, appears excessive. It is therefore highly likely that the Berg River permit-holders overestimated their effort levels during the questionnaire survey. The use of factory sales as a measure of effort, however, is also not reliable, because many catches may not be sold or may be sold to different buyers.

ILLEGAL GILLNETS

In 1984, the gillnet fishery targeting galjoen *Dichistius capensis* along the West Coast was banned, largely in response to recreational angler complaints and conservation and management concern over the status of the stocks (Bennett 1988). However, the now illegal fishery has continued, *D. capensis* gillnetting being much more lucrative than *L. richardsonii* netting. Black-market prices for *D. capensis* are in the region of R18–20 kg^{-1} compared with R2.5–3 kg^{-1} for *L. richardsonii.* Sauer and Erasmus (1996) estimated that approximately 50 gillnets of illegal mesh size were in use, mostly between St Helena Bay and Elands Bay. Information on the annual sales of monofilament gillnets, however, show that approximately 180 illegal nets are sold annually (Table IV).

In addition to *D. capensis*, illegal gillnet fishers target other valuable linefish species, such as kob *Argyrosomus spp*., hottentot *Pachymetopon blochii* and *P. saltatrix*,. During the past decade an illegal gillnet fishery for sharks, targeting smoothhound *Mustelus mustelus*, which fetches high export prices, has developed in Langebaan Lagoon, and anecdotal evidence suggests it is spreading to St Helena Bay. At least three net-fishers interviewed admitted to targeting *M. mustelus* in the Saldanha–Langebaan area. These fishers claimed catches of up to 800 kg per night or 20 tons per month over the summer. Illegal gillnetting is not only confined to the West Coast. Cape Nature Conservation recently confiscated two gillnets (one 75-mm stretch mesh, 450 m length; one 57-mm stretch mesh, 225 m length) set in Hermanus Lagoon. Anecdotal evidence once again suggests that illegal gillnetting in estuaries and the sea along the South-West Coast is extensive.

Although evidence of illegal netting was observed during monitoring of commercial net landings (fishers unloading illegal nets from vessels), no illegally caught fish were landed by those fishers. Fishers would obviously be more secretive when large illegal catches

Table IV: Approximate annual sales of monofilament gillnets and species targeted. Illegal mesh sizes are embolded

Stretched mesh size (mm)	Number sold annually	Species targeted
44	10	*Liza richardsonii*
48	60	*L. richardsonii*
51	60	*L. richardsonii*
54	50	*L. richardsonii*
57	80	*L. richardsonii*
64	60	*L. richardsonii*
76	50	*Argyrosomus* spp., *Pomatomus saltatrix*
100	50	*Dichistius capensis, Argyrosomus spp.*
145	80	*D. capensis, Mustelus mustelus*
178	80	*Callorhinchus capensis*
Total	580	

Table V: Illegal net-fish catch estimated from confiscated nets (effort = 1 800 days, estimated from annual net sales)

Species	Number confiscated	Percentage total	Percentage occurrence	Catch rate (number day^{-1})	Estimated catch of fish
Liza richardsonii	100	40	12.5	12.5	22 500
Callorhinchus capensis	14	5.6	12.5	1.75	3 150
Dichistius capensis	106	42	75	13.25	23 850
Argyrosomus inodorus	15	6.0	12.5	1.88	3 375
Rhinobatos annulatus	6	2.4	12.5	0.75	1 350

of linefish were made. The only estimates of illegal gillnet catch rates available were from the fish found in eight nets confiscated by MCM inspectors during the study period. A conservative effort estimate of 1 800 illegal gillnet-days (180 nets used 10 times per year) in conjunction with these catch rates give minimum estimates of illegally caught net-fish (Table V). It must be stressed that these are not a complete list of all illegally caught fish. Considering that illegal net sales make up 30% of all net sales annually (Table IV), and that these are only new or replacement nets, it is likely that actual illegal net-fishing effort is in the region of 5 000 net-days (about 30% of the estimated legal net fishing effort). However, this may be an overestimate, because illegal nets are often set over rocky substrata and catch larger fish than legal floating 44–64 mm nets; which means that they are more likely to be damaged and require more frequent replacement. These catch rates are, however, based on illegal net-fish operations that were apprehended, often staked nets that were recently set, and therefore had only a relatively short soak time. The more efficient net-fishers, who are not caught, probably have much higher catch rates. Only a small proportion of this illegal netting activity is apprehended, because most takes place at night in remote areas, and the MCM inspectorate has severe manpower and transport restrictions. Some 80 × 145 mm "galjoen" nets and 100 × 76–100 mm "barbel" nets are sold annually (Table IV), but in the past five years, only 119 of these nets have been confiscated (Table VI). The amount of fish confiscated (Table VI) is also negligible compared even with the minimum estimate of the amount being caught (Table V).

Gillnet catch rates of *L. richardsonii* along the West Coast generally exceed those recorded for inshore net-fisheries targeting small pelagic species in other regions globally (Table VII). The widely varying gear types and measures of *cpue* provided are not standardized, so when comparing catch rates, the net length and measure of *cpue* must be noted. Given that many West Coast gillnetters use the maximum permitted net length (300 m), it is apparent that standardized *cpue* in the region, where effort is high, is actually substantially less than that recorded for the South African south and east coasts, where gillnetting effort is low. This does not imply that gillnetting is more viable along the South and East coasts. At greater levels of effort, the current catch rates in those areas are unlikely to be sustainable and would probably decline to less than those currently recorded along the biologically more-productive West Coast.

BEACH-SEINE NETS

Beach-seine questionnaire respondents once again claimed a greater average number of trips annually than telephone survey respondents, but the difference was not significant (*t*-test, $p > 0.05$). Questionnaire respondents also claimed larger average catches than those observed at monitored landings, or documented in factory sales (Table VIII). Telephone respondents who were asked for a total catch over the previous 12 months claimed the lowest catch rates (Table VIII). The total annual catch estimates obtained using catch rates from monitored landings and factory sales and

Table VI: Nets and fish confiscated by Marine and Coastal Management inspectors on the West Coast during the period 1994–1999

Net Type	Number of nets confiscated	Mass/number of fish confiscated
"Harder" (44–57 mm)	241	7 945 kg *Liza richardsonii*
"Galjoen" (145 mm)	116	14 *Dichistius capensis*, 3 *Pachymetopon blochii*, 2 *Rhabdosargus globiceps*
"Shark" (145–178 mm)	3	50 *Mustelus mustelus*
"Barbel" (90–100 mm)	12	

Table VII: Comparison of South Africa's west coast gillnet catch rate and catch composition with those made in other regions (adapted from Dalzell 1996)

Location	Net length (m)	Mesh size (cm)	Target stock	*Cpue* Range	*Cpue* Mean	Principal catch components	Source
Kiribati	na	5.7–12.7	Reef and lagoon species	5.0–96.0 kg trip^{-1}	43.4 kg trip^{-1}	Albulidae Carangidae Mugilidae Mullidae	Anon. 1989
Solomon Islands	na	5–15	Reef and lagoon species	0.26–0.90 kg 100 m of net^{-1} h^{-1}	0.46 kg 100 m of net^{-1} h^{-1}	Sharks Chanidae Carangidae Mugilidae	Blaber *et al*. (1990)
Cook Islands	90–230	4.5–5.0	Small pelagic and reef fish	0.14–18.04 kg 10 m of net^{-1}	2.2 kg 10 m of net^{-1}	Carangidae Priacanthidae Mullidae Caesionidae	Chapman and Cusack (1989)
Fiji (Rabi Island)	150	1.9–7.6	Reef and lagoon species	15–26 kg set^{-1}	18.9 kg set^{-1}	Lethrinidae Lutjanidae Mugilidae Holocentridae	Anon. (1983a)
Fiji (Rotuma)	229	7.6	Reef and lagoon species	10.0–60.0 kg set^{-1}	31.8 kg set^{-1}	Mugilidae Carangidae Lutjanidae Lethrinidae	Anon. (1983b)
Papua New Guinea	35–100	3.8	Small pelagics	0.7–6.7 kg set^{-1}	3.0 kg set^{-1}	Carangidae Clupeidae	Dalzell (1993)
Seychelles	50	5.7–6.4	Small pelagics	38–75 kg set^{-1}	55.7 kg set^{-1}	Scombridae Caesionidae Carangidae	De Moussac (1987)
South Africa (KwaZulu-Natal)	30	9	Lagoon and lake species	na	5 kg net-day^{-1}	Mugilidae Haemulidae Pomatomidae	Mann (1995) Kyle (1999)
South Africa (East Coast)	75	4.4–5.7	Small pelagics	na	59 kg net-day^{-1}	Mugilidae	Lamberth *et al*. (1997)
South Africa (South Coast)	75	4.4–5.7	Small pelagics	na	71 kg net-day^{-1}	Mugilidae	Lamberth *et al*. (1997)
South Africa (West Coast)	75–300	4.4–5.7	Small pelagics	3–2 198 kg trip^{-1}	148 kg day^{-1}	Mugilidae Carangidae Pomatomidae	This study

na = not available

Table VIII: Beach-seined *Liza richardsonii* catch-and-effort estimates, excluding False Bay

Parameter	Telephone (±*SE*)	Questionnaire (±*SE*)	Monitoring (±*SE*)	Factory (±*SE*)
Number of permit-holders	93	93	93	93
Sample (permit-holders)	22	23	6	4
Mean effort (number of hauls)		23.8 (±8.8)	37.4 (±9)	
Annual effort (number of hauls)		2 211 (±718)	3 478 (±729)	
Sample (number of sales landings^{-1})			9	50
Mean *cpue* (kg haul^{-1})	250	979 (±240)	746 (±208)	795 (±98)
Annual catch (tons)	553 (±115)	3 403 (±678)	1 650 (±426)	1 758 (±505)

effort from the telephone survey were similar, at around 1 700 tons.

Lamberth (1994) estimated an annual effort of 1 000 hauls and a catch of 200 tons of *L. richardsonii* for False Bay. The best estimate of total annual beach-seine catch and effort in the Western Cape, using telephone survey effort and factory- or monitoring-based *cpue*, is therefore approximately 3 300 hauls and 1 900 tons of *L. richardsonii*. West coast beach-seine *cpue* calculated from monitored hauls (746 kg haul^{-1}) and factory sales (795 kg sale^{-1}) during this study exceed earlier estimates by Lamberth *et al*. (1997) for the region (294 kg haul^{-1}). These catch rates are also greater than those reported for other regions in South Africa, and elsewhere (Table IX).

Accuracy of compulsory catch returns

MONITORED CATCHES

Of the 135 boat-landings monitored during 1998/99, the owners of 118 were positively identified as net-fish permit-holders, and their catch returns were checked for matches with observed catches. Most (112) of the landings monitored were gillnet trips made on the West Coast by 48 different permit-holders, the remaining six being beach-seine catches made by three different operators. Some 20 of the gillnet permit-holders reported some of the trips that were monitored, but only 11 reported all trips made. Two of the three beach-seine permit-holders reported hauls that were monitored. In all, 44 of the 112 gillnet trips monitored were reported (39%), but one permit-holder with a history of cooperation with management accounted for 16 of the reported trips. A figure of 29% of the monitored effort being reported is probably more realistic. Totals of 18 872 kg of *L. richardsonii* and 4 175 bycatch fish were landed by fishers for these trips. Only 5 349 kg of *L. richardsonii* (28%) and 605 bycatch fish (14.5%) were reported (Table X). For landings where returns were submitted, the reported catch of 3 208 kg of *L. richardsonii* did not differ significantly from the monitored catch of 3 351 kg (paired *t*-test, $p > 0.41$).

Reporting of bycatch varied from 0 to 32% for the different species, but the fact that 97% of the bycatch reporting was by the one permit-holder mentioned above, who cooperated with researchers, means that these reporting levels are an overestimate. It is likely that the other monitored fishers landed bycatch species at the same rate as this permit-holder, but these fish were hidden from researchers and were not recorded. Further evidence of under-reporting can be found in a comparison of observed bycatch rates in 44–64 mm gillnets monitored with the reported catch rates and total catch (Table XI). For almost all species caught, the observed catch rates and estimated annual catch were an order of magnitude greater than the reported catch rates and total catch. This comparison suggests that the true level of bycatch reporting is between 1 and 3%.

FACTORY SALES

Out of the total of 360 factory sales by gillnet and 50 sales by beach-seine permit-holders who were positively identified, made during the 1998/1999 season, 74 (21%) and 31 (62%) respectively were reported on catch return forms. This proportion (21%) is probably a more accurate reflection of effort reporting by gillnet fishers during 1998/1999 than the levels determined from monitored catches (40%), bcause a fisher who is monitored may feel obliged to report a catch that a researcher has witnessed. Furthermore, factory sales provide a far larger sample and a more complete record of fishers' activity over a season than the "snapshot view" achieved during monitoring.

There was substantial under-reporting of catches, only 8% of the *L. richardsonii* sold by gillnet fishers being reported (Table XII). This is as a result of the large number of trips that were not reported (79%), as well as the fact that when permit-holders do submit returns, they substantially under-report the quantity of fish caught. The average catch rate based on factory sales (196 kg sale^{-1}) is more than double the average

Table IX: Comparison of South Africa's west coast beach-seine catch rate and catch composition with those made in other regions (adapted from Dalzell 1996)

Location	Net length (m)	Mesh size (cm)	Target stock	*Cpue*		Principal catch components	Source
				Range	Mean		
Java	na	na	Small pelagics		200 kg haul^{-1}	Engraulidae Sciaenidae Leiognathidae	Dudley and Tampubolon (1986)
Papua New Guinea	200	2.5	Small pelagics	na	350 kg haul^{-1}	Carangidae Clupeidae	Dalzell (1993)
Seychelles	na	na	Small pelagics	8.5–565.3 kg haul^{-1}	159 kg haul^{-1}	Scombridae Caesionidae	De Moussac (1987)
South Africa (KwaZulu-Natal)	100	1.4	Small pelagics	na	48 kg haul^{-1}	Mugilidae Haemulidae Pomatomidae	Beckley and Fennessy (1996)
South Africa (East Coast)	137	4.4	Small pelagics	na	199 kg.haul^{-1}	Mugilidae Haemulidae Pomatomidae Sciaenidae Sparidae	Lamberth *et al*. (1997)
South Africa (South Coast)	137	4.4	Small pelagics	na	393 kg.haul^{-1}	Mugilidae Pomatomidae Sciaenidae Sparidae	Lamberth *et al*. (1994)
South Africa (West Coast)	50–275	4.4	Small pelagics	41–2 772 kg trip^{-1}	795 kg.haul^{-1}	Mugilidae Sparidae Sciaenidae	This study

na = not available

Table X: Observed and reported catches for 118 monitored net landings (*Liza richardsonii* are given as kg, other fish as numbers)

Species	Gillnets			Beach-seines		
	Monitored catch (number)	Reported catch (number)	Percentage reported	Monitored catch (number)	Reported catch (number)	Percentage reported
Liza richardsonii (kg)*	15 672	3 208	20	3 100	2 141	69
Callorhinchus capensis	1 875	343	18			
Trachurus t. capensis	3 112	334	11	1	0	0
Pomatomus saltatrix	760	229	30			
Chelidonichthys capensis	82	21	26			
Galeichthyes feliceps	34	7	21			
Dichistius capensis	31	10	32			
Rhabdosargus globiceps	23	0	0	44	0	0
Spondyliosoma emarginatum	20	0	0			
Argyrosomus inodorus	20	0	0			
Merluccius capensis	12	0	0			
Mustelus mustelus	13	2	15			
Pachymetopon blochii	5	0	0			
Austroglossus microlepis	4	0	0			
Lithognathus lithognathus	2	0	0			
Liza tricuspidens				1	0	0
Lichia amia				1	0	0
Sharks and skates	6	2	33			
Total	21 671	4 156	19	3 147	2 141	68

* Given by mass

reported catch (77 kg day^{-1}). None of the bycatch sold was reported because the fishers responsible for the sales failed to submit any returns. The four beach-seine permit-holders reported 62% of all sales recorded and 66% of the mass of fish sold (Table XII). For the 74 gillnet sales for which catch returns were submitted, only 35% of the fish sold were reported. Reported catches were significantly less than documented sales (paired *t*-test, $p < 0.001$). Although 92% of the *L. richardsonii* sold by beach-seine operators who submitted returns was reported, documented and reported catches still differed significantly (paired *t*-test, $p < 0.05$). A few permit- holders who did submit catch returns consistently reported more trips and smaller quantities than what was sold. This appears to be a case of deliberate over-reporting of effort (to influence allocation decisions) and under-reporting of catch (for tax-evasion purposes).

Historical trends in reported annual catches

Gilchrist (1899, 1900, 1901) provided the earliest statistics of total annual landings of *L. richardsoni*. Annual catches for the period 1898–1900 ranged from 1.3 to 1.6 million fish. Gilchrist (1914) reported, on complaints by commercial fishers in St Helena Bay, that large catches of juvenile fish by gillnet and seine-net

Table XI: Comparison of observed and reported bycatch rates for 44–64 mm gillnets

Species	Observed *cpue* (number net-day^{-1})	Estimated annual catch (number)*	Reported *cpue* (number net-day^{-1})	Reported annual catch (number)
Trachurus trachurus capensis	42	523 070	1.56	6 262
Pomatomus saltatrix	10	127 930	0.15	618
Chelidonichthys capensis	0.79	13 077	0.07	268
Galeichthyes feliceps	0.43	6 396	0.04	180
Dichistius capensis	0.40	4 952	0.01	29
Rhabdosargus globiceps	0.83	4 378	0.04	176
Spondyliosoma emarginatum	2.08	8 333	0.02	10
Pachymetopon blochii	0.63	1 188	0.02	10

* Calculated using effort values obtained by telephone survey

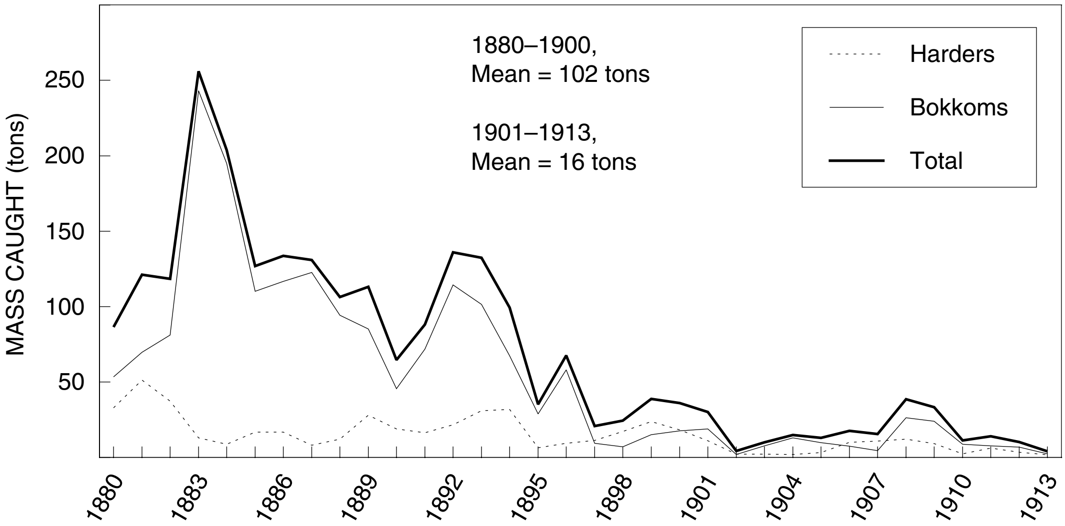

Fig. 4: Reported net catches of adult (harders) and juvenile (bokkoms) *L. richardsonii* by Messrs Stephan Bros of St Helena Bay, 1880–1913 (after Gilchrist 1914)

fishers in the Berg River were leading to a decrease in supply to the former. In that report, evidence of decreasing catches in St Helena Bay are provided in the form of annual catches of adult and juvenile *L. richardsonii* by Messrs Stephan Bros. for the period 1880–1913. Assuming those data were accurate, the recorded catches for a 33-year period provide a valuable insight into the net-fishery in St Helena Bay at that time. There was a drastic reduction in annual catches, the average annual catch prior to 1900 being approximately 102 tons (calculated from a conversion ratio of 5 adults kg^{-1} and 8 juveniles kg^{-1}), declining to an annual average of only 16 tons thereafter, equivalent to a 85% decrease (Fig. 4).

Further catch statistics only became available with the licensing of gillnets and beach-seines in 1973 (De Villiers 1987). Compulsory catch returns were, however, inaccurate, many permit-holders substantially under-reporting catches or failing to submit returns at all. Those catch returns can still, however, be used to examine temporal trends in total catch, if the degree of under-reporting and the number of permit-holders submitting returns is assumed to have remained relatively constant. The reported annual catch of *L.richardsonii* was remarkably constant until 1986, at around 5-6 million fish per year, the exception being between 1980 and 1982 when reported catches peaked at 8-14 million fish (Fig. 5; De Villiers 1987, Stander 1991). Since 1986, the reported annual catch has shown a sustained decrease, the 1998/1999 average (718 tons) being only 42% of the pre-1986 average (Fig. 5).

Table XII: Fish sold and reported by net permit-holders

Species	Gillnets			Beach-seines		
	Sold (kg)	Reported (kg)	Percentage reported	Sold (kg)	Reported (kg)	Percentage reported
Liza richardsonii	69 843	5 737	8	37 584	24 767	66
Cpue (kg day^{-1} or kg $sale^{-1}$)	196	77	39	752	799	106
Trachurus trachurus capensis	2 235	0	0			
Pomatomus saltatrix	111	0	0			
Rhabdosargus globiceps	4	0	0			
Argyrosomus inodorus	16	0	0			
Total	72 209	5 737	8	37 584	24 767	66

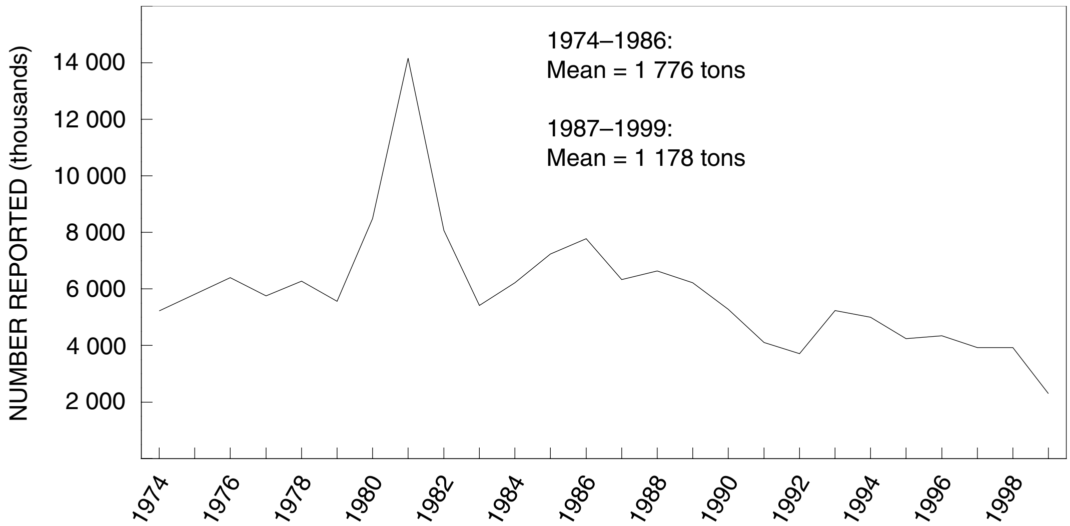

Fig. 5: Total annual reported catch of *L. richardsonii* by gillnet and beach-seine permit-holders in the Western Cape, 1974–1999 (MCM unpublished data)

Seasonality of catch and effort

Gillnet fishing effort in the St Helena Bay area and the Berg River is largely confined to summer, when weather conditions are favourable, catch rates are higher and permit-holders who are involved in other fishing sectors (e.g. pelagic, linefish) have time off. Analysis of factory records, from one of the buyers of large amounts of *L. richardsonii* in the area, provide the most comprehensive insight into catch-and-effort trends during the fishing season (Fig. 6). St Helena Bay gillnet effort peaked in October and February and declined steadily thereafter, no purchases were made before September 1998 or after May 1999. The low number of sales made (≈ effort) during December appears to be the result of something other than fish availability, because the highest average sales (≈ *cpue*) were recorded during that month. *Cpue* remained steady at about 200 kg per sale for the first four months of the fishing season and then declined (with the exception of April, possibly a result of migration of fish into the Bay) to around 90 kg per sale by March. Particularly high average catches were made during December and April, when fishing effort was low (Fig 6).

Prior to 1998, Cape Nature Conservation (CNC) imposed a 6-month closed season on the Berg River fishery, from 1 April to 30 September. Fishers successfully campaigned for the scrapping of the closed season, arguing that the river "closed itself to fishing" during winter because of floodwaters and that the reason for the closed season (to protect spawning fish) was flawed, because *L. richardsonii* do not spawn in freshwater. It was announced at the September 1998 Berg River Net-fish Association AGM that the closed season would no longer be enforced. The closed season was, however, still in place during the winter of 1998 and initial effort in October after opening of the season was high (Fig. 6). Berg River effort peaked in January and March, periods of low fishing effort in St Helena Bay, and in contrast to marine fishing activity, showed an opposite trend of increasing effort as the season progressed towards winter. The average daily purchase of fish per fisher from the Berg River peaked at around 45 kg during October and January and, like the St Helena Bay *cpue*, declined towards autumn, 25 kg being the average purchase during April and May.

In contrast to the fishery in St Helena Bay and the Berg River, gillnet fishers in Saldanha Bay and Langebaan Lagoon are active throughout the year (Fig. 7). No trend in monthly effort is apparent from records for Langebaan Lagoon, with effort being high in late summer and winter. Average monthly *cpue* of *L. richardsonii* was higher during late summer, autumn and spring than during winter and early summer. As was the case in St Helena Bay, *cpue* was higher than average during months of low effort (April, May, September and January). Factory records of Saldanha Bay fish purchased during five months in 1998 show an increasing trend in average *cpue* from June (150 kg) to October (400 kg).

Beach-seine operators appear to operate opportunistically in most areas, either during periods of high fish

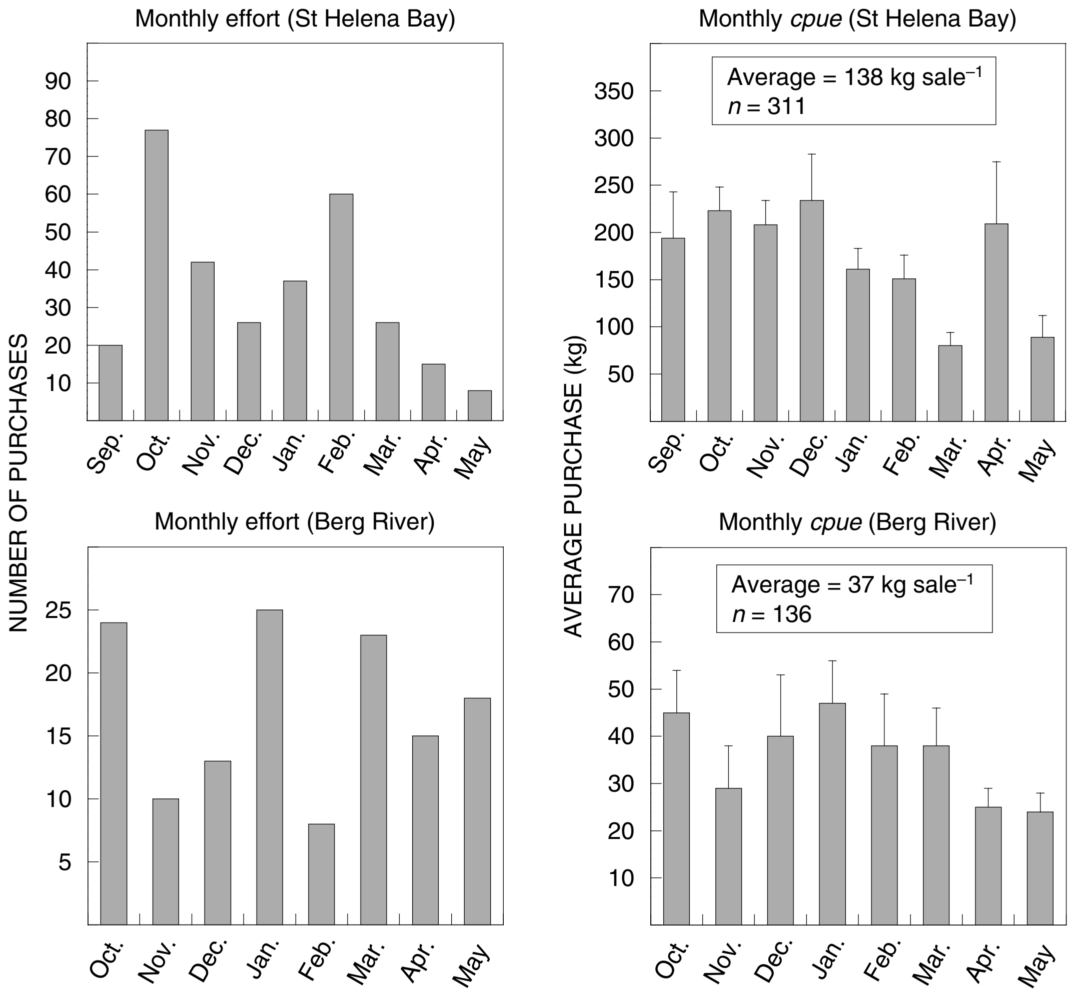

Fig. 6: Seasonal catch and effort of *L. richardsonii* for the St Helena Bay and the Berg River gillnet fishery

abundance, favourable weather conditions that concentrate *L. richardsonii* shoals, or during periods when it is not possible to undertake other fishing activities. False Bay beach-seine effort is seasonal, only two of the seven crews being active through winter. On the West Coast (Langebaan to Elands Bay), however, fishers operate sporadically and no discernible trend, other than zero hauls during late winter (July and August), is evident in factory purchase records for 1998/1999 (Fig. 8). Bad weather (strong westerly winds and large swells) usually prevents beach-seining during that period.

Struis Bay beach-seine effort was recorded daily for a period of six months (1 October 1998–30 March 1999), but only two crews (there are 27 permit-holders licensed to operate in the area) were observed to be active, making a total of 25 hauls over that period (Fig. 8). They increased their effort during late summer, when south-easterly winds prevent linefish boats from going to sea. Such winds also concentrate *L. richardsonii* shoals close inshore and increases their availability to beach-seine fishers. It was not possible to assess the seasonality of beach-seine catch and effort in other areas during this study, because so few operations were encountered. The majority of permit-holders interviewed, however, claimed to be more active during summer, citing favourable weather and presence of fish as the main reasons.

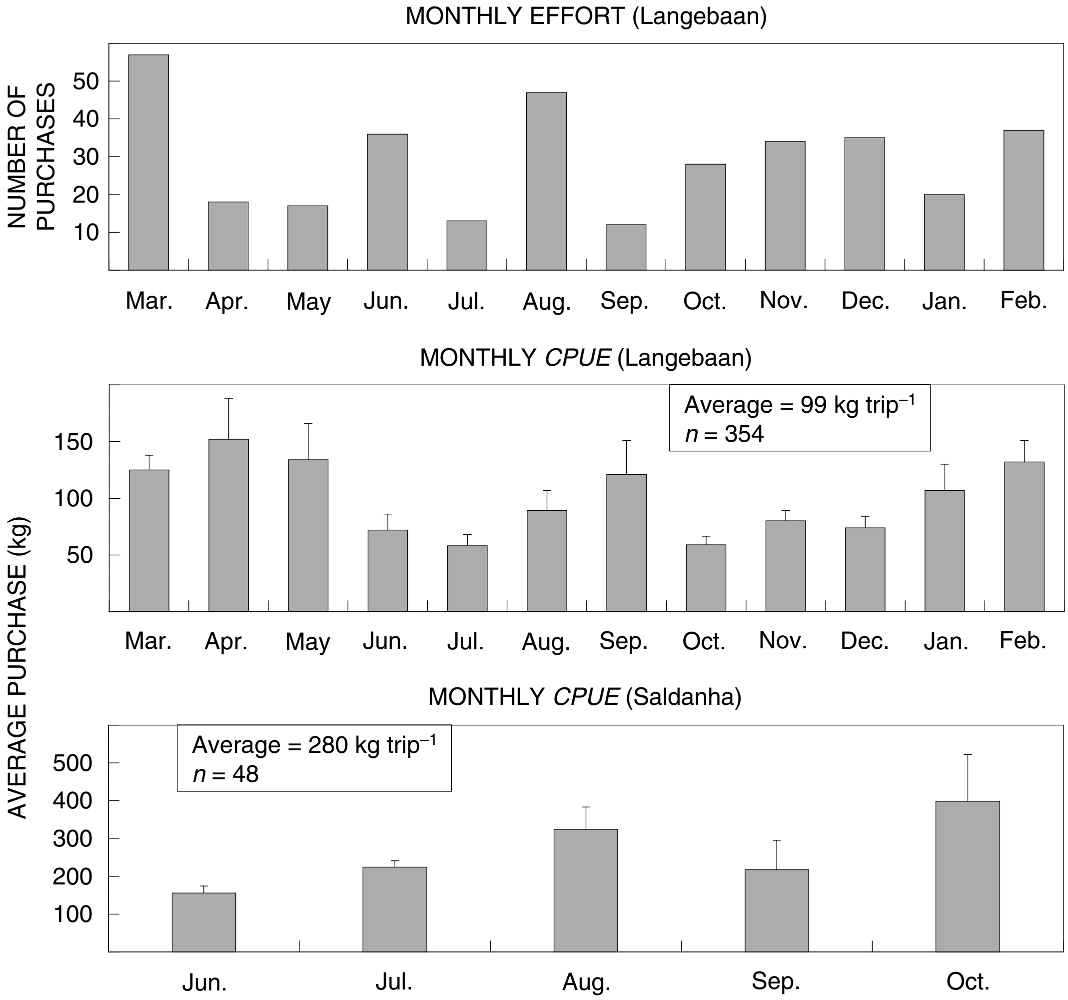

Fig. 7: Seasonal catch and effort of *L. richardsonii* for the Saldanha and Langebaan gillnet fisheries

DISCUSSION

Catch and effort

SURVEY ERRORS

Angler surveys are subject to various sources of error. Pollock *et al*. (1994) groups these errors into three general categories: sampling errors, response errors and non-response errors. Several of these errors, despite efforts taken to reduce them, certainly affected the results obtained during this study and might account for some of the discrepancies in the data.

SOURCES OF ERROR IN EFFORT ESTIMATION

Fishers interviewed during the questionnaire survey were contacted both at their residential addresses (obtained from the permit lists) and at landing sites when fishing operations were monitored. These contact methods resulted in an indeterminate amount of non-response bias in the case of home interviews and avidity bias in the case of on-site interviews (Pollock *et al*. 1994). Permit-holders who were available (at home) were more likely to be those who did not have other employment (particularly in other fishing sectors that require long periods at sea), or were retired and therefore had more time than other permit-holders to

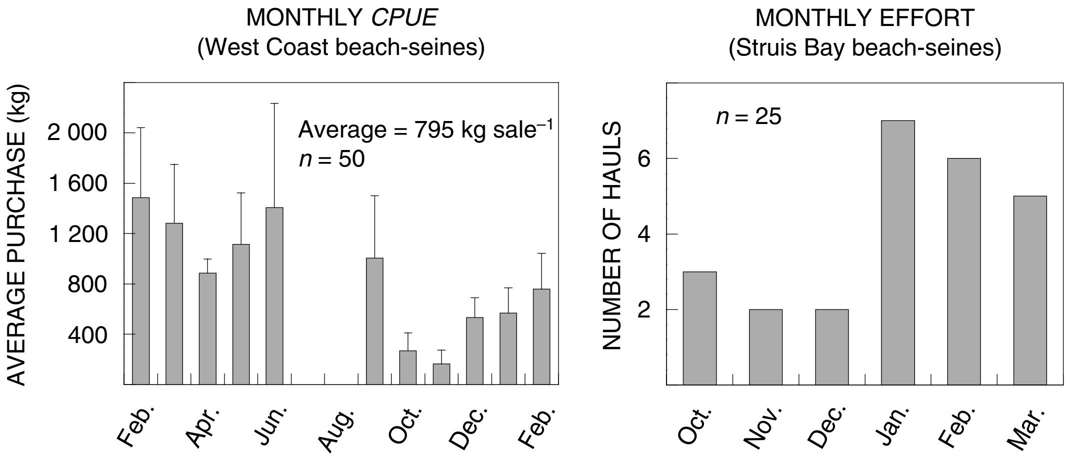

Fig. 8: Seasonality of *cpue* of *L. richardsonii* for the West Coast and effort for Struis Bay beach-seines

participate in net-fishing. Because of the probability of an encounter, fishers interviewed at landing sites were more likely to be those who fished more often (avidity bias). These biases would cause the average activity rates claimed by respondents to the questionnaire survey (the sample) to be higher than that for all permit-holders (the population). This is probably the reason why total annual effort estimates based on questionnaire survey data were much greater than the estimates based on the telephone survey data. The telephone survey as an off-site method is not subject to avidity bias. Furthermore, after hours and weekend callbacks meant that those permit-holders with or without other employment had a more equal probability of being sampled, so the results of the survey were less likely to have been affected by non-response bias.

Both the telephone and questionnaire surveys required fishers to remember how many trips they had made over the past 12 months, and such results are subject to recall bias. Fishers may have difficulty in recalling the number of trips they have made, or may assign trips from a previous period to the one being asked about (Pollock *et al*. 1994.). In an attempt to minimize this bias, anglers were asked about their activity over the previous week, month and year. Despite this, net-fishers appeared to overestimate their activity. For example, in St Helena Bay, even the lower telephone effort estimate of 12 300 days annually implies an average of 34 fishers going to sea every night of the year, including winter, when there is little net-fishing. The maximum number of landings monitored in that area on a single day during this study was only 14, with an experienced fisher never recalling more than 30 boats on the water, even during times of high fish abundance. There is strong evidence that, because of recall bias, angler surveys result in overestimates of fishing effort (Anon. 1998).

South African commercial fishing rights were under review during the present study, and many permit-holders were aware that their fishing rights could be withdrawn if they had not been active. An overriding "fear of permit loss" bias almost certainly led fishers to exaggerate and claim more trips than they actually made, despite assurances that the surveys were confidential and answers would not affect their status as permit-holders. Fishers angry with the fisheries management authority, or who think they can influence fishery rules to their benefit, are likely to deceive questionnaire agents (Pollock *et al*. 1994). Most net-fishers are annoyed with MCM for failure to communicate with them over redistribution of fishing rights, and many felt they could influence management decisions regarding catch and gear restrictions through their answers to the survey.

With the exception of Saldanha Bay and Langebaan Lagoon fishers, net-fishing is the primary source of income for only a small percentage of permit-holders; <25% in St Helena Bay claim to make more than half their income from net-fishing (Hutchings and Lamberth 2002b). Given the part-time nature of the fishery and the different people involved with widely varying activity rates (Fig. 3), the moderate standard errors (10–30%) associated with total annual effort estimates are to be expected. Telephone-survey effort estimates, with the exception of Stratum 1, did, however, have relative standard errors of <20%, an acceptable standard for fisheries data (Smith 1998). Owing to the above-mentioned biases, which probably led fishers to exaggerate their activity, it is likely that the values obtained from the telephone survey, approximately 25 000 gillnet days (including estuarine effort, illegal net effort and effort directed at St Joseph *Callorhinchus capensis*) and 3 200 beach-seine hauls annually, are overestimates. However, these are the best estimates at present, considering that effort is drastically underreported on compulsory catch returns. Indeed, scaling-up of the reported effort for 1998/1999 by the degree of under-reporting gives values of 19 000 gillnet days (excluding estuarine and illegal net effort) and 1 900 beach-seine hauls (excluding the estimated 1 000 hauls made annually in False Bay). These figures are within 25% of the estimates obtained from the survey.

SOURCES OF ERROR IN CATCH-RATE ESTIMATION

When asked for the average catch per trip, fishers are more likely to remember the more memorable trips, when large catches were made, than trips when no fish or small catches were made. It is expected that this recall bias and possibly also prestige bias (exaggeration of catch size or rate) would cause fishers to overestimate their catches (Pollock *et al*. 1994). It is also likely that fishers interviewed on site had made larger than average catches or were the more successful fishers, because larger catches take longer to off-load. Beach-seine permit-holders appeared to overestimate their average catches, questionnaire respondents on average claiming average catches about 20% greater than those monitored or documented in factory sales. Part of the explanation may be that factory sales do not include fish that may be retained by the crew for own consumption or local sale. On the other hand, gillnet questionnaire respondents claimed much lower catch rates than those observed during monitoring, or documented in factory records (Fig. 2). Several respondents expressed concern that information regarding their catches would be available to the Receiver of Revenue and result in negative tax implications. This "fear of the taxman" bias and reluctance by fishers to reveal their actual catches to management are the probable reasons for fishers underreporting their catch rates (Lamberth 1994, Lamberth *et al*. 1997).

Telephone survey respondents were asked to provide their total catch over the previous 12 months, a figure that they would more likely be able to remember accurately and less likely to be affected by recall bias than an average daily catch. Total annual catches claimed by both beach-seine and gillnet operators (particularly in St Helena Bay) in the telephone survey translate into catch rates that are much lower than those determined by other methods. Telephone respondents were even less confident than in the face-to-face questionnaire interview that the information they were giving was confidential. Many also probably felt that the telephone survey was some sort of check on their compulsory catch returns and were reluctant to admit catching more fish than they had reported. The telephone survey was also conducted shortly after permit-holders had to reapply for their fishing rights. The West Coast Net-fish Association had held a meeting to discuss how its members should complete their application forms, and it was apparently decided that all members should claim to catch between 2 and 2.5 tons per year. This would give a total catch for the area that did not exceed the total reported catch by too much. Because of the above biases, the total catches, or catch rates, claimed by fishers are not realistic. Indeed the average catch rate claimed by St Helena Bay fishers in the telephone survey would mean that they operate at an annual loss of nearly R 5 000 per year, given the daily trip and annual maintenance expenses claimed by fishers (Hutchings and Lamberth 2002b).

Catch-rate estimates based on monitored landings and factory sales are not vulnerable to recall bias or exaggeration by fishers. It can be argued that larger-than-average catches are more likely to be monitored, because of length-of-stay bias, or that large catches only are sold to factories. In an attempt to reduce this effect during monitoring, the catches of all boats docking were assessed as rapidly as possible. Factory purchases do not appear to be limited to large catches only, sales of as little as 2–3 kg of *L. richardsonii* being recorded. Fishers claim to sell only about 90% of their catch, the remainder being kept for crew or own consumption. It would therefore be expected that the average factory sale would be smaller than the average monitored landing. However, this was not the case, the average monitored catch in most areas being slightly less than the average factory sale. This difference can be ascribed to researchers possibly underestimating the weight of the catch and the fact that zero catches are not recorded in factory sales, although several zero catch trips were monitored.

Daily gillnet catches observed during monitoring ranged from 0 to 1 008 kg and factory records from 2 to 2 198 kg. This natural high variability in catches means that sample estimates such as mean daily catch will have high error levels, the only way of reducing this error being to increase sample size. In this respect, the catch rates that were estimated from the 900 factory sales are more accurate than those calculated from the 141 monitored net landings. However, calculation of total catch based on these catch rates assumes that the fishers encountered, or whose factory sales were recorded, have the same catch rates as those who were not monitored or who do not sell their fish. Accepting this assumption, and using the telephone survey effort estimates (which may be exaggerated) and monitoring and factory catch rates respectively, the best annual *L. richardsonii* catch estimates for 1998/1999 are 2 500 –3 000 tons for marine gillnets and 1 850–2 000 tons for beach-seines. Adding to this a rough estimate of 250 tons of estuarine and 4.5 tons of illegally caught fish, the total annual *L. richardsonii* net catch for the region (Olifants to Breede Rivers) is 4 600–5 250 tons. Scaling up of the reported catch by correction factors based on the degree of under-reporting also gives a total annual catch estimate of about 5 500 tons. Gillnet fishers in the study region also land approximately 130 tons of bycatch, consisting of at least 27 species, whereas illegal gillnet fishers catch about 100 tons of *M. mustelus* and 50 tons of linefish per year. The total mass of fish caught by nets in the study area is therefore approximately 6 000 tons per year, substantially more than the mean annual reported catch of 1 369 tons per year.

Current status of the fishery

The fact that *L. richardsonii* catch rates on the West Coast are greater than those made in more tropical regions elsewhere in South Africa and in other countries should not be taken as evidence of a healthy resource. The West Coast net-fishery, with the exception of the area north of Elands Bay, is mostly commercial or recreational, few participants needing to fish to survive (Hutchings and Lamberth 2002b). Net-fishers therefore operate mostly at times of known fish abundance and average catch rates are relatively high. In the Olifants River Estuary, where net-fishers operate on a subsistence level and are forced to fish at every opportunity, catch rates (10–20 kg day^{-1}) are less and similar to those made in other gillnet fisheries (Sowman *et al.* 1997). Furthermore, the examples of other net-fisheries are mostly from subtropical and tropical regions, in less productive waters than the cool temperate upwelling regions along the West Coast (Pillar and Hutchings 1989, Shannon 1989). Indeed, despite operating in the highly productive Benguela upwelling region, West Coast gillnetters achieved smaller individual catch rates than the few South and East Coast gillnetters.

Anecdotal and historical evidence suggests that *L. richardsonii* catch rates on the West Coast were much higher in the past. The average annual catch of adult *L. richardsonii* for the period 1900–1913 was only 32% of what it was prior to the turn of the century, whereas the average annual catch of juvenile *L. richardsonii* ("bokkoms") decreased by a massive 87% (Fig. 4, Gilchrist 1914). Unfortunately, the number of people employed or the number of days fished is not provided in the earlier reports, so the role of increasing or decreasing effort in the observed catch decline cannot be assessed. It is unlikely, however, that the catch decline was attributable to decreases in effort, because the fishers were complaining and demanding that action be taken against Berg River fishers. As Gilchrist (1914) notes, however, the Berg River fishers could not be fully responsible for the declines, as their total "bokkom" catch was substantially less than that made by fishers in the sea. It appears likely that the observed crash in catches was attributable to the high fishing effort by both estuarine and marine net-fishers. The particularly noticeable decrease in the number of juveniles caught suggests a degree of recruitment overfishing (Fig. 4).

Although the reported total annual catch prior to 1986 was relatively constant, there is evidence that the stock may be overexploited, particularly in regions with high effort levels, such as St Helena Bay. It is interesting that the reported catch for this period was made by approximately 400 active permit-holders (De Villiers 1987), equivalent to only 4.3 tons per permit-holder. This is a substantially lower annual catch than that achieved by Messrs Stephan Bros during the early 1900s, even after the decline in catches (approximately 16 tons per year). This comparison is, however, not strictly valid because many of the current permit-holders do not fish commercially, whereas a century ago they undoubtedly did. Active, professional beach-seine permit-holders from St Helena Bay and Elands Bay still report annual catches in the region of 20 tons per year (MCM unpublished data).

Permit-holders have become increasingly disillusioned at the management authority in recent years, largely because of the uncertainty over future access rights. As a result, many have stopped submitting catch returns, and the sharp decrease in reported catch in 1998/1999 is undoubtedly partly a result of increased under-reporting (Fig. 5). However, there seems to be a substantial real decrease, <70% of questionnaire respondents stating that their catches have declined since they entered the fishery. A further 10–42% of gillnet respondents and 23% of beach-seine respondents felt that the fishery was no longer economically viable and had ceased fishing (Hutchings and Lamberth 2002b). Indeed, if the level of under-reporting was relatively constant, the total annual catch would have been in the region of 10 000 tons 10 years ago, more than double the estimate for 1998/1999.

Further evidence that the *L. richardsonii* resource is maximally or overexploited can be found in the seasonal trends in *cpue* and effort determined from factory records for St Helena Bay and Saldanha Bay; maximum average *cpue* was during months with the lowest effort levels. The trend of steady *cpue* in St Helena Bay for the first four months of fishing and then a steep decrease for the second half of the season suggests that the stock that built up over the previous winter is being fished down rapidly (Fig. 6). Indeed, the better catch rates observed during months of low effort (December and April) suggest that the stock is maximally exploited. An alternative explanation is that fisher interference during months of high effort result in lower individual catch rates, and that the less disturbed shoals during periods of low effort result in higher catch rates.

CONCLUSION

Once-off surveys such as this study can only provide data on a fishery at one point in time (Pollock *et al*. 1994). Catch composition can vary from year to year and the catch-and-effort estimates determined during this study only describe the fishery as it was during 1998/1999. Changing market forces also affect catch and effort in the net-fishery. For example, a recently developing market for frozen *L. richardsonii*, used as bait in the longline tuna fisheries, may be pushing effort levels above those that used to saturate the salted fish market. A collapse in the St Joseph shark market as a result of conflict in Central Africa has resulted in unusually low levels of effort directed at that species as well as catch over the last two years (B. T. Pedro, B. P. Marine Products, pers. comm.). Although this survey provided a useful "snapshot" view of the net-fishery in the Western Cape, the approach has many shortcomings, most notably inaccurate total catch-and-effort estimates because of various types of survey error. The system of self-policing via compulsory catch returns also appears to have failed, because of a combination of apathy, distrust and fear of permit loss or tax implications on behalf of the fishers and a lack of feedback and enforcement from management. Independent, on-the-ground monitoring of the gillnet and beach-seine fisheries is the only method that will produce data suitable for use in the scientific assessment of the status of fish stocks.

The gillnet and beach-seine fisheries of the Western Cape appear oversubscribed in most regions, only a few permit-holders operating on a regular commercial or subsistence basis. The majority of net permit-holders fish recreationally or are inactive, and claim that low catches and the sporadic seasonal availability of fish make it economically impossible to fish regularly. Although catch-and-effort estimated during this study are much greater than the reported values, there is compelling evidence that the *L. richardsonii* resource is overexploited. It appears that net permits for most areas have been freely available, the exceptions being areas where conflict or potential conflict within the net-fishery itself, or with other sectors, have forced management to reduce the number of net permit-holders (De Villiers 1987, Penney 1991, Stander 1991). This free availability of permits has resulted in overcapitalization in some areas, fishers investing more in boats, nets, outboards, etc. than they can make by catching *L. richardsonii* (Hutchings and Lamberth 2002b). As a consequence, fishers either stop fishing commercially or are forced into illegal net-fishing. The large number of participants result in low individual catch rates, either as a result of fisher interference or simply scarcity of fish.

If the management authorities wish to manage the net-fisheries to maximize effort and participation, rather than sustainable catch and economic yield, then this has already been achieved. On the other hand, reducing the latent and part-time recreational netting effort will have benefits for *bona fide* commercial net-fishers by reducing fishing interference during holiday periods or weekends and preventing decreases in market prices during times of high fish abundance. The corresponding decrease in total net-fishing effort and catch may allow the *L. richardsonii* stock to recover and will also help minimize the ecosystem effects of the fishery by reducing the bycatch. A suitable reduction in the number of permit-holders in areas that are oversubscribed will allow for improved monitoring and policing of the fishery and hopefully improve reporting of catch returns and compliance with regulations. A reduction in participation in the net-fishery will unfortunately not allow more people to derive benefit from the resource, but an economically viable and sustainable fishery is surely more desirable than an oversubscribed non-sustainable one in which the fishers are condemned to poverty.

ACKNOWLEDGEMENTS

We thank all the net-fishers who gave freely of their time to answer questionnaires and allowed us access to their catches. The cooperation and assistance of the MCM inspectorate is acknowledged. We also thank Prof. C. L. Griffiths and Drs B. M. Clark (University of Cape Town [UCT]), A. C. Cockcroft, L. Hutchings (MCM), W. H. H. Sauer (Rhodes University) and S. A. Shepard (SA Research and Development Institute, Adelaide, Australia) for comments on earlier drafts of this manuscript. Prof. J. G. Field (UCT) is thanked for statistical advice. The research was funded by the Marine Living Resources Fund and the staff of Research Support Services at UCT is thanked for administration of the funding.

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