CATCH, EFFORT AND SOCIO-ECONOMIC CHARACTERISTICS OF THE GILL AND BEACH-SEINE NET FISHERIES IN THE WESTERN CAPE, SOUTH AFRICA

by

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Bokkoms innie wind; kreef is innie net
Suiker innie koffie; koeksusters innie vet
Brood is innie as; vleis is annie braai
Daars net een plekkie en dis my plekkie daai

From the song Weskusklong by David Kramer

DECLARATION

This study was conducted under contract and was funded by the Department of Marine and Coastal Management with the aim of providing improved, up to date information on the inshore net fisheries for management purposes. The project was designed by S. J. Lamberth who initially undertook the contract in 1997, with the candidate taking over in February 1998. The work presented in this thesis is, however, the sole responsibility of the candidate. This work has not been submitted for a degree at any other university.

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ABSTRACT. Hutchings, K. 2000. *Catch, effort and socio-economic characteristics of the gill and beach-seine net fisheries in the Western Cape, South Africa.* M. Sc. thesis, University of Cape Town

This study was conducted with the overall objective of providing scientific information relevant to the management of the gill and beach-seine net fisheries, particularly with respect to decisions about increased participation in the fisheries. Its primary aims were to provide quantitative estimates of total catch and effort, to assess the current and potential future importance of by-catch in the fisheries, to describe the socio-economic status of participants and to evaluate the management measures currently in effect.

Face – to – face questionnaire, telephone and access-point surveys, analysis of factory records and compulsory catch returns were used to estimate total catch and effort for the inshore net-fisheries in the Western Cape, South Africa. A total of 138 562 fish representing 29 species from 20 families were recorded in 141 monitored commercial gill-net 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 gill net catch. *Pomatomus saltatrix, Trachurus trachurus, Chelidonichthyes capensis* and *Galeichthyes feliceps* were the most common by-catch species, and contributed 4.2 % to the total catch numerically and occurred in 12-47 % of the marine 44-64 mm gill-net catches that were monitored. Five species most frequently targeted by shore anglers on the West Coast, *Dichistius capensis, Rhabdosargus globiceps, Pachymetopon blochii, Argyrosomus inodorus* and *Lithognathus lithognathus*, also occurred in gill-net catches. Most of the by-catch comprises immature, undersize fish that are often injured during entanglement and are not released alive. Records of illegal mesh size gill net sales indicate substantial illegal gill-netting activity. *Liza richardsonii* also numerically dominated the beach-seine hauls that were monitored (> 99 %) with only four by-catch species being recorded in low numbers. Beach-seine questionnaire respondents, however, reported sporadic catches of at least 17 by-catch species, including occasional substantial catches of the important line-fish species, *L. lithognathus* and *A. inodorus*. Survey estimates indicate that approximately 25 000 gill-net days and 3 200 beach-seine hauls made annually land in the region of 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. The lower catch rates, smaller average size of fish caught, historical and anecdotal evidence suggest that the *L. richardsonii* stock is regionally overexploited in areas with high fishing effort.

Data collected by questionnaire and telephone surveys conducted during 1998 and 1999 are used to describe socio-economic characteristics of inshore net fishers in the Western Cape. Most net fishers are Afrikaans speaking, middle aged, white and coloured males who live in coastal communities. Approximately two thirds of net fishers work or have worked in other fishing sectors and a further 6-50 % are retired. Very few (0-11 %) permit holders in most areas classified their occupations as net fishers and, with the exception of Saldanha-Langebaan fishers, the majority claimed to make less than 5 % of their income from net fishing. More than one third of gill net permit holders and all beach-seine crew claimed to earn less than R 10 000 per year from all work, which is less than the estimated household subsistence level.

Estimated costs and returns to net permit holders suggests that in most areas, commercial net fishing at current catch and effort levels, is not economically sustainable in the long term. Only Saldanha-Langebaan gill-netters and beach-seine permit holders, on average, manage to cover their opportunity costs and make an economic profit. The lack of profits in other areas is compelling evidence that the net fishery is at or beyond the open access equilibrium point and an effort reduction in the order of 60 % is required in order to obtain maximum economic yield. The net fisheries do, however, provide part-time employment for approximately 2 000 crew in the Western Cape and provide additional economic benefits and employment directly related to the fishery in the form of equipment and fuel purchases made by fishers, maintenance of fishing gear and the sale of fish.

Between 42-76 % of respondents felt that their catches had declined since they had started net fishing and most felt that no new permits should be issued. Knowledge of catch restrictions amongst respondents was low (53-73 %), which is indicative of a lack of communication between management and fishers, poorly defined and vague permit conditions and a lack of enforcement. Many of the fishers interviewed feel it is unfair that they are restricted to catching only low value target species and do not adhere to the catch restrictions even if they do know them.

In order to ascertain the potential catch if the gill-net fishery was to expand along the Southwest Coast, a program of experimental netting was conducted. Estuarine and coastal marine sites between the Olifants and Breede Rivers were sampled bi-monthly, using a range of gill-nets equivalent to those used in the commercial fishery (44-178 mm mesh). Although the target species, *L. richardsonii,* dominated the catches on both coasts, at least 33 of the species caught were also targeted by the commercial or recreational line-fish sectors. For all net types used, the number of species captured and the line-fish (by-catch) *cpue* were greatest in areas currently closed to the commercial gill-net fishery. Multivariate analysis indicated significant differences in catch rates and composition between exploited West Coast and unexploited Southwest Coast areas. A combination of natural biogeographical trends and the impact of over 100 years of commercial gill-netting on the West Coast are the likely causes of these differences. An expansion of the gill-net fishery along the Southwest Coast will compromise the nursery value of estuaries in the region, possibly cause undesirable genetic or phenotypic responses in vulnerable fish populations, have a detrimental impact on already overexploited line-fish stocks and lead to increased user conflict.

The inshore net fishery in the Western Cape is oversubscribed in most regions and a reduction in latent and recreational effort is urgently needed. 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 by-catch, improve catch rates for *bona fide* commercial fishers, allow for improved monitoring and policing of the fishery and hopefully improve compliance with regulations. The importance of the net fishery for participants varies greatly between and within different areas. In order to reduce effort in an equitable manner current and potential new permit holders should be assessed on an individual merit basis. The current spatial restriction on the area where gill net fishing is permitted should remain in force.

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GENERAL INTRODUCTION

The origins of inshore net-fishing in South Africa date back to the use of beach-seine nets by English and Dutch seafarers during the seventeenth century (Thompson 1913, De Villiers 1987, Penney 1991, Lamberth 1994). By the end of the 17th century, the Dutch had established beach-seine fishing outposts as far afield as Langebaan Lagoon (Poggenpoel 1996). Most of the catch was salt cured, dried ("bokkoms") and used to supply the Dutch East India Company trading boats, troops and slaves at the castle in Cape Town with "rantsoen vis"(Poggenpoel 1996). With the expanding colonial settlement in the Cape, beach-seine fishing became widespread and was the most frequently employed fishing method in most areas. Thompson (1913) writes:

> "Nearly every sea-board hamlet and coast farm have a net or two, whilst at Struis Bay, Keimouth and similar stations "trekking" is practically the only mode of fishing carried on. The St Helena Bay and Saldanha Bay areas and False Bay are the chief centers of the seining industry, which in these localities has long been the means employed for dealing with the large shoals of harders, white stumpnose, elft, albacore and young white steenbras that are periodically on the move close inshore."

By the time of Thompsons' writing, the link between agriculture and beach-seine fishing was well established. Coastal farmers either worked their own nets, or purchased fish from fishing settlements on the coast. The fish was still processed into "bokkoms" and given to farm labourers as "rantsoenvis" in part payment for their work. Many of the fishers were tenants on coastal land, rented from farmers or the colonial state, and worked seasonally during harvest time on the farms (van Sittert 1992). The farmers' attitude towards these beach-seine fishers was ambivalent. On the one hand they were welcome as a source of seasonal labour and provided a supply of cheap fish. On the other hand they were seen as unwelcome squatters, cutting down trees for firewood, using fresh water from the farmers' wells and were often accused of alcohol-facilitated antisocial behavior (van Sittert 1992).

The first major threat to the supremacy of beach-seine nets as the gear of choice for inshore fishing, particularly along the West Coast, was the introduction of gill nets by Italian immigrants during the late 1800's (Thompson 1913). Beach-seine fishers alleged that the gill-nets set across the entrance to bays or in the main channels of the Berg River diverted the shoals from their normal course and were the cause of their catch declines (Gilchrist 1896, Thompson 1913). The conflict (occasionally violent) escalated rapidly, both at sea and in the courtrooms of the Pikietberg magisterial district (van Sittert 1992). The colonial government, however, felt that the industrious Italian fishermen with their more technologically advanced fishing methods were an asset to the fishing industry and was reluctant to ban the use of gill nets (Gilchrist 1896). Despite their admiration of the gill net, the state was also not keen to alienate the beach-seine fishers or farmers and drafted various regulations aimed at minimizing the conflict between the two sectors (Thompson 1913, van Sittert 1992). This culminated in the legislation in 1909 of an exclusive beach-seine fishing zone in St Helena Bay, prohibiting the use of gill nets to the north of the Berg River mouth (van Sittert 1992). At the same time, many of the Italian gill-net fishers began to work in the expanding rock lobster fishery and competition for fish and the "rantsoen vis" market between the two groups decreased (van Sittert 1992). By 1912, however, over 300 gill nets were in use in the Berg River and in the sea to the south of the river mouth (van Sittert 1992). This indicates the extent to which these nets had been incorporated into the inshore fisheries along the West Coast, and beach-seining was no longer the dominant net fishing method.

The declaration of the exclusive beach-seine fishing zone in St Helena Bay did not entirely resolve the conflict between beach-seine and gill-net fishers. The Italians continued to poach with gill nets in the prohibited area, mainly to obtain bait for their rock lobster traps (van Sittert 1992). They vigorously campaigned for a reduction in the size of the beach-seine fishing area and to be granted the right to use larger mesh (100-145 mm) gill nets in the area to catch sharks and barbel for bait (van Sittert 1992). The use of these large mesh gill nets must also have resulted in substantial catches of "linefish" such as galjoen *Dichistius capensis*, kob *Argyrosomus inodorus* and steenbras *Lithognathus lithognathus*. Many of the rock lobster and gill-net fishers motorized their boats during the 1920's and poached at night. As a result, neither the beach-seine fishers nor the fisheries authorities could successfully apprehend and prosecute the transgressors (van Sittert 1992).

The importance of inshore gill and beach-seine fishing along the West Coast was further reduced with the start of the purse-seine fishery during the 1930's. Purse-seine fishers were simply more efficient at catching large quantities of the same shoaling species, harders *Liza richardsonii* and maasbanker *Trachurus trachurus*, than beach-seine and gill-net fishers. The large quantities of purse-seine caught fish flooded the "rantsoen vis" market, causing prices to collapse and considerable hardship for gill and beach-seine net fishers (van Sittert 1992). This prompted many of the traditional beach-seine and gill-net fishers to either join the purse-seine fishery themselves, or to seek alternative employment. Increased demand for fish during the Second World War led to the construction of numerous canning factories and the purse-seine fleet began targeting the more abundant pelagic sardines *Sardinops sagax* and anchovy *Engraulis japonicus*. Smaller purse-seine vessels did, however, continue to catch considerable quantities of harders. Despite numerous complaints by gill and beach-seine fishers, management was slow to respond, officially requesting purse-seines not to target harders in 1973 and banning the practice only in 1984 (Theart *et al.* 1983, De Villiers 1987).

Commercial gill-net fisheries targeting harders do not appear to have developed around Cape Town or along the Southwest Coast and beach-seining remained the primary type of net-fishing in these areas. Large mesh gill nets were, however, extensively used to target "line-fish" both commercially and in what appears to have been a recreational fashion in False Bay and along the Southwest Coast. A 1949 angling column in the *Cape Times* complains bitterly about the presence of over 40 gill nets set in the kelp channels at Pringle Bay (eastern shore of False Bay) in one weekend, which resulted in large catches of undersize galjoen *D. capensis* (Anon. 1949).

After the early attempts to resolve conflict between gill and beach-seine fishers around the turn of the century and probably due to the decreasing importance of the sector, the inshore net fisheries received little management attention for almost 50 years. Any person could fish anywhere along the coast with gill or beach-seine nets, the only restriction being a minimum mesh size of 44 mm, aimed at preventing catches of juvenile *L. richardsonii* (De Villiers 1987). In 1967, the old conflict between beach-seine and gill-net fishers again threatened to develop. An investigation by the Sea Fisheries Research Institute revealed that the numbers of beach-seine and gill nets in use was increasing rapidly (Treurnicht *et al.* 1980, Stander 1991). This was possibly due to the collapse of the West Coast sardine stock in the late 1960s (Crawford 1981) and the subsequent need for purse-seine fishermen to once again supplement their incomes by inshore net-fishing. Technological innovations that were developed during the 1950s and 1960s could now be used by gill-net fishers, including monofilament nylon nets, outboard motors, echo-sounders, and powerful spotlights for night fishing. These developments meant that gill net fishers were now far more efficient at locating and catching fish. With the growth of recreational line fishing, anglers and conservation-minded members of the public were becoming increasingly opposed to inshore net fishing, which they alleged was a threat to the stocks of numerous fish species (De Villiers 1987, Penney 1991, Stander 1991, Lamberth 1994).

These concerns were addressed by several official investigations (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). Numerous control measures were introduced, including the compulsory registration of all nets in 1974, with permit holders required to submit daily catch returns on a monthly basis, gear and catch restrictions and the restriction of net fishing to certain areas (De Villiers 1987). A reduction of inshore net fishing effort became official policy and permits were only awarded to so called *bona fide* fishers or pensioners with a history of participation in the fishery (De Villiers 1987, Stander 1991). The number of beach-seine permits issued for the popular angling areas of False Bay and Walker Bay were drastically reduced and gill netting was confined to the West Coast (Theart 1983, Penney 1991, Stander 1991, Lamberth 1994).

Throughout the history of the net fisheries in the Western Cape, management has focussed on resolving conflict amongst the net fishers themselves and with other sectors (pelagic, commercial and recreational line fisheries). 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). A recent study by Lamberth *et al.* (1997) found that the compulsory reporting of catches is inaccurate, and concluded that knowledge of the inshore net fisheries is poor, with up to 85 % of catch and effort unaccounted for. 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).

With the new political structure in South Africa, official policy has changed, with the emphasis now on providing increased access to marine resources (Living Marine Resources Act 1998). As a result, management has come under increasing pressure to provide net permits to fishers who claim to have been historically excluded from, or have operated illegally in, the fishery and/or to permit the catching of linefish by this sector. It is, however, unknown whether the resource can support the present participants in the fishery, let alone any future increase in their number. Furthermore, little is known about the social and demographic structure of the current net permit holders and their crew, the extent to which they rely on the net fishery for food or income and the economic viability of the fishery. Temporal and spatial variation in total catch, catch composition and effort is also unknown. The accuracy of reported catch returns and the importance of by-catch, particularly of "angling" species to the fishery, also requires further investigation.

This study was initiated in September 1997 with the main aim of providing the required information to allow for scientific management of the inshore net fisheries, particularly with respect to any future increases in participation. In order to achieve this objective, the following key questions were asked:

1. What is the total catch and species composition in the gill and beach-seine net fisheries on the Cape west and southwest coasts (from the Olifants to the Breede River) and how does the catch vary across this region?

2. What is the current by-catch of species other than harders in the gill and beach-seine net fisheries in the study area, how susceptible are these species to capture by these nets and what is the value of these by-catch species to the fishers involved?

3. How accurate are compulsory commercial catch returns submitted by the net fishers and what alternate data collection systems could be used to validate existing returns, or to monitor the netfishery in place of compulsory returns?

4. Which fishers currently participate in the drift and beach-seine net fisheries in the study area, what are the socio-economic characteristics of these participants and how dependent are these fishers on netfishing for food or income?

5. Can these net fisheries support additional effort and, if so, in which areas and what criteria should be used to select new participants?

6. How should current regulations and management measures for the gill and beach-seine net fisheries be revised to promote the long-term viability of these fisheries?

Thesis outline

Chapter 1 addresses the first three key questions. Monitoring of commercial catches, face-to-face and telephone surveys and analysis of factory purchase records were conducted to obtain independent estimates of catch composition, total catch and effort for different regions. The occurrence of by-catch and catch rates made by inshore net fishers are compared to other sectors. The accuracy of compulsory catch returns was assessed by comparison of monitored landings and documented factory sales with reported catches. Seasonal and historical trends in catches made in different areas are described. Sources of survey error, possible biases and the accuracy of the catch and effort estimates are discussed.

Chapter 2 describes the socio-economic status of net fishers. Using information obtained from the questionnaire survey, the demographics, occupations and economic status of net fishers are described. Costs and returns to net permit holders and crew and the contribution of net fishing to the regional economy are estimated. Respondents' attitudes and responses to management measures are also evaluated.

Chapter 3 addresses the question of increased participation in the netfishery, particularly with respect to the possible impacts of an eastward expansion of the gill-net fishery. Data from a fishery-independent netting survey are analyzed to elucidate differences in catch composition and catch rates between currently open and closed areas. The possible influences of natural biogeographical trends and fishery effects on the observed differences are investigated. The consequences of increased by-catch and the impact of gill-netting in estuaries along the Southwest Coast are discussed.

In the concluding chapter, the findings of the study with respect to the key questions are summarized and suggestions pertinent to the future management of the net fisheries in the Western Cape are made.

CHAPTER 1

Catch and effort in the gill and beach-seine net fisheries in the Western Cape, South Africa

Introduction

By-catch in net-fisheries, particularly gill net fisheries, is a global concern. Many recent international studies have focussed on identifying and quantifying these catches, for example in Australia (Russell 1988), Ireland (Berrow 1994), Japan (Akiyama 1997), Korea (Han *et al.* 1997) and the United States (Bronte & Johnson 1983, Quinn 1988, Hale *et al.* 1996, Julian & Beeson 1998). In the Western Cape of South Africa, catches have only been quantified for the beach-seine fishery in False Bay (Lamberth 1994) and gill-net catch composition is largely unknown.

Conflict between net fishers and other users of inshore fish resources, particularly recreational and commercial line-fishers, is not a recent phenomenon in the Western Cape. As early as 1895, political pressure by line-fishers, who felt that gill nets were decimating line-fish stocks, particularly geelbek *Atractoscion aequidens*, resulted in action been taken against gill net fishers in Table Bay (Thompson 1913). As recreational angling grew in popularity, public concern over large net catches of what was perceived as "angling" fish species, such as galjoen *Dichistius capensis,* increased (Anon. 1949, De Villiers 1987, Penney 1991, Lamberth 1994). This concern about inshore net fishing was addressed by several investigations (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 1980's, numerous management measures were implemented. These included a reduction in overall netting effort, gill netting was restricted 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, gill and seine-net permits in the Western Cape, with the exception of False Bay, were awarded solely for the capture of harders *Liza richardsonii* and St Joseph shark *Callorhinchus capensis*. The targeting or catching of "linefish" species was prohibited.

The average annual reported *Liza richardsonii* catch for the period 1974-1984 was 1 745 tons (De Villiers 1987), substantially more that the 1 368 tons reported in 1996-1997 (Lamberth *et al.* 1997), or the 778 tons reported in 1998-1999 (MCM 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 collapse. Recent studies however, have shown catch returns to be inaccurate, with up to 90 % of the catch and effort, particularly of by-catch species, not reported (Lamberth *et al.* 1994, Lamberth *et al.* 1997). Furthermore, permit holders who operate in estuaries and in Langebaan Lagoon submit returns to different licensing authorities and the accuracy of these have 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 the true catch composition, total catch and effort in the fishery were unknown and certainly exceed those reported (Lamberth *et al.* 1997).

Conflict between recreational anglers and the net-fishers is likely to increase in the Western Cape, given the increasing angler numbers and decreasing line-fish stocks targeted by these fishers, but also caught as by-catch in the net fisheries. 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 line-fishery and recreational shore angling sectors (Sauer *et al.* 1997, Brouwer *et al.* 1997). This study aims to complement these surveys by providing similar information on the commercial net fishery. Such estimates are particularly important if decisions about increased, or decreased, participation in the net fishery are to be made. In this study, a combination of on and off site survey methods and analysis of factory purchases were used to provide the first estimates of total annual catch and effort for the net-fishery in the Western Cape that are independent of catch returns. Spatial and temporal trends in catch and effort, the biases inherent in the different survey methods and the accuracy of these estimates are discussed.

Methods

Study Area

The stretch of the South African coast for which net-fish catch and effort were assessed is shown in Figure 1.1. Catch and effort of the West Coast gill-net 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. 1.1). It was apparent that the gill-net fishery to the north of Elands Bay and in the area of Yserfontein was similar in nature (gear type, catch and effort levels), and both these regions were grouped as

Stratum 1. The beach-seine fishery within the study area was treated as homogenous, with the exception of False Bay, where the fishery operates under unique permit conditions. Estimates of catch and effort for False Bay were extracted from Lamberth (1994).

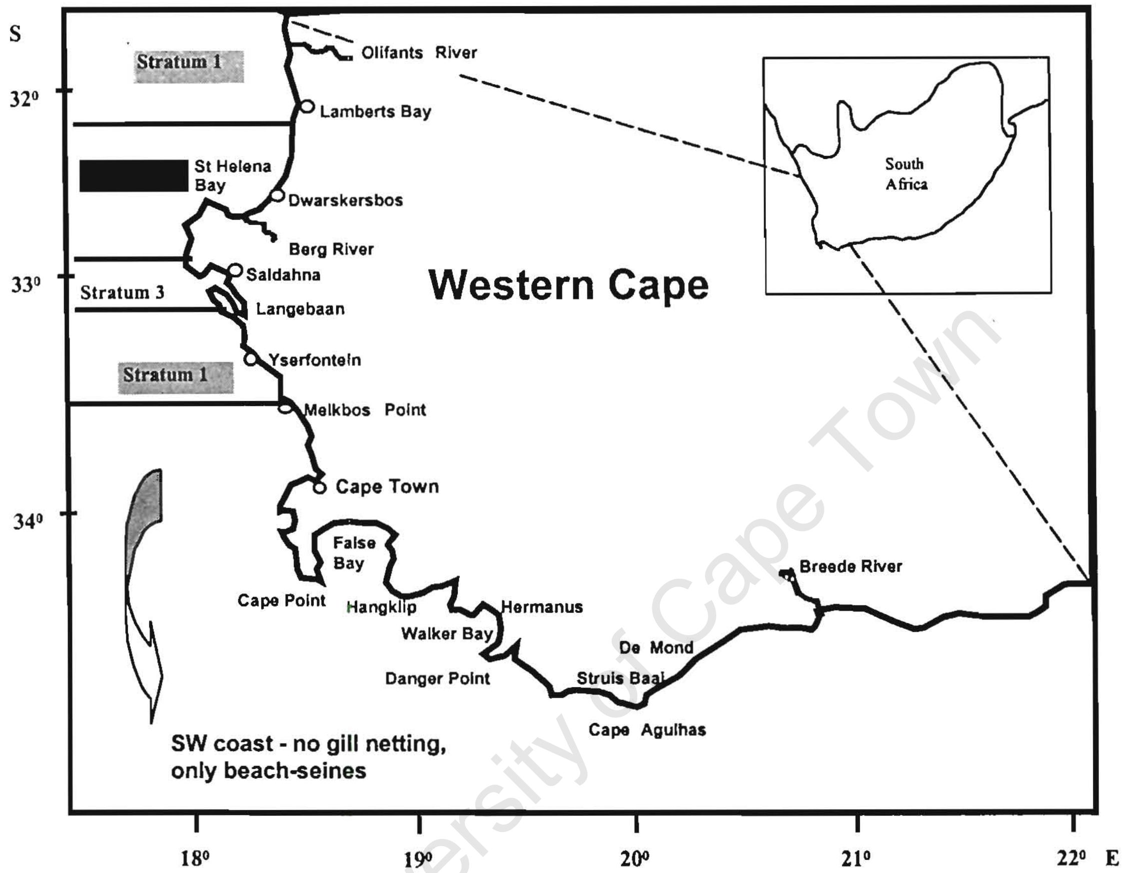


Fig. 1.1: Map of the Western Cape showing the areas for which catch and effort were assessed. Note that Stratum one includes the area north of St Helena Bay and south of Langebaan Lagoon.

Description of fishing methods and current legislation of the net fisheries

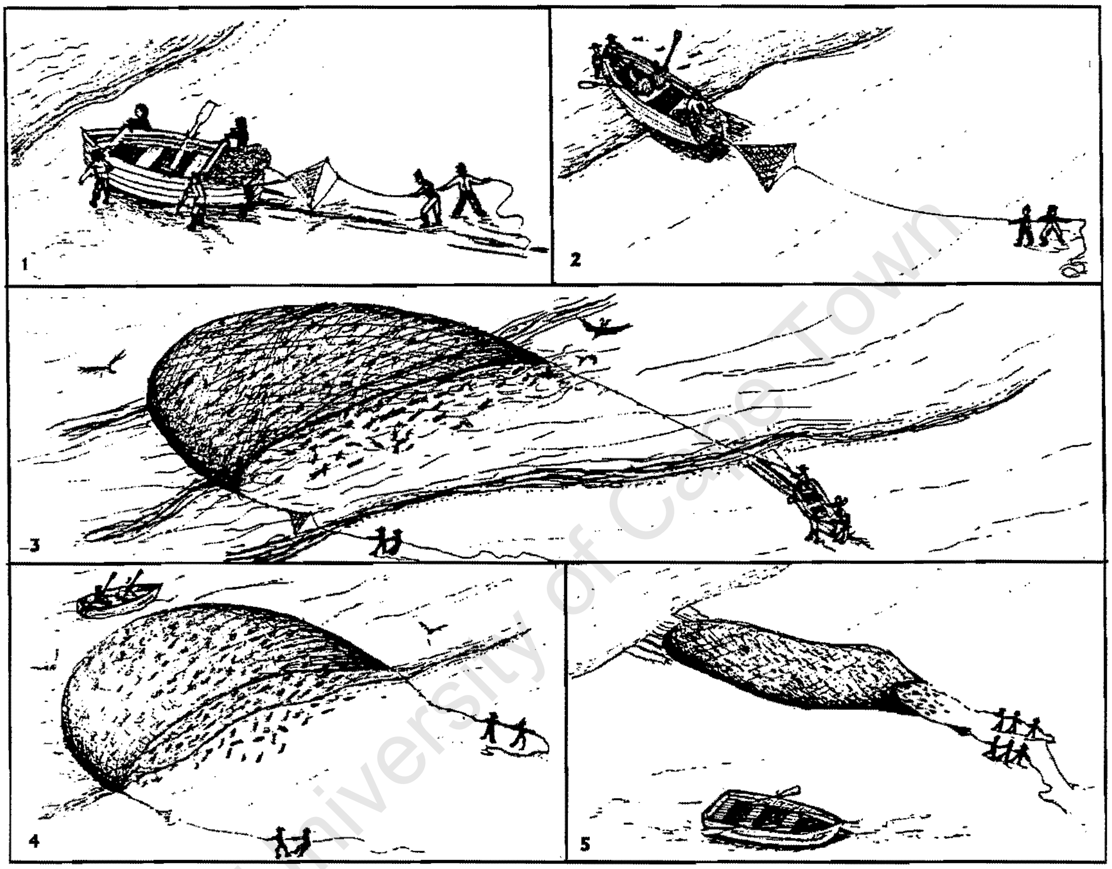
Beach-seine fishing has remained essentially unchanged since the technique was introduced to South Africa in the mid 1600s. The only technological improvements in the fishing gear relate to the use of woven nylon rather than cotton nets, glass fiber dinghies and four-wheel drive vehicles to transport the rig 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 and the length of the haul, then hauls the net, attached to head ropes, shoreward (Fig. 1.2). 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" 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".

Gill netting is normally a passive form of fishing in which nets are deployed (usually from a boat) in the water in the hope that a shoal of fish will swim into them and become entangled. Gill nets 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 (Fig. 1.2). Gill nets used to target *C. capensis* are negatively buoyant, are set along the sea floor and are buoyed and anchored at both ends (Fig. 1.2). Gill nets used by fishers to illegally target linefish e.g. *D. capensis*, are also negatively buoyant, but are often staked overnight or set without marker buoys to avoid detection (Fig. 1.2).

Although cotton and multifilament braided nylon mesh was used in the past, all the gill nets 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 due to its low visibility in the water is widely accepted to be much more efficient at catching fish (Hylen & Jakobsen 1974, Collins 1979, Grant 1980, Collins 1987). Many commercial gill net fishers have learnt to locate shoals of fish by using echo sounders or spotlights at night and employ a more active type of gill-netting. Shoals may be completely encircled, or the nets are thrown in a semicircle in front of the direction the shoal is moving. The fisher then scares the fish into the net by revving the outboard motor and completing the circle behind the shoal.

Approximately 321 gill net permit holders are licensed to operate in the sea on the West Coast north of Melkbos Point only, and an additional 185 permits are issued for the Olifants and Berg Rivers (Fig. 1.1). Seventy-three percent of all marine gill net permit holders operate in St Helena Bay and may legally use up to four 75-m floating "harder" (44-64 mm stretch mesh) or sinking "St Joseph" (178 mm stretch mesh) nets. Fishers north of St Helena Bay may obtain permits for up to four "harder" nets, but most (78 %) only use one, whereas the 10 Saldanha Bay permit holders may use two 75-m "harder" nets. Permit holders for Langebaan Lagoon, the Berg River and Yserfontein are only allowed to operate one 75-m "harder" net, whilst Olifants River permit holders are restricted to one "harder" net of 35 m length. 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 Southwest coasts. Beach–seine nets are restricted to 137 m in length to the east of Walker Bay and to 275 m to the west.

Beach-seine netting



Gill netting

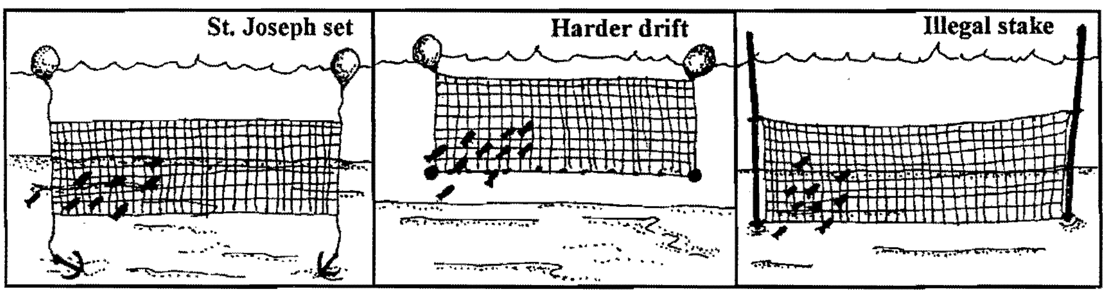


Fig 1.2: Beach-seine and gill-net fishing.

Adapted from van Sittert (1992)

Survey methods

Information pertinent to the current legislation of net-fishing activity was obtained from officials of Marine and 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 frames for questionnaire (Appendix 1) and telephone (Appendix 2) surveys.

The questionnaire survey was conducted both on-site, during monitoring of commercial net-fishing operations, off-site at permit holders' places of residence or work and at the AGM 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, the species of fish caught and the average daily catch rates for these species. Data on the gill-net fishery from this survey were stratified, into the regions described above, 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 as claimed by telephone and questionnaire survey respondents respectively, was 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 Kruskil-Wallis ANOVA by ranks using the STATISTICA software program (Statsoft 1999).

Access Point Surveys (APS) were undertaken during the period February 1998 - October 1999 with sampling effort concentrated at known accessible landing sites and during times of high net-fishing activity in order to obtain sufficient samples, given the limited manpower and budget available. Any net-fishing activity encountered fortuitously during the 16 two-week field trips and 10 two-day trips was also monitored. At all monitored landings, the total masses of harders *L. richardsonii* and St Joseph sharks *C. capensis* were estimated by counting the number of bins or individual fish and the total number of any by-catch individuals were counted. 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. Mass to number of *L. richardsonii* and *visa versa* was converted using a ratio based on the average weight of fish landed in that area (ratio varied from 5.7-7.8 fish per kg in the different areas). Where possible, all fish were measured to the nearest millimeter total length. If the size of the catch precluded total coverage, a representative sample was measured. Differences in the average total length of *L. richardsonii* landed by gill-net 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.

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 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 mass 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 *cpue* and the validation of catch returns. Although these factory books mostly only documented purchases of *L. richardsonii*, several purchases of by-catch 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. As the quantity of fish is accurately weighed, only reporting of more, not less fish than the mass sold is feasible (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 harder 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 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:

$$\hat{E}_i = N_i \bar{e}_i$$

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

The effort variance for each stratum was calculated as:

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

Where:

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

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

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

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

$$\mathrm{Var}(\hat{E}) = \mathrm{Var}(\hat{E}_1) + \mathrm{Var}(\hat{E}_2) + \mathrm{Var}(\hat{E}_3)$$

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 were 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 catch per unit effort (*cpue*):

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

Where c_i is the average catch of fish claimed by the ith respondent, and n is the number of net-fishers interviewed.

Data from the APS and factory records were used to calculate *cpue* as:

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

Where c_i is the number or mass (kg) of fish retained or sold by the ith net-fisher, e_i is 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^{-1}.

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 the sample variance (Zar 1996):

$$\text{Var}(cpue) = \frac{\sum_{i=1}^{n} c_i^2 - \frac{\left(\sum_{i=1}^{n} c_i\right)^2}{n}}{n - 1}$$

Where c_i is the average catch of fish claimed by the ith respondent or the mass (kg) retained by the ith 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*:

$$C = cpue \text{ x } E$$

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

$$\text{Var (C)} = \text{Var}(cpue) \times \text{Var (E)}$$

Results

1.1 Catch composition

(a) Gill-nets

In all areas, respondents to the questionnaire survey claimed that harders, *L. richardsonii,* were the most common species they caught. Many respondents insisted that *L. richardsonii* was the only species caught, but others admitted to catching between six (Berg River) and 17 (St Helena Bay) by-catch species (Fig. 1.3). Marine gill-netters reported catching similar by-catch species in all regions e.g. elf *Pomatomus saltatrix*, maasbanker *Trachurus trachurus,* St Joseph shark *C. capensis*, and gurnard *Chelidonichthys capensis*. Saldanha Bay and Langebaan Lagoon fishers, however, claimed a fairly distinctive catch composition, with species such as houndshark *Mustelus mustelus*, white stump *Rhabdosargus globiceps* and steentjie *Spondyliosoma emarginatum* being caught frequently. Estuarine permit holders also claimed a very different by-catch, with all species with the exception of *T. trachurus* having some degree of estuarine association. The claimed estuarine by-catch is dominated by elf and included the freshwater alien carp *Cyprinius carpio*.

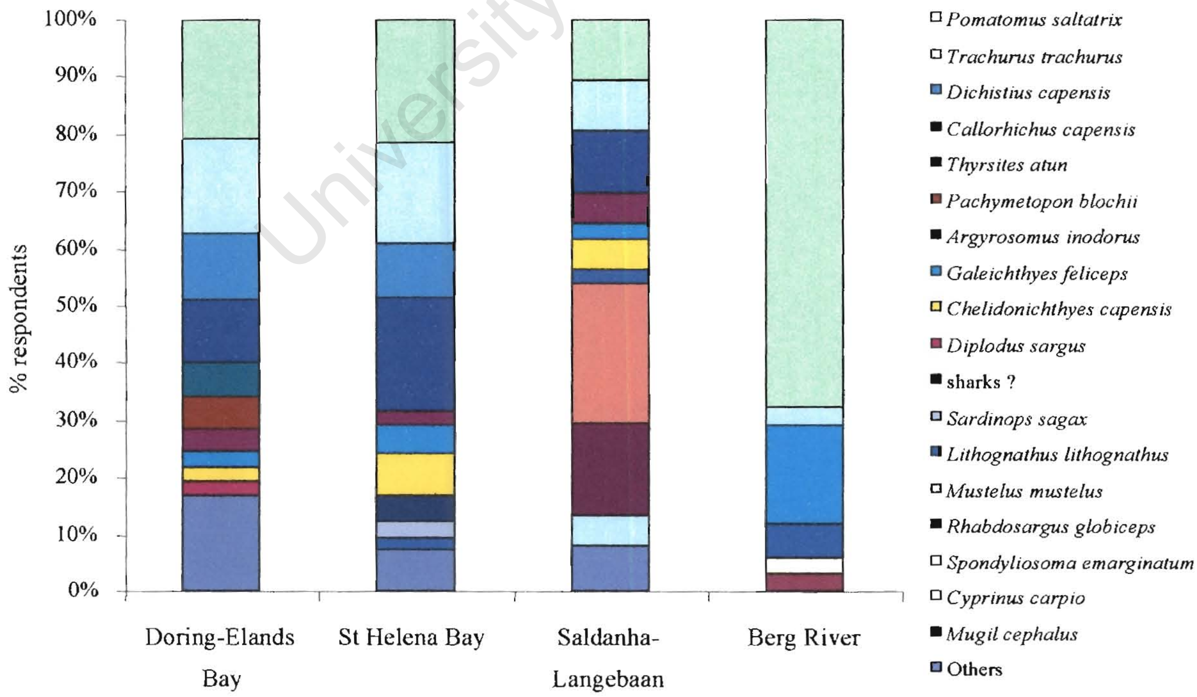


Fig. 1.3: By-catch claimed by gill-net questionnaire respondents.

These figures 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 have caught. Furthermore, species may be incorrectly identified. For example; fishers often group elasmobranchs (sharks, skates and rays). Permit holders also certainly deliberately refrain from mentioning catches of line-fish, which are prohibited. Respondents were asked for an average daily catch of these species, but insisted that such catches were small and sporadic and they could not supply any figures.

Accurate data on by-catch composition and catch rates could only be obtained by monitoring of commercial landings. A total of 138 562 fish representing 20 different families and 29 species (12 more than claimed by respondents) were recorded in 141 monitored, commercial gill-net fishing operations (Table 1.1). 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, whilst nine species were recorded in both the 178 mm and "illegal" (44-145 mm) 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 1.1). It must however, be noted that these fishers typically use only one 35-75 m gill-net 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" (44–145 mm) net catches of teleosts were substantially 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 and occurring in all estuarine and 96 % of the marine 44-64 mm net landings monitored (Table 1.1). The other target species, *C. capensis* only contributed 0.67 % of the total catch numerically, 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 1.1). *Pomatomus saltatrix* occurred in half the 44-64 mm net landings in estuarine and marine environments whilst *T. trachurus, Chelidonichthys capensis* and *G. feliceps* occurred in more than 10 % of the marine 44-64 mm net landings (Table 1.1). *Dichistius capensis* only occurred in 4 % of the legal 44-64 mm net landings, but in 75 % of the illegal nets monitored, evidence of the extensive illegal targeting of this species.

Table 1.1: Summary of information on species composition and abundance of all fish caught in 141 monitored gill-net fishing operations in the Western Cape during the period February 1998 to October 1999. * Illegal nets confiscated by MCM inspectors.

		Number of fish landed	Percent total	*Cpue:* no.fish.day^{-1} (% occurrence)			
				W. coast Estuarine	W. coast Marine		
Net mesh size				44 –51 mm	44 –64 mm	178 mm	44 –145mm*
OSTEICHTHYES							
Ariidae	*Galeichthyes feliceps*	41	0.039	0.5 (12)	0.36 (12)		0.63 (25)
	Galeichthyes ater	1	< 0.001			0.33 (33)	
Carangidae	*Trachurus trachurus*	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	Osteichthyes	133 987	99.29	313	1 140	6.33	28.53
No. of species		20		7	15	4	6
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	Chondrichthyes	2 200	0.704	0	1.58	255.29	2.75
No. of species		9		0	4	5	3
No. of landings monitored		141		8	117	8	8
Total		138 562		313	1 141.65	261.62	31.28

Size distribution of gill net catches

The size frequency distributions of *L. richardsonii* caught in commercial gill-net operations at different areas along the West Coast are shown in Figure 1.4. Significant differences were found between the average lengths of fish landed in the different areas (ANOVA, $F_{0.5, 5, 47} = 21.63$, $p < 0.05$). Fishers in Langebaan Lagoon caught fish that were significantly larger on average than those caught in any other area (Tukey HSD test, $P < 0.05$). Size frequency distributions of *L. richardsonii* caught in Stratum 1 (to the north of Dwarskersbos and to the south of Langebaan) and the Olifants River were similar. The mean lengths of fish landed in these areas were not significantly different (Tukey HSD test, $P > 0.05$) but were significantly greater than the average size fish landed in the heavily fished St Helena Bay and Berg River (Tukey HSD test, $P < 0.001$). Generally, the mean lengths of landed fish decreased, and the proportion of the catch that was immature increased, as gill-netting effort increased (Fig. 1.4).

Length frequency distributions of some of the more common by-catch species landed in commercial gill-net sets on the West Coast are shown in Figure 1.5. With the exception of *T. trachurus*, the catch of the most common by-catch species, *P. saltatrix*, *R. globiceps* and *G. feliceps*, in legal 44-64 mm "harder" nets is predominately (76-100 %) immature fish. The catch of species that were caught in both the small mesh "harder" nets and the larger mesh "illegal" (44-145 mm) and "St Joseph" (178 mm) nets comprised both mature and immature individuals. The traditional "galjoen" net with a stretch mesh of 145 mm seldom retains *D. capensis* of less than 350 mm total length (pers. obs.). The observed 66 % immature fish in the current gill net catch is partly due to the incidental capture of a few individuals in legal 44-64 mm nets, but mostly due to the increased use of smaller, 75 mm 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 that were measured were mature. These fish do not usually gill properly in the nets and frequently become entangled by their spiny head parts. Slightly more than half the *Callorhinchus capensis* caught were mature individuals. Net mesh size has little size selective effect on these fish, the majority becoming entangled by the dorsal spine or the tentaculum of mature males. Ninety-eight percent of the smooth hound sharks landed were immature individuals.

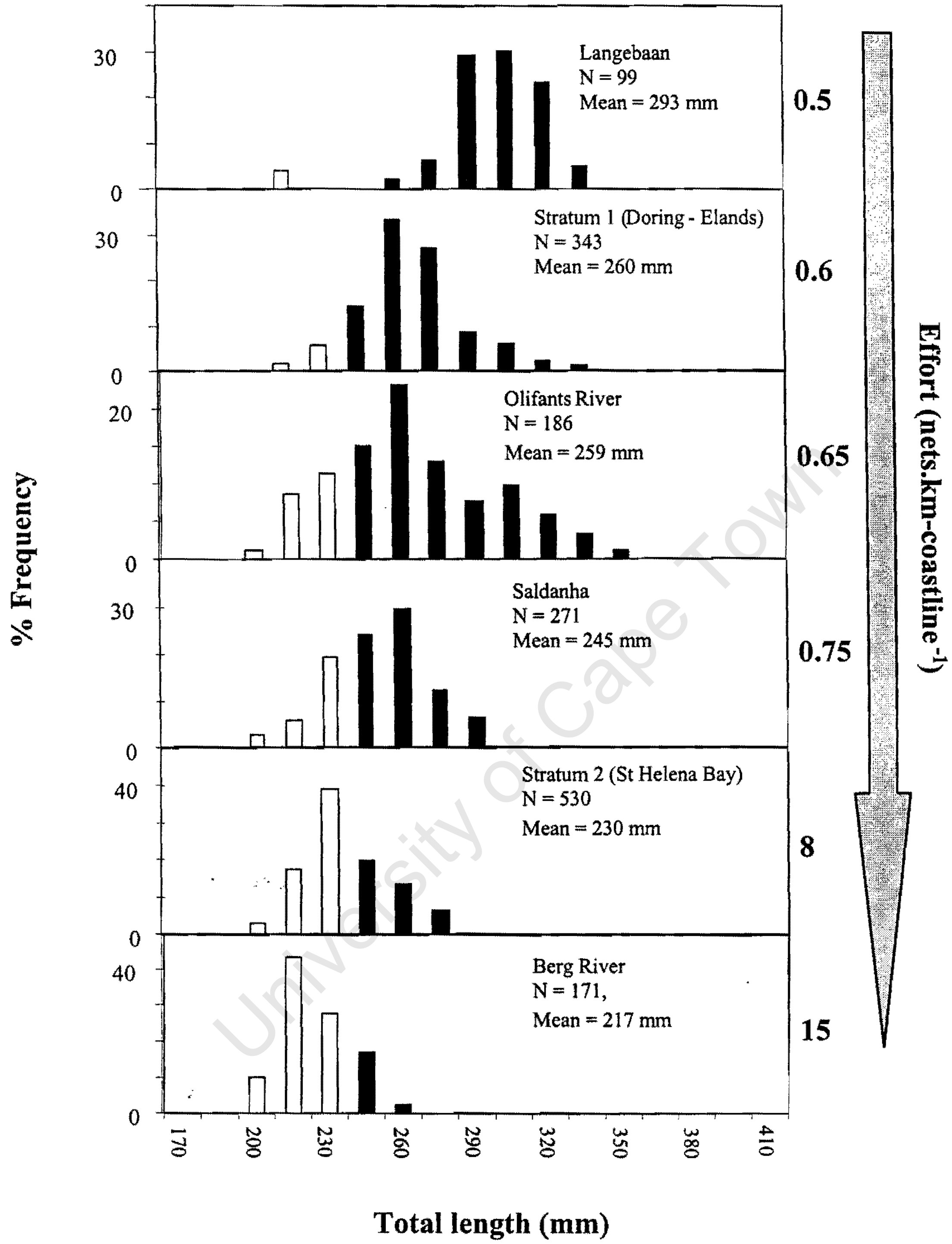


Fig. 1.4: Length frequency distributions of *Liza richardsonii* landed by commercial gill-netters in different regions. Potential effort levels (nets.km-coastline^{-1}) are included for a comparative purpose. Unshaded bars represent immature fish (De Villiers 1987).

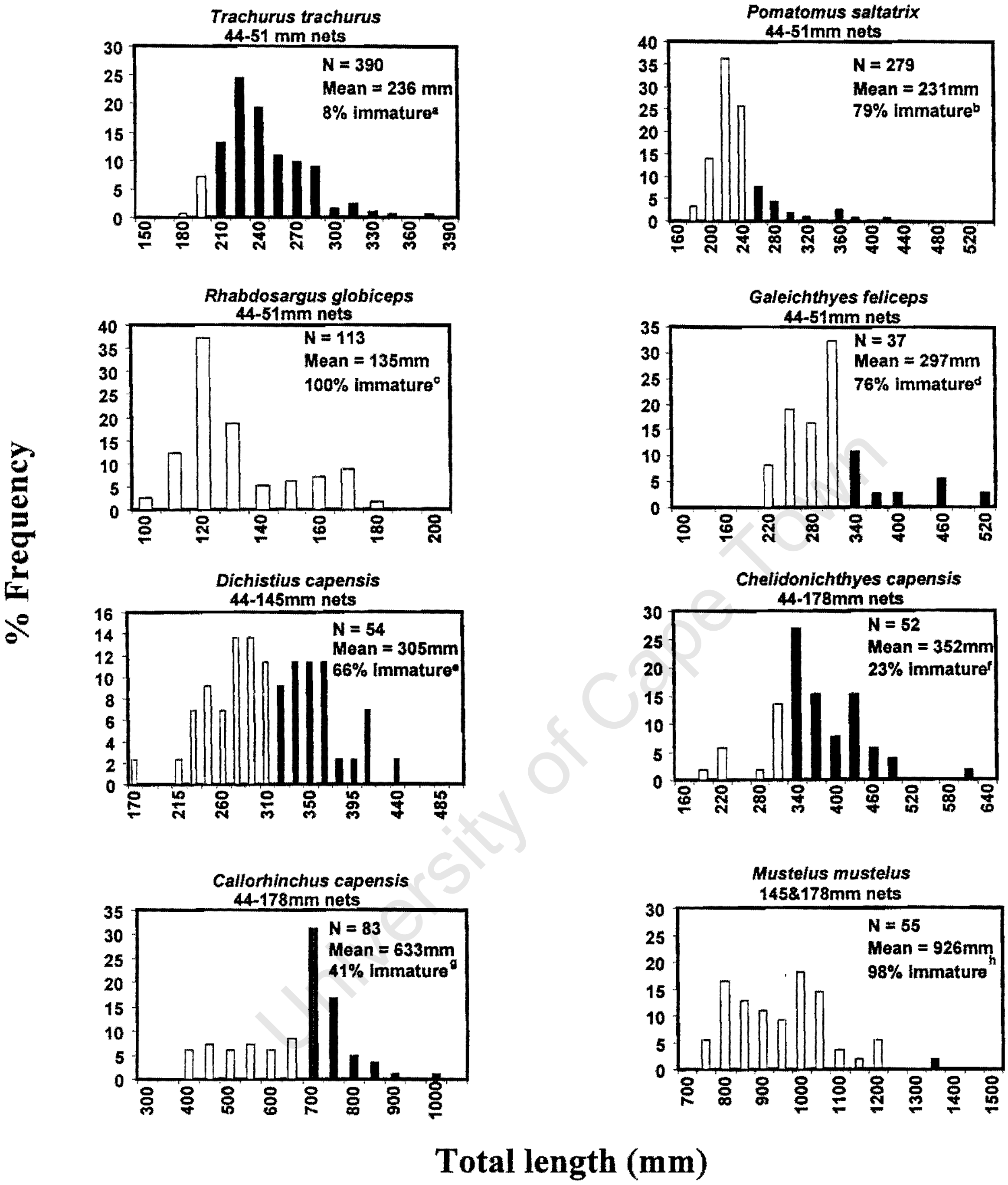


Fig. 1.5: Length frequency distributions of the more common gill-net by-catch.

□ = fish TL < 50% maturity a. Geldenhuys (1973), b. Van der Elst (1976), c. Talbot (1955), d. Tilney (1990), e. Bennett & Griffiths (1986), f. Hecht (1977), g. Freer & Griffiths (1994) h. Smale & Compango (1997).

(b) Beach seines

Beach-seine permit holders, who were interviewed, reported catching 17 different species in addition to *L. richardsonii* (Fig. 1.6). This list is subject to the same recall bias, possible misidentification of species and intentional deception, as the species lists obtained for gill nets. When asked, some respondents admitted to substantial landings of by-catch species, up to 500 kg of *A. inodorus* and three tons of *L. lithognathus* in individual hauls, and up to eight tons of *S. sagax* and 10 tons of sandshark *Rhinobatos annulatus*, per year. It was insisted, however, that these incidents were rare and usual catches were in the range of 0-100 by-catch fish on a day. Fishers reported that by-catch is very low or non-existent when the net is deployed on shoals of *L. richardsonii* that have been spotted. However, by-catch can be substantial when "blind" seines are made in the dark or through patches of dirty water or when valuable line-fish species are intentionally and illegally targeted (pers. obs.).

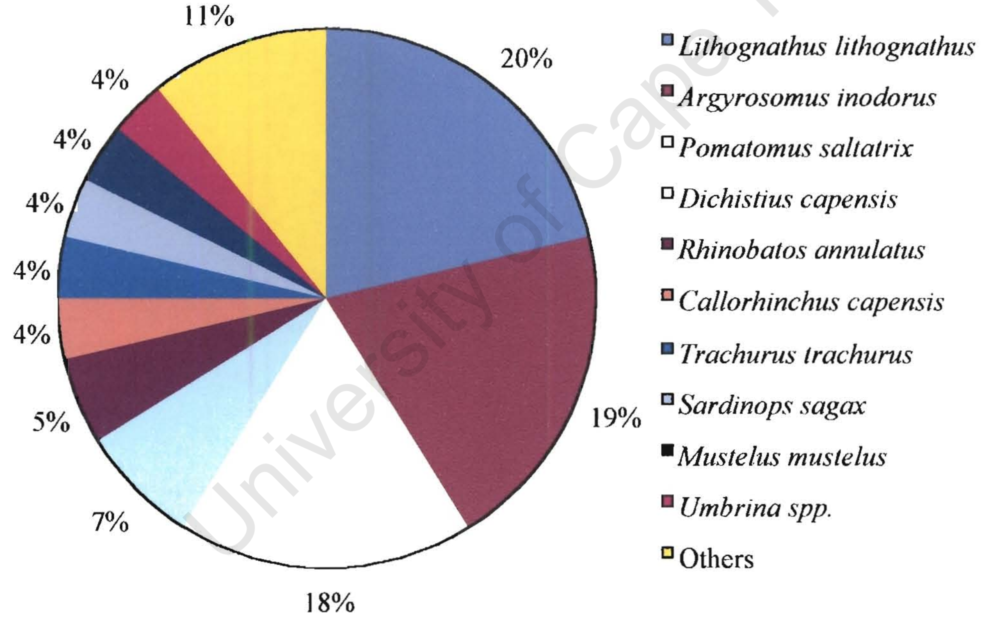


Fig. 1.6: By-catch claimed by beach-seine questionnaire respondents (excluding False Bay permit holders).

Despite the fact that over 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. In these nine landings, nearly seven tons of *L. richardsonii* were landed, but in most cases either no by-catch was landed, or researchers arrived too late to accurately assess the by-catch. In the three hauls where the entire operation was observed, the one haul had zero by-catch, the second landed one striped mullet, *Liza tricuspidens*, and one leervis, *Lichia amia*, and the third landed 44 juvenile *R. globiceps* and one *P. saltatrix*. In all three cases, the by-catch was less than 5 % of the harder catch numerically, but due to the paucity of the beach-seine monitoring these figures are not representative of the fishery as a whole.

1.2 Catch and effort estimates

(a) Marine gill nets

The average number of fishing days per annum claimed by gill-net permit holders in all strata responding to the questionnaire survey, was significantly greater than that claimed by respondents to the phone survey (t-test, $p < 0.05$). Because of this, the total marine gill-net effort calculated from the questionnaire survey data (27 075 fisher-days) was substantially more than that calculated using the telephone survey data (18 270 fisher days) (Table 1.2). It was concluded that the telephone survey effort estimate was less 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 calculate total catch estimates (Table 1.2).

Permit holders from Stratum 2, contacted during the telephone survey, all claimed an annual *L. richardsonii* catch in the region of 2-2.5 tons (Table 1.2). At the same time respondents claimed to make an average of 52 trips in a year. 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 1.2). Therefore, despite using the same effort values obtained from the telephone survey, total catch estimates calculated using catch rates based on monitoring or factory sales are 2.5-3 times greater than the total catch estimated by the telephone survey (Fig. 1.7).

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 (Kruskil-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 that were similar to those calculated using catch rates based on monitoring or factory sales and telephone survey effort (Fig. 1.7).

Table 1.2: Marine gill net *Liza richardsonii* and *Callorhinchus capensis* catch and effort estimated by different survey methods. Mean values ± SE. **Callorhinchus capensis* gill net effort estimated as 20 % of harder net effort, based on responses to phone survey, catch rate based on 8 monitored landings. ** No factory records available, values from monitored landings.

Value	Stratum 1: Doring-Elands + Yserfontein	Stratum 2: Dwarkersbos – North Head	Stratum 3: Saldanha- Langebaan		Total
Questionnaire survey					
No. permit holders	58	235	28		321
Sample (interviews)	37	46	16		99
Average annual effort (trips)	60 ± 7	77 ± 9	195 ± 19		
Total annual effort (trips)	3 494 ± 235	18 110 ± 4 182	5 470 ± 342		27 075 ± 4 202
L. richardsonii cpue (kg.trip $^{-1}$)	34 ± 7	112 ± 21	78 ± 16		
Annual *L. richardsonii* catch (t)	119 ± 8	2 023 ± 402	425 ± 19		2 567 ± 403
Telephone survey					
Sample (interviews)	12	48	10		70
Average annual effort (trips)	33 ± 10	52 ± 8	142 ± 20		
Total annual effort (trips)	1 900 ± 500	12 300 ± 1670	4 000 ± 458		18 270 ± 1 800
Average catch (kg.yr^{-1} claimed)	858 ± 296	2 312 ± 471	15 925 ± 4 793		
Annual *L. richardsonii* catch (t)	50 ±15	543 ± 98	446 ± 108		1 040 ± 146
L. richardsonii cpue (kg.trip^{-1})	26	44	112		
Annual *C. capensis* catch (t)	/	290	/		290
Access point survey (Telephone survey effort)					
Sample (No. of landings)	8	95	14		117
L. richardsonii cpue (kg.trip^{-1})	9.8 ± 4.9	159 ± 18	136 ± 39		
Range (kg.trip $^{-1}$)	0 – 40	0 – 1 008	0 – 550		
Annual *L. richardsonii* catch (t)	19 ± 7	1 949 ± 284	542 ± 67		2 510 ± 292
C. capensis annual effort *	/	2 570	/		
C. capensis cpue (kg.trip^{-1})	/	252 ± 58	/		
Annual *C. capensis* catch (t)	/	647	/		647
Factory records (Telephone survey effort)	**		Saldanha	Langebaan	
Sample (permit holders)		30	3	6	39
Sample (No. sales)		312	48	354	714
L. richardsonii cpue (kg.sale $^{-1}$)		183 ± 11	280 ± 48	99 ± 5	
Range (kg.sale $^{-1}$)		3 – 1 149	17 – 2 198	5 – 693	
Annual effort (trips)	1 900 ± 500	12 300 ± 1 670	1 117 ± 173	2 808 ± 309	18 125 ± 1 800
Annual *L. richardsonii* catch (t)	19 ± 7	2 251 ± 327	313 ± 57	278 ± 31	2 861 ± 334

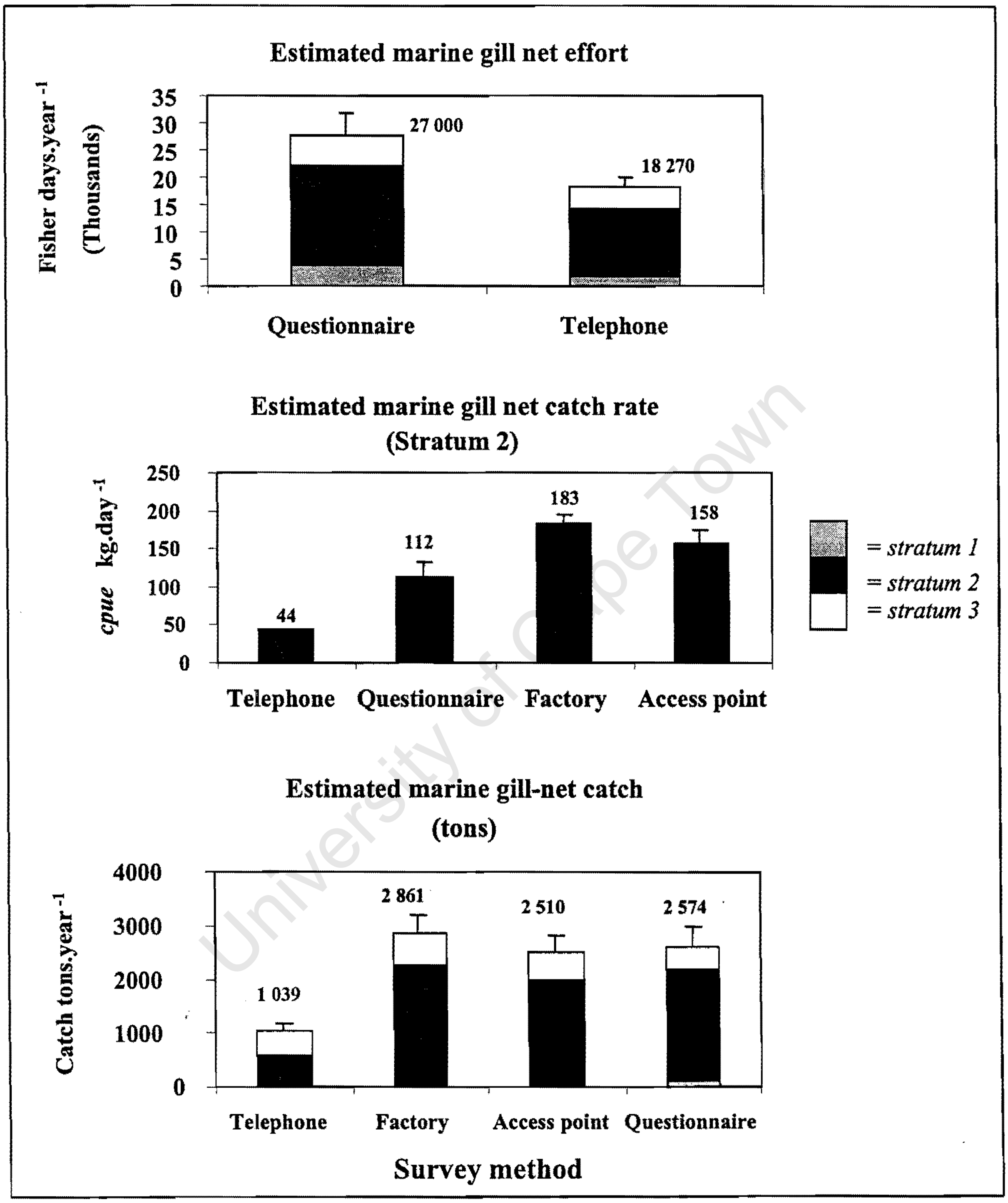


Fig. 1.7: Comparison of marine gill-net *Liza richardsonii* catch and effort estimated by different methods.

The majority of permit holders operate opportunistically in a very small-scale commercial or recreational fashion, and a fair number have not been active at all (Fig. 1.8). Permit holders fishing in the Doring to Elands Bay region (Stratum 1) are the least active, whilst those operating in Saldanha - 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. 1.8), is the cause of the high variances associated with effort estimates.

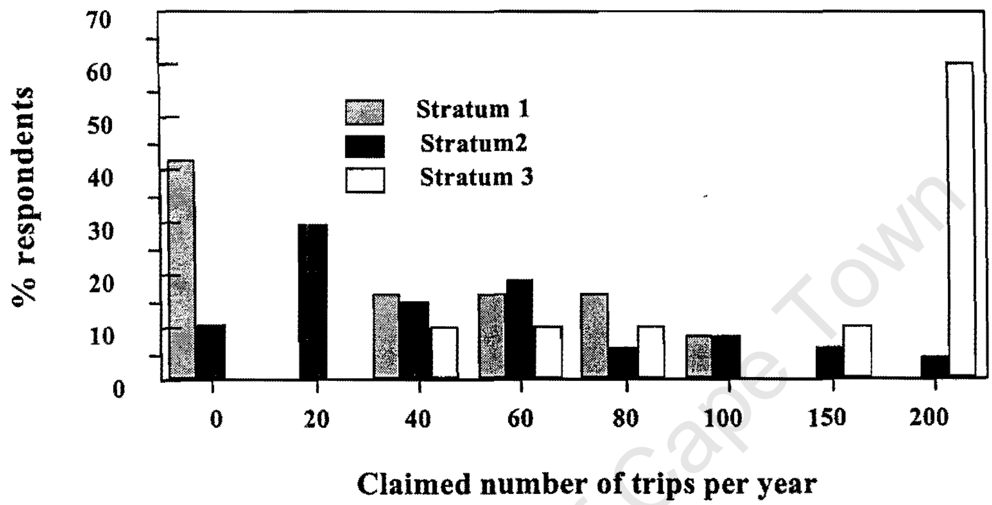


Fig. 1.8: Frequency distribution of annual effort claimed by gill net respondents in the telephone survey.

Estimates of the total annual marine 44-64 mm gill-net landings of the more common by-catch species are shown in Table 1.3. These estimates are based on observed catch rates in monitored landings and the effort levels claimed by net-fishers in the telephone survey.

Table 1.3: Annual marine 44-64 mm gill net by-catch estimated by access point survey, effort estimate from telephone survey.

Species	Common name	Percentage occurrence	Doring-Elands + Yserfontein	Dwarkersbos – North Head	Saldanha-Langebaan	Total
			Estimated number caught (*cpue*: No.trip^{-1})			
Trachurus trachurus	Maasbanker	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 Stump	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

(b) Estuarine gill nets

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". Sowmen *et al.* (1997) estimated that approximately 100 tons of *L. richardsonii* and 6-8 tons of by-catch, predominately juvenile *P. saltatrix*, are landed annually.

Fifty-nine of the 120 fishers who received permits for the Berg River in September 1998 responded to the questionnaire survey that was 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. These fishers anticipated making an average of 110 trips on the river during 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 1.4).

This huge discrepancy between the number of trips fishers claim to make, and the number of sales documented, means that the actual *L. richardsonii* catch from the Berg River could be anything between 100-500 tons (Table 1.4). The most common by-catch in the Berg River, *P. saltatrix* occurred 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 vs. 65) and the longer nets permitted (75 m vs. 35 m) in the Berg River fishery compared to the Olifants River fishery, 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 highly likely therefore, 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, as many catches may not be sold, or may be sold to different buyers.

Table 1.4: West Coast estuarine *Liza richardsonii* catch and effort estimates. Values ± SE.

Value	Berg River (Factory data)	Berg River (Questionnaire data)	Olifants River (Sowman *et al.* 1997)
No. 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 (No. sales)	136		No data
Mean *cpue* (kg/trip)	37 ± 3		20-50 fish.net-hr^{-1}
Annual catch (tons)	95 ± 44	489 ± 27	100

(c) Illegal gill nets

In 1984 the gill-net fishery targeting *D. capensis* along the West Coast was banned, largely in response to recreational angler complaints and conservation and management concern over the status of *D. capensis* stocks (Bennett 1988). The now illegal fishery has, however, continued, with *D. capensis* gill-netting being far more lucrative than *L. richardsonii* netting. Black market prices for *D. capensis* are in the region of R 18-20.kg^{-1} compared with R 2.5-3.kg^{-1} for *L. richardsonii.* Sauer and Erasmus (1996) estimated that approximately 50 illegal mesh size gill nets were in use, mostly between St Helena Bay and Elands Bay. Information on the annual sales of monofilament gill nets, however, show that approximately 180 illegal mesh size nets are sold annually (Table 1.5).

In addition to *D. capensis*, illegal net fishers target other valuable line-fish such as *Argyrosomus* spp., *P. saltatrix*, and *P. blochii.* Over the last 10 years an illegal shark gill-net fishery, targeting *M. 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 gill-netting is not confined to the West Coast; Cape Nature Conservation recently confiscated 2 set gill nets (one 75 mm stretch mesh, 450 m length and one 57 mm stretch mesh, 225 m length) that were found in Hermanus Lagoon. Anecdotal evidence once again suggests that illegal gill-netting in estuaries and the sea along the Southwest Coast is extensive.

Table 1.5: Approximate annual sales of monofilament gill nets and species targeted.
Bold font indicates illegal mesh sizes.

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

Although evidence of illegal netting was observed during monitoring of commercial net landings (fishers unloading illegal mesh size nets from vessels), no successful trips were recorded. Fishers would obviously be more secretive when large illegal catches of line-fish were made. The only estimates of illegal net catch rates available were from the fish found in a few (8) nets confiscated by MCM inspectors during the study period. A conservative effort estimate of 1 800 illegal net-days (180 nets used 10 times per year) in conjunction with these catch rates give minimum estimates of illegally caught net-fish (Table 1.6).

Table 1.6: Illegal net-fish catch estimated from confiscated nets.
(Effort, 1 800 days, estimated from annual net sales).

Species	Number confiscated	Percent total	Percent occurrence	Catch Rate (No.day $^{-1}$)	Estimated catch (No.)
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

It must be stressed that these are minimum estimates and not a complete list of all illegally caught fish. Considering that illegal net sales make up 30 % of all net sales annually (Table 1.5), and 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 – 30 % of the estimated legal net fishing effort. This may, however, be an overestimate as 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 based on illegal net-fish operations that were apprehended, often staked nets that were recently set. 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 as the majority takes place at night in remote areas and the MCM inspectorate has severe manpower and transport restrictions. Approximately eighty 145 mm "galjoen" nets and one hundred 76-100 mm "barbel" nets are sold annually (Table 1.5), but in the last 5 years only 132 of these nets have been confiscated (Table 1.7). The amount of fish confiscated (Table 1.7) is also negligible compared to even the minimum estimate of the amount been caught (Table 1.6).

Table 1.7: Nets and fish confiscated by Marine and Coastal Management inspectors on the West Coast during the period 1994:1999.

Net Type	Nets confiscated	Fish confiscated
"Harder" (44-64 mm)	241	7 945kg *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	

Gill net catch rates of *L. richardsonii* along the South African West Coast generally exceed those recorded for inshore net fisheries targeting small pelagic species in other regions globally (Table 1.8, see pg. 34). 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 gill-netters use the maximum permitted net length (300 m), it is apparent that standardized *cpue* in this region, where effort is high, is actually substantially less than that recorded for the South African East and South Coasts, where gill-netting effort is low. This does not imply that gill netting is more viable along the South and East Coasts. At higher effort levels, the current catch rates in these areas are unlikely to be sustainable and would probably decline to less than those currently recorded along the more biologically productive West Coast.

(d) Beach-seine nets

As for gill nets, beach-seine effort was estimated by questionnaire and telephone surveys. 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 1.9). Telephone respondents who were asked for a total catch over the previous 12 months claimed the lowest catch rates (Table 1.9). The total annual catch estimates obtained using catch rates from monitored landings and factory sales and effort from the phone survey were fairly similar in the region of 1 700 tons.

Table 1.9: Beach-seine *Liza richardsonii* catch and effort estimates, excluding False Bay. Values ± SE

Value	Telephone	Questionnaire	Monitoring	Factory
No. permit holders	93	93	93	93
Sample (permit holders)	22	23	6	4
Mean effort (hauls)	23.8 ± 8.8	37.4 ± 9		
Annual effort (hauls)	2 211 ± 718	3 478 ± 729	2 211 ± 718	2 211 ± 718
Sample (No. sales / landings)			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

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 3300 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 1.10).

Table 1.8: Comparison of South African West Coast gill-net catch rate and catch composition with those made in other regions. (Table adapted from Dalzell 1996).

Location	Net length (m)	Mesh size (cm)	Target stock	CPUE		Principal catch components	Source
				Range	Mean		
Kiribati	N/A.	5.7 – 12.7	Reef and lagoon species	5.0 – 96.0 kg/trip	43.4 kg.trip^{-1}	Albulidae, Carangidae, Mugilidae, Mullidae	Anon. (1989)
Solomon Islands	N/A.	5 – 15	Reef and lagoon species	0.26 – 0.90 kg/100mnet-h	0.46 kg.100m net-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/10m of net	2.2 kg.10m of net^{-1}	Carangidae, Priacanthidae, Mullidae, Caesionidae	Chapman & Cusack(1989)
Fiji (Rabi Island)	150	1.9 – 7.6	Reef and lagoon species	15 – 26 kg/set	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	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	3.0 kg.set^{-1}	Carangidae, Clupeidae	Dalzell (1993)
Seychelles	50	5.7 – 6.4	Small pelagics	38 – 75 kg/set	55.7 kg.set^{-1}	Scombridae, Caesionidae, Carangidae	De Moussac (1987)
South Africa KZN	30	9	Lagoon and lake species	N/A	5 kg.net-day^{-1}	Mugilidae, Haemulidae, Pomatomidae	Mann (1997), Kyle (1999)
South Africa E. coast	75	4.4 – 5.7	Small pelagics	N/A	59 kg.net-day^{-1}	Mugilidae	Lamberth *et al.* (1997)
South Africa S. coast	75	4.4 – 5.7	Small pelagics	N/A	71 kg.net-day^{-1}	Mugilidae	Lamberth *et al.* (1997)
South Africa W. coast	75 – 300	4.4 – 5.7	Small pelagics	3 – 2 198 kg/trip	148 kg.day^{-1}	Mugilidae, Carangidae, Pomatomidae	This study

Table 1.10: Comparison of South African West Coast beach-seine catch rate and catch composition with those made in other regions. (Table adapted from Dalzell 1996).

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

1.3 Accuracy of compulsory catch returns

(a) 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 West Coast gill-net trips made by 48 different permit holders, the remaining six being beach–seine catches made by three different operators. Twenty of the gill-net permit holders reported some of the trips monitored, but only 11 reported all trips made. Two of the three beach-seine permit holders reported hauls that were monitored. Forty-four of the 112 gill-net 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. A total of 18 872 kg of *L. richardsonii* and 4 175 by-catch individuals was landed by fishers for these trips. Only 5 349 kg of *L. richardsonii* (28 %) and 605 by-catch individuals (14.5 %) were reported (Table 1.11). For landings where returns were submitted, the reported harder catch, 3 208 kg, did not differ significantly from the monitored catch 3 351 kg (paired t-test, $p > 0.05$).

Table 1.11: Observed and reported catches for 118 monitored net landings. (*Liza richardsonii* are given as kg, other fish as numbers)

Species	Gill nets			Beach-seines		
	Monitored catch	Reported catch	Percent reported	Monitored catch	Reported catch	Percent reported
Liza richardsonii	15 672	3 208	20	3 100	2 141	69
Callorhinchus capensis	1 875	343	18			
Trachurus trachurus	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 & skates	6	2	33			
Total	21 671	4 156	19	3 147	2 141	68

Reporting of by-catch varied from 0-32 %, but the fact that 97 % of the by-catch 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 by-catch species at the same rate as this permit holder, but these fish were hidden from researchers and were not recorded. Further evidence of underreporting can be found in a comparison of observed by-catch rates monitored in 44-64 mm gill nets with the reported catch rates and total catch (Table 1.12). For almost all species caught, the observed catch rates and estimated annual catch were one or two orders of magnitude greater than the reported catch rates and total catch. This comparison suggests that the true level of by-catch reporting is in the region of 1-3 %.

Table 1.12: Comparison of observed and reported by-catch rates for 44-64 mm gill nets.
* Calculated using effort values obtained by telephone survey

Species	Observed *cpue* (Number.net-day^{-1})	Estimated annual catch* (Number)	Reported *cpue* (Number.net-day^{-1})	Reported annual catch (Number)
Trachurus trachurus	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

(b) Factory sales

Out of the total of 360 factory sales by gill-net 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 in catch return forms. This proportion (21 %) is probably a more accurate reflection of effort reporting by gill-net fishers during 1998/1999 than the levels determined from monitored catches (40 %), as a fisher who is monitored may feel obligated 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.

Table 1.13: Fish sold and reported by net permit holders.
(All quantities are in kilograms)

Species	Gill-nets			Beach-seines		
	Sold	Reported	(%)	Sold	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	2 235	0	0			
Pomatomus saltatrix	111	0	0			
Rhabdosargus globiceps	4	0	0			
Argyrosomus inodorus	16	0	0			
Total	72 405	5 737	8	37 584	24 767	66

There was substantial under-reporting of catches; with only 8 % of the *L. richardsonii* sold by gill-net fishers reported (Table 1.13). This is due to the large number of trips that were not reported at all (79 %), as well as the fact that when permit holders do submit returns, they substantially under-report the amount of fish caught. The average catch rate based on the factory sales (196 kg.sale^{-1}) is more than double the average reported catch (77 kg.day^{-1}). None of the by-catch sold was reported as the fishers responsible for the sales failed to submit any returns. The four beach-seine permit holders reported 62 % of the sales made and 66 % of the mass of fish caught (Table 1.13). For the 74 gill-net sales where 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 the amount 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).

1.4 Historical trends in reported annual catches

Gilchrist (1899, 1900, and 1901) provides the earliest available statistics of total annual *L. richardsonii* landings in his reports as Government Marine Biologist. Annual catches for this period ranged from 1.3-1.6 million fish. Gilchrist (1914) also reports on complaints by commercial fishers in St Helena Bay, that large catches of juvenile fish by gill and seine net fishers in the Berg River were leading to a decrease in supply to the former. In this report, evidence of decreasing catches in St Helena Bay are provided in the form of annual catches of adult (harders) and juvenile ("bokkoms") *L. richardsonii* by Messrs. Stephan Bros. for the years 1880-1913. Assuming these are accurate (figures are not rounded off), the recorded catches for a 33 year period provide a valuable insight into the net fishery in St Helena Bay at the time. A drastic reduction in annual catches occurred, with the average annual catch prior to 1900 of approximately 102 tons (calculated from a conversion ratio of 5 harders.kg^{-1} and 8 bokkoms.kg^{-1}) declining to an annual average of only 16 tons thereafter, equivalent to a 85 % decrease (Fig. 1.9).

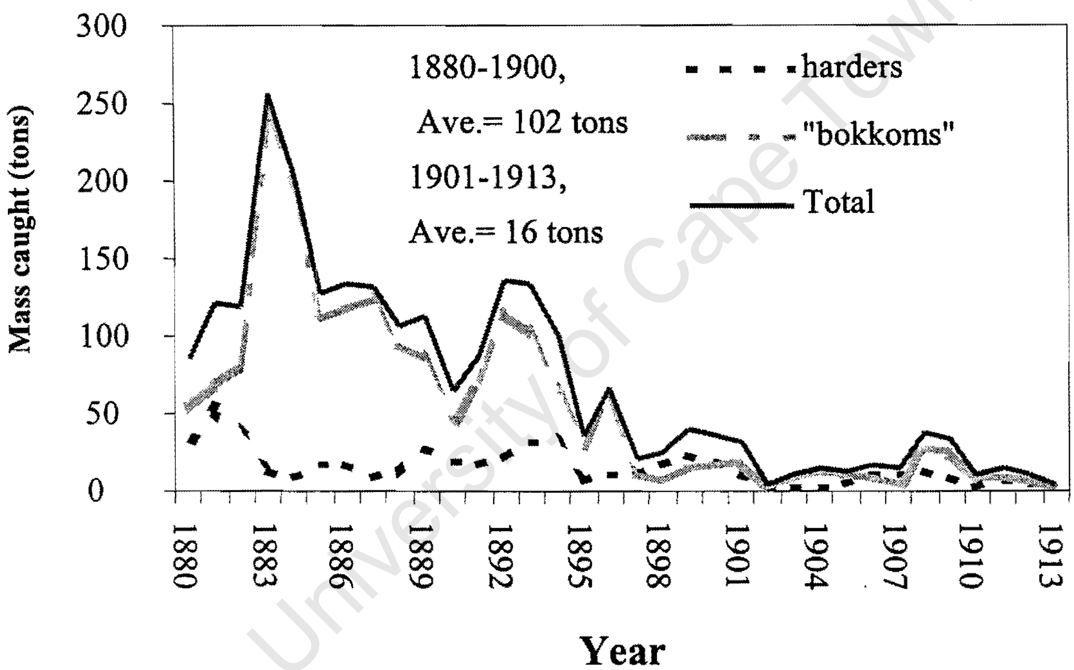


Fig. 1.9: Recorded net catches of adult (harders) and juvenile (bokkoms) *Liza richardsonii* by Messrs. Stephan Bros. of St Helena Bay, 1880-1913 (Gilchrist 1914).

Further catch statistics only became available with the licensing of gill and beach-seine nets in 1973 (De Villiers 1987). Compulsory catch returns have been shown to be inaccurate, with many permit holders substantially underreporting catches or failing to submit returns at all. These catch returns can still, however, be used to examine temporal trends in total catch, if the degree of underreporting and the number of permit holders submitting returns is assumed to have remained relatively constant. The reported annual catch of *L. richardsonii* has been remarkably constant until 1986, at around 5-6 million fish per year, with the exception of the 1980-1982 period when reported catches peaked at 8-14 million fish (Fig. 1.10), (De Villiers 1987, Stander 1991). Since 1986, the reported annual catch has shown a sustained decrease, with the 1998/1999 average (718 tons) being only 42 % of the pre-1986 average (Fig. 1.10).

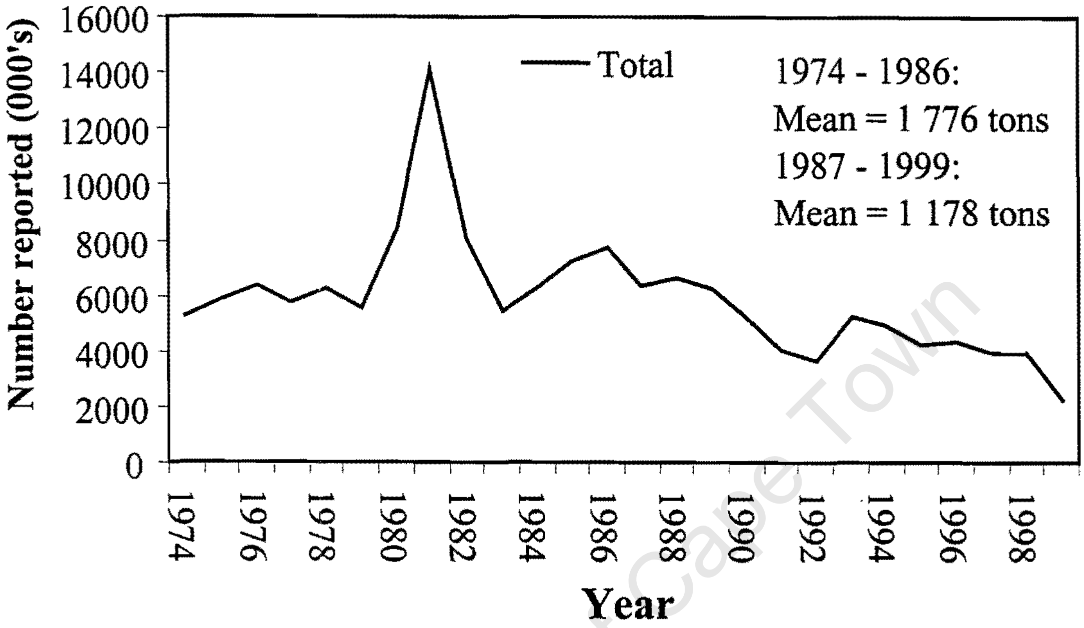


Fig. 1.10: Total annual reported *Liza richardsonii* catch by gill and beach-seine net permit holders in the Western Cape, 1974-1999 (MCM unpublished data).

1.5 Seasonality of catch and effort

Gill-net fishing effort in the St Helena Bay area and the Berg River is largely confined to the summer months, when weather conditions are favorable, catch rates are higher and permit holders who are involved in other fishing sectors (e.g. pelagic, line-fish) have time off. Analysis of factory records, from one of the large buyers of *L. richardsonii* in the area, provide the most comprehensive insight into catch and effort trends over the fishing season (Fig. 1.11). St Helena Bay gill-net 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, as the highest average sales (*cpue*) were recorded during this month. *Cpue* remained steady in the region of 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 the months of December and April when fishing effort was low (Fig 1.11).

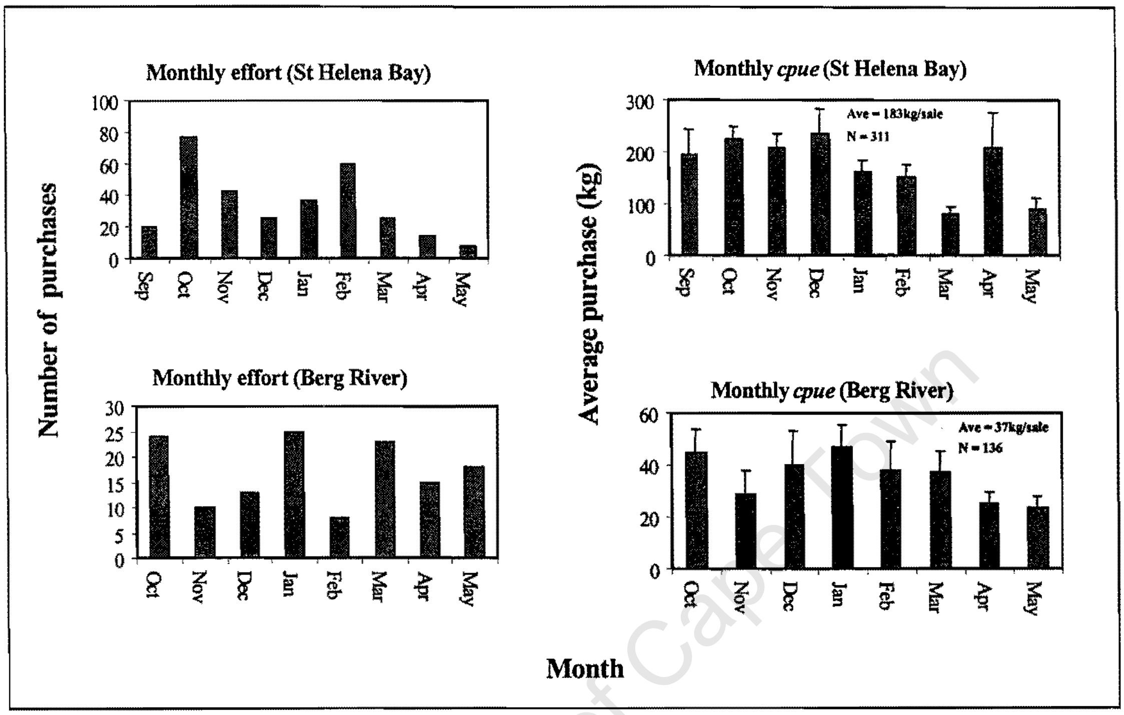


Fig. 1.11: Seasonal *Liza richardsonii* catch and effort trends for the St Helena Bay and the Berg River gill-net fishery.

In the past, Cape Nature Conservation (CNC) imposed a 6-month closed season on the Berg River fishery from 1 April - 30 September. Fishers successfully campaigned for the scrapping of the closed season, arguing that the river "closed itself to fishing" during winter due to floodwaters and that the reason for the closed season - to protect spawning fish, was flawed, as *L. richardsonii* are not known to spawn in fresh water. It was announced at the 1998 September 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. 1.11). Berg River effort peaked in January and March, months 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 purchase of fish from the Berg River peaked at around 45 kg during October and January and, like the St Helena Bay *cpue*, declined towards Autumn with 25 kg being the average purchase during April and May.

In contrast to the fishery in St Helena Bay and the Berg River, gill net-fishers in Saldanha Bay and Langebaan Lagoon are active throughout the year (Fig. 1.12). No trend in monthly effort was apparent from records for Langebaan Lagoon, with high effort levels recorded in late summer and winter. Average monthly *L. richardsonii cpue* was higher during the late summer, autumn and spring months than during winter and early summer. As was the case in St Helena Bay, higher than average *cpue* occurred 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).

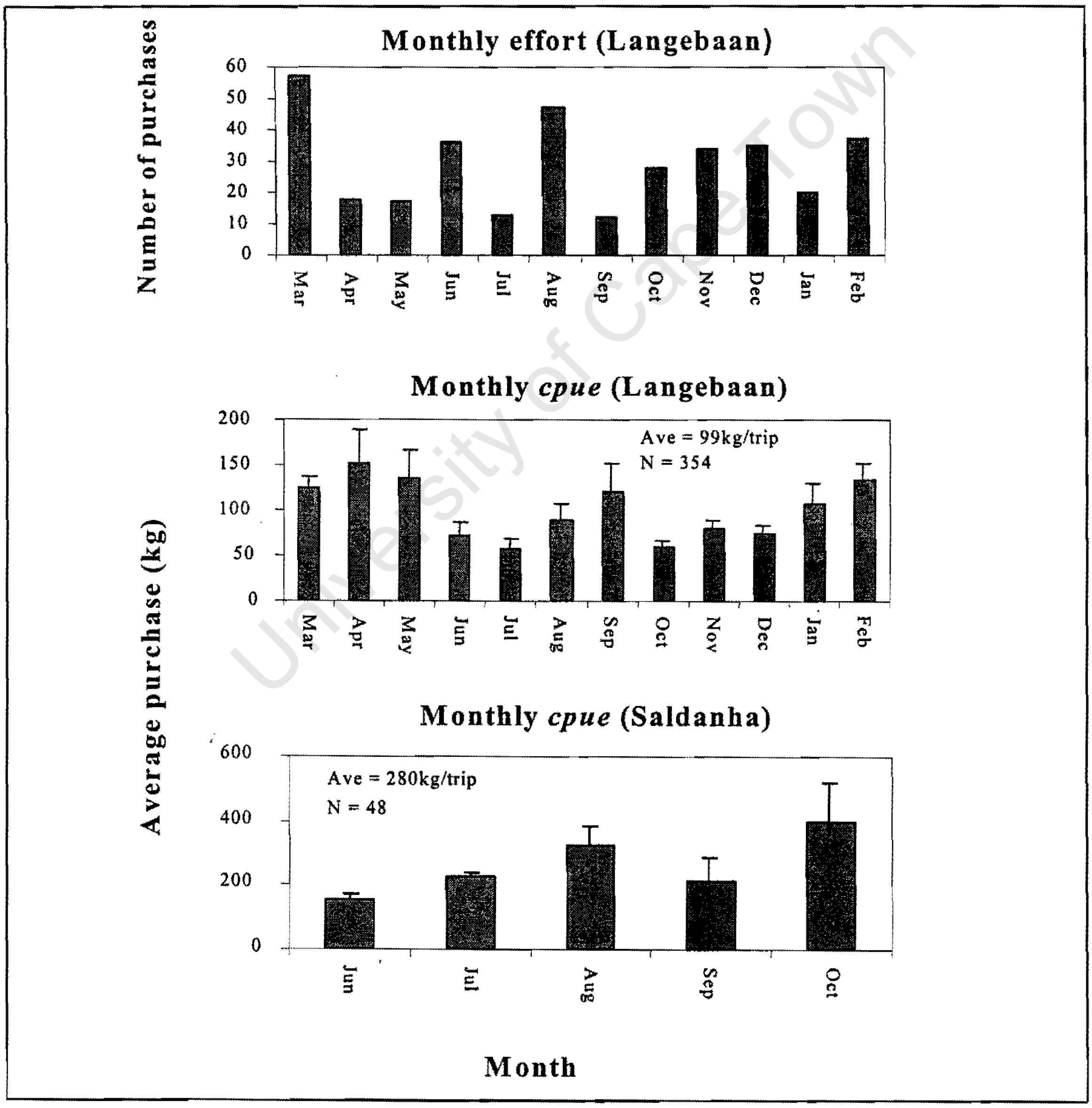


Fig. 1.12: Seasonal *Liza richardsonii* catch and effort trends for the Saldanha and Langebaan gill-net fisheries.

Beach-seine operators appear to operate opportunistically in most areas, either during periods of high fish abundance, favorable 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, with only two of the seven crews active through the winter. On the West Coast (Langebaan to Elands Bay), however, fishers operate sporadically and no discernable trend, other than zero hauls during late winter (July and August), is evident in factory purchase records for 1998/1999 (Fig. 1.13). Bad weather (strong westerly winds and large swells) usually prevents beach-seining during this period.

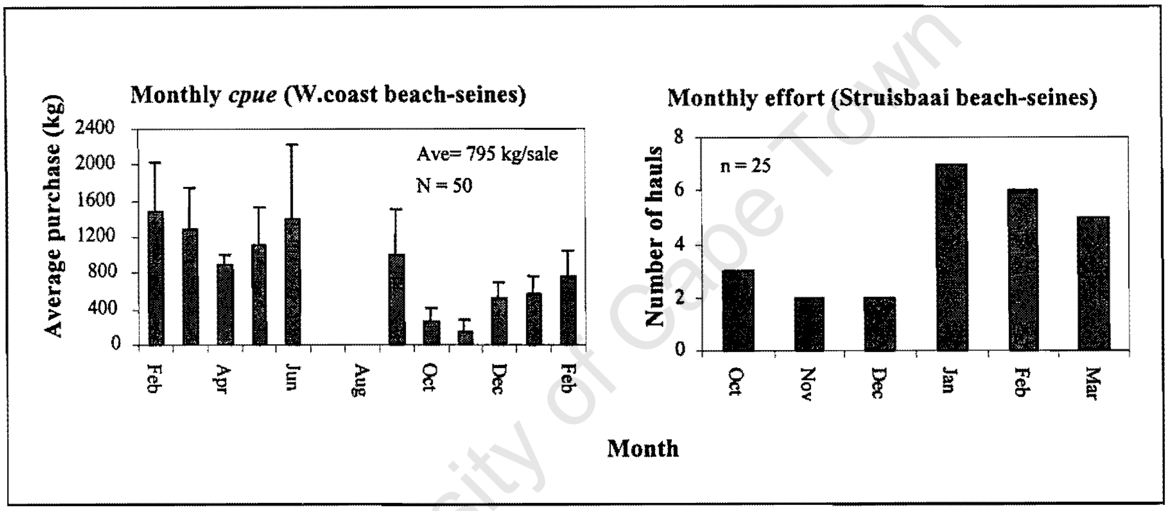


Fig. 1.13: Seasonal trends in *Liza richardsonii cpue* for West Coast and effort for Struisbaai beach-seines.

Struisbaai 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 this period (Fig. 1.13). These fishers increased their effort during late summer when SE winds prevent line-fish boats from going to sea. The SE winds also concentrate *L. richardsonii* shoals close inshore and increases their availability to seine fishers. It was not possible to assess the seasonality of beach-seine catch and effort in other areas during this study, as so few operations were encountered. The majority of permit holders interviewed however, claimed to be more active during the summer months, citing favorable weather and presence of fish as the main reasons.

Discussion

Catch composition

Four previous studies have dealt with the gill-net fishery in the Western Cape, but these were limited in scope, being restricted spatially to certain regions, or by 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 *C. capensis* and did not provide the complete catch composition. Freer & Griffiths (1994) described the gill-net fishery for St Joseph and observed a similar elasmobranch by-catch to that recorded during this study, but only mention *Chelidonichthys capensis* and *M. capensis* as teleost by-catch. Sowman *et al.* (1997) investigated the Olifants River fishery with the intent of developing a co-management arrangement between the fishers and the management authority. Catch rates of *L. richardsonii* were provided but mention was made of only three by-catch species that used to occur in catches and that "fairly large numbers" of elf *P. saltatrix* are still landed. Lamberth *et al.* (1997) described the status of South African beach-seine and gill-net fisheries on a national scale and attempted to validate reported catches of West Coast permit holders based on observed catches in 383 hauls by gill nets and beach seines combined. Overall only 3.6 % of the observed catch of at least 10 different species was reported. This current study has provided the first complete description of catch composition and catch rates for the marine gill net fishery.

For all net types monitored, the target species, *L. richardsonii* for 44-64 mm nets, *C. capensis* for 178 mm nets and *D. capensis* for illegal 145 mm nets, were caught at much greater rates than any by-catch species (Table 1.1). With the exception of *P. saltatrix,* the next most commonly caught species in legal net-fish landings, *T. trachurus*, *Chelidonichthys capensis* and *G. feliceps* are not usually targeted by shore anglers. *Trachurus trachurus* 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.). Hake *Merluccius capensis* and snoek *Thyrsites atun* are principal catch components of the demersal trawl fishery (Payne 1989, Payne & Badenhorst 1989), whilst sardine *Sardinops sagax* is one of the most important purse-seine target species (Armstrong & Thomas 1989). *Thyrsites atun* and hottentot *Pachymetopon blochii* are the two most important species in the commercial boat-based line-fishery on the West Coast (Sauer *et al.* 1997). Although all these species occurred in monitored gill net landings, catch rates of these species 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 *C. capensis* (0.67 %) along with *T. trachurus* (3.1 %) which is classified as a bait species, contributed 98.65 % numerically to the total gill net catch (138 562 fish) monitored during this study. Of the remaining 26 species, the eight species that can be considered important to the recreational and commercial linefisheries only made up 1.15 % of the total catch numerically. Hale *et al.* (1996) concluded that the extremely low by-catch (< 1 %) in the striped mullet gill net 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 gill-net fisheries, which have a total annual effort of approximately 25 000 days.

Catch rates of "shore angling" species in legal nets were very low relative to catch rates of target species. These catch rates are, however, significant when compared to 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*, silver kob *Argyrosomus inodorus* and white steenbras *Lithognathus lithognathus*, most often targeted by shore anglers on the West Coast (Brouwer *et al.* 1997), all occur as by-catch in the commercial and predominantly illegal net-fish catch. The combined catch rate of these species in legal gill nets (1.16 fish.net-day $^{-1}$) is similar to the shore angler catch rate, but the illegal net catch rate (15.14 fish.net-day $^{-1}$) is far greater than that achieved by shore anglers. Although not extensively targeted by shore anglers on the West Coast, *P. saltatrix* is a very popular angling fish along the south and east coasts. West Coast gill net catch rates of this species (8.14 – 27.4 fish.net-day^{-1}) exceed shore angler *cpue* for all species combined (1.18 – 2.06 fish.angler^{-1}.day $^{-1}$, Brouwer *et al.* 1997).

The estimated total annual gill net by-catch (Table 1.6), particularly line-fish, is significant when compared to catches made by other sectors. Brouwer *et al.* (1997) estimated total shore angler effort along the West Coast to be 205 242 angler-days.year $^{-1}$ more than 10 fold the estimated annual gill net effort (18 269 net-days. year^{-1}) along this coast. The estimated total shore-angler catch for the region is 192 927 fish (Brouwer *et al.* 1997). The estimated 44-64 mm gill-net line-fish catch alone (210 000 fish, Table 1.6) exceeds the shore angling catch, despite the fact that line-fish by-catch makes up less than 1.5 % of the total gill net catch. This figure excludes by-catch species such *as T. trachurus, Chelidonichthys capensis*, and *G. feliceps* that are not targeted by shore anglers as well as several species that are, such as *A. inodorus* and *L. lithognathus,* but were only recorded in a few 44-64 mm gill net landings. Inclusion of the "illegal" net line-fish catch (Table 1.9) and the undetermined St Joseph and beach-seine by-catch, indicate that numerically the current net catch of line-fish species certainly exceeds that made by shore anglers along the West Coast. Given the overlap in catch composition between commercial net-fishers and recreational shore anglers on the West Coast and the great potential for conflict, it is essential that the enforcement of regulations relevant to line-fish by-catch in nets is increased and that illegal netting is controlled.

Most legal net-fishers understandably believe that their by-catch of "line-fish" is negligible when compared to their harder catches, or the collective catches made by the more numerous shore anglers. Furthermore they correctly argue that the catch is unintentional and mortality of the by-catch is often unavoidable given the nature of the fishing operation. Enforcement of regulations relevant to line-fish by-catch in netting operations is, however, almost non-existent (pers. obs.). An increase in enforcement would certainly encourage fishers to reduce by-catch levels, either by moving from areas where by-catch is high, or by returning more non-target and undersize fish to the water. Historical and anecdotal evidence suggests that net catches of line-fish were much greater in the past (Thompson 1913, Biden 1954, Bennett 1988, 1993a) and the current low catch rates are simply a reflection of the current overexploited status of most South African line-fish (Attwood & Farquhar 1999, Griffiths 1999).

Gill nets actively select certain size fish as a function of the mesh size and the fish shape and size, and the thickness, material and color of net twine, hanging ratio and method of fishing may also affect selectivity (Dalzell 1996). The theoretical distribution of catch frequencies follows 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 44-64 mm gill nets, much of the by-catch (which often comprises species that have deeper body profiles than the elongate target species *L. richardsonii*), consists of undersize, immature fish. These small by-catch 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 ("stroopers") who clean the nets. Large mesh "St Joseph" and "illegal" nets, however, catch much larger fish, particularly sharks, and 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 not enough individuals in the affected population survive to maturity, recruitment overfishing may occur (Bohnsack & Ault 1996). Clark *et al.* (1994) showed that the beach-seine fishing mortality on juvenile teleosts in False Bay was insignificant when compared to the natural mortality rates of the size classes that were captured. Although much of the 44-64 mm gill-net by-catch is immature fish, the average sizes of fish caught (for example, *P. saltatrix*, 24 cm, *R. globiceps*, 13.5 cm and *D. capensis*, 33 cm), are not as small as those referred to in the False Bay study. Most of these fish have already survived the early, highly vulnerable juvenile stage at the size which they are captured in 44-64 mm gill nets and it is likely that the fishing mortality is significant relative to natural mortality for these size classes. By-catch in the larger mesh illegal gill nets and St Joseph gill nets is often 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, overexploited species such as *L. lithognathus* and *A. inodorus* (Bennett 1993a, Griffiths 1997a) does occur. The large illegal catches of these species in beach-seine hauls, although sporadic and only made by a few operators, must contribute substantially to the total fishing mortality for these species (Bennett 1993a).

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

Archeological evidence from the historical site Oudepost on the shores of Langebaan Lagoon, which was occupied by the Dutch during the 17^{th} and early 18^{th} centuries (Poggenpoel 1996), suggests that considerable changes have occurred in the relative abundance of different species in catches. Such changes are widely accepted as some of the most likely detectable effects of fishing pressure (Jennings & Lock 1996). During an archeological dig at this West Coast site, Poggenpoel (1996) identified 20 taxa according to characteristic body parts. Numerically, more than 75 % of the fish found at the site were line-fish species, including *R. globiceps* (63 %), *L. lithognathus* (8 %), *A. inodorus* (3 %) and *P. saltatrix* (1%). On the other hand, *L. richardsonii*, which today makes up more than 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 & Moller 1994). It was noted that the catch was not just a single species, but consisted of all types of fish, including many line-fish. Biden (1954) also documents substantial net catches of line-fish along the West Coast, including *L. lithognathus*, *R. globiceps*, *D. capensis*, *P. saltatrix* and *A. inodorus*. Although possible, it is unlikely that these operators were intentionally targeting line-fish 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 net fishers interviewed also recalled making large catches of line-fish as little as 30 years ago.

Catch and effort

Survey errors

Angler surveys are subject to various sources of error; Pollock *et al.* (1994) group these errors into three general categories: sampling errors, response errors and non-response errors. Several of these errors, despite efforts that were taken to reduce them, certainly affected the results obtained during this study and can explain 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 undeterminable 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 participate in net-fishing. Due to the probability of an encounter, fishers interviewed at landing sites were more likely to be those who fished more often, and this would introduce 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 the estimates based on the telephone survey data. The telephone survey as an off-site method is not subject to avidity bias. Furthermore, it was conducted over a two-week period that coincided with a worker strike in the pelagic fishing industry and after hours and weekend callbacks meant those permit holders with or without other employment had a more equal probability of been sampled.

Both the telephone and questionnaire surveys required fishers to remember how many trips they had made over the past 12 months and the 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 been asked about (Pollock *et al.* 1994.). In an attempt to minimize this, anglers were asked about their activity over the previous week, then month then 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, means that if every permit holder was active, an average of 34 fishers should be encountered on every day of the year, including winter, a season of almost zero net-fishing activity due to bad weather and low fish availability. The maximum number of landings monitored in this 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 mounting evidence that angler surveys result in overestimates of fishing effort (Anon. 1998).

South African commercial fishing rights were under review during the period that this study was conducted 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 intentionally lie 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 who are angry with the fisheries management authority, or think they can influence fishery rules to their benefit, are likely to deceive survey 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 – less than 25 % in St Helena Bay claim to make more than half their income from net fishing (Chapter 2). Given the part-time nature of the fishery and the different people involved with widely varying activity rates (Fig. 1.8), 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 less than 20 %, an acceptable standard for fisheries data (Smith 1998). Due to the biases discussed above that probably led fishers to exaggerate their activity, it is felt that the values obtained from the telephone survey, approximately 25 000 gill net days, (including estuarine, St Joseph and illegal net effort) and 3 200 beach-seine hauls annually, are overestimates. These are, however, the best estimates at present, considering that effort is drastically underreported on compulsory catch returns. Indeed, scaling-up of the reported effort for 1998/99 by the degree of underreporting, gives values of 19 000 gill net days (excluding estuarine and illegal net effort) and 1 900 beach-seine hauls. These figures are within 25 % of the estimates obtained from the survey.

Sources of error in catch rate estimation

When asked for an 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 low 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 catch rates (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, as larger catches take longer to off load. Beach-seine permit holders did appear to overestimate their average catches, with 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. Gill-net questionnaire respondents on the other hand, claimed much lower catch rates than those observed during monitoring, or documented in factory records (Fig. 1.7). 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 of catch rates (Lamberth 1994, Lamberth *et al.* 1997).

Telephone survey respondents were asked to provide their total catch over the past year, a figure that they would more likely be able to remember accurately and less likely to be affected by recall bias than when asked for an average catch per trip. Total annual catches claimed by both beach-seine and gill net 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 obviously 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 fill in their application forms and it was apparently decided that all members should claim to catch between 2-2.5 tons per year. This would give a total catch for the area that did not exceed the total reported catch by too much. Due to 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 annual loss of nearly R 5 000 per year, given the daily trip and annual maintenance expenses claimed by fishers (Chapter 2).

Catch rate estimates based on monitored landings and factory sales are not vulnerable to recall bias or intentional deception 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, with sales of as little as 2 kg and 3 kg of *L. richardsonii* having been recorded. Fishers claim to sell only about 90 % of their catch, the remainder been kept for crew or own consumption. It would therefore be expected that the average factory sale would be smaller than the average monitored landing. This was not the case, with 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, but several zero catch trips were monitored.

Daily gill-net catches observed during monitoring ranged from 0-1 008 kg and factory records from 2-2 198 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. Calculation of total catch based on these catch rates, however, assumes that 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 gill nets, 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 underreporting also gives a total annual catch estimate in the region of 5 500 tons. Gill-net fishers in the study region also land approximately 130 tons of by-catch comprising at least 27 species, whilst illegal gill-net fishers catch in the region of 100 tons of hound shark and 50 tons of line-fish 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 and management suggestions

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 to the north of Elands Bay, is mostly commercial or recreational, with very few participants relying on the netfishery as a sole source of food or income (Chapter 2). Net fishers therefore operate mostly at times of known fish abundance and average catch rates are 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 gill net fisheries (Sowman *et al.* 1997). The examples of other net fisheries are mostly open access, as opposed to the permit controlled fishery on the West Coast, and many are operating at effort levels in excess those that would give maximum economic yield. Furthermore, the examples of other net fisheries are mostly from subtropical and tropical regions, widely accepted to be less productive than cool temperate upwelling regions such as the South African West Coast (Pillar and Hutchings 1989, Shannon 1989). Indeed, despite operating in the highly productive Benguela upwelling region, West Coast gill-netters achieved lower individual catch rates (if the number of nets used is taken into account) than the small number of South and East Coast gill-netters.

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 (harders) *L. richardsonii* for the period 1900-1913 was only 32 % of what it was prior to the turn of the century, whilst the average annual catch of juvenile *L. richardsonii* ("bokkoms") decreased by 87 % (Fig. 1.9, Gilchrist 1914). Unfortunately, the number of people employed or the number of days fished is not provided, 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 as 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 due to the high fishing effort by both estuarine and marine net fishers. The particularly noticeable decrease in the number of juveniles caught suggests that a degree of recruitment over-fishing had occurred (Fig. 1.9).

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 to note that the reported catch for this period was made by approximately 400 active permit holders (De Villiers 1987), equivalent to just 4.3 tons per permit holder. This is a substantially lower annual catch than that achieved by Messrs. Stephan Bros. during the early 1900's, even after the decline in catches (approximately 16 tons per year). This comparison is, however, not strictly valid as many of the current permit holders do not fish commercially, whilst the Stephan Bros. undoubtedly did. Active, professional beach-seine permit holders from St Helena Bay and Elands Bay do still report annual catches in the region of 20 tons per year (MCM unpublished data).

Permit holders have become increasingly disillusioned and angry at the management authority (MCM) in recent years, largely due to uncertainty over future access rights. As a result many permit holders have stopped submitting catch returns and the sharp decrease in reported catch in 1998/99 is undoubtedly partly due to increased underreporting (Fig. 1.10). It does appear, however, that a substantial real decrease has occurred, with over 70 % of questionnaire respondents stating that their catches have declined since they entered the fishery. A further 10-42

% of gill net respondents and 23 % of beach-seine respondents felt that the fishery was no longer economically viable and had ceased fishing (chapter 2). Indeed, if the level of underreporting has stayed 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 harder resource is maximally or over-exploited 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* occurring 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 the stock that built up over the previous winter is being fished down (Fig. 1.11). Indeed, the higher catch rates observed during months of low effort, December and April, suggests 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 the less disturbed shoals during periods of low effort result in higher catch rates.

Analysis of size frequency distributions of *L. richardsonii* caught in commercial netting operations also indicates that the harder stock is regionally overexploited. In St Helena Bay, Saldanha Bay and the Berg Rivers, areas with high net fishing effort, the average size fish caught is significantly smaller than elsewhere on the West Coast, in areas with relatively lower net-fishing effort (Fig. 1.4). 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). The evidence is, however, not conclusive as 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 do use smaller mesh nets (44-48 mm) more regularly than fishers elsewhere and net selectivity is partly responsible for the observed size frequency distributions. Fishers obviously select mesh sizes in order 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 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 that were made by the Dutch at Langebaan Lagoon and Table Bay (near 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 have not yet been investigated, but are probably related to the availability of food and the relatively high water temperature, which may allow more rapid growth. In order to maximize their catch rates, gill-net fishers in Langebaan Lagoon use large mesh sizes (57-64 mm). It can be argued that the use of these large mesh nets is the reason for the observed size frequency distribution, but the argument is circular. Furthermore, experimental gill-netting conducted during this study, using much smaller (48 mm) mesh nets landed fish of a similar size to those landed in commercial operations (although catch rates were lower as the fish were too large to mesh properly!).

Once-off surveys, such as this study, can only provide data on a fishery at one point in time (Pollock *et al.* 1994). Inter-annual natural variation in fish populations mean that catch rates and even 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 1998/99. Changing market forces also affect catch and effort in the net-fishery. For example, a recently developing market for frozen *L. richardsonii*, which are used as bait in the long-line 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 due to conflict in Central Africa has resulted in unusually low levels of St Joseph directed effort and catch over the last two years (B. T. Pedro 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 due to various types of survey error. The system of self – policing via compulsory catch returns also appears to have failed, due to 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 gill and beach-seine net fisheries is the only method that will produce data suitable for use in the scientific assessment of fish stocks.

Conclusion

The gill and beach-seine net fishery in the Western Cape appears oversubscribed in most regions, with 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 harder 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 with fishers investing more in boats, nets, outboards etc. than they can make by catching *L. richardsonii* (Chapter 2). 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 due to fisher interference or simply not enough fish to go around.

If government wishes to manage the net-fisheries to maximize effort and participation, rather than sustainable catch and economic yield, this has already been achieved. On the other hand a reduction of the latent and part-time recreational netting effort will have benefits for *bona fide* commercial or subsistence 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 amount of by-catch. 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 more desirable than an oversubscribed non-sustainable one where the fishers are condemned to poverty.

Although in theory, net permits are issued solely for the capture of *L. richardsonii* and *C. capensis*, and the landing of other species in nets is technically limited to 10 fish per day, these permit conditions are unrealistic and are often ignored. By-catch species, often in excess of the allowed 10.day $^{-1}$ often die in gill nets before the fisher has even noticed them, whilst the financial rewards of keeping large line-fish that are caught far outweigh the very low risk of a fine. The number of species vulnerable to capture in gill nets and beach-seines, even along the relatively low diversity West Coast, is far greater than reported. Individual gill and beach-seine fishers can and do on occasion make much larger catches than line-fishers. If management strategies aimed at rebuilding linefish stocks are to be successful, gill and beach-seine net by-catch and more urgently, illegal gill net catches, will have to be controlled through increased enforcement and education of fishers. Any management action that is likely to limit net-fishers access to fish in favor of other sectors must however, take cognizance of the fact that the net-fisheries 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). Net-fishers can thus claim a traditional right to fish commercially with nets and co-management initiatives to reduce by-catch, rather than confrontation, is advised.

CHAPTER 2

SOCIO-ECONOMIC CHARACTERISTICS OF GILL AND BEACH-SEINE FISHERS IN THE WESTERN CAPE, SOUTH AFRICA

Introduction

Since the licensing of gill and beach-seine nets became compulsory in 1974, inshore net permits in the Western Cape have always been classified as commercial fishing rights (De Villiers 1987). This implies that permit holders fish in an economically viable manner, with the primary aim of making profits. Management was, however, aware that the majority of permit holders did not rely solely on net-fishing as an occupation, but rather fished in a part-time commercial fashion and relied on the fishery to supplement income, particularly during periods when other fisheries were not productive. The part-time commercial nature of the fishery was actively encouraged by management, with permits awarded preferentially to applicants who were considered *bona fide* fishers with employment in other fishing sectors, or to retired fishers (De Villiers 1987, Stander 1991). This policy unfortunately amounted to effort subsidization in the net-fisheries, to the detriment of fishers who were attempting to operate in a full-time commercial manner.

In theory access into the Western Cape net-fisheries is controlled by the permit system. Management, however, faced huge political pressure when not all applicants for permits in 1974 were successful (Treurnicht *et al.* 1980). As a result management was forced to capitulate and although permits were required, the initial situation was essentially that of open access fishery. Later investigations into the net fisheries recommended a substantial reduction in the number of permit holders (Theart *et al.* 1983, Stander 1991), but with the exception of areas that were regarded as sensitive (e.g. False Bay and Walker Bay), only moderate reductions in total effort were implemented in most areas. The only other regulation aimed at limiting total effort, namely a restriction on the maximum length and number of nets that may be used by permit holders, is seldom effectively enforced.

It appears likely that the net-fisheries have been operating as an open access system (only excluding fishers without the right political connections). Consequently it can be expected that fishers do, or have, operated at effort levels greater than that which would result in maximum or optimal sustainable yield and as a result, the resource has been overexploited (Anderson 1986, McManus 1996). This is the usual outcome of open access fisheries where individual, competitive use of common property results in a "tragedy of the commons" scenario (Hardin

1968). Indeed, in areas with high effort levels, the fishery may be operating at or beyond the open access equilibrium point, i.e. at the level of effort at which no excess (or economic) profit is possible (Anderson 1986, McManus 1996). On the other hand, many permit holders have alternative livelihoods and could simply have stopped fishing, or resorted to fishing in a recreational fashion when it became apparent that they were no longer operating profitably.

One of the primary aims of South Africa's Living Marine Resources Act of 1998 is to provide more equitable access to marine resources, particularly for people who have been historically disadvantaged or excluded due to political policies in the past. Low technology fisheries, such as gill and beach-seine netting appear to be ideal solutions for allowing poor coastal communities access to marine resources (Grant 1981). Before any new net permits are allocated, however, information on the demographics and economic status of the current permit holders, their attitudes towards management regulations and perception of the resource, is needed. In terms of the optimum yield concept, fisheries managers are required to consider biological, ecological and socio-economic aspects of a fishery (Riechers *et al.* 1991). This chapter does not attempt a comprehensive economic evaluation of the inshore net fisheries, but supplies largely descriptive information that is comparable to that provided by McGrath *et al.* (1997) for the South African linefishery and should assist fisheries management in decision making.

Methods

After several trial interviews, a detailed questionnaire was developed and translated into Afrikaans, the language spoken by the majority of fishers (Appendix 1). Fishers involved in netting activities were questioned in face-to-face interviews, either on site where vessels landed, or off-site at their places of residence (obtained from Marine and Coastal Management and South African National Parks lists of permit holders). Estuarine net-fishers were requested to complete questionnaires at the 1998 AGM of the Berg River Net-fish Association. Gill net fishers who operate in the Olifants River estuary and beach-seine fishers from False Bay were not contacted during this survey, as both have been the focus of recent studies, viz. Sowman *et al.* (1997) & Lamberth (1994).

In order to assess the costs and returns to net-fishers, respondents were asked to supply information on the type and estimated replacement value of equipment used, the anticipated life span of the equipment, annual maintenance costs, daily running costs, their activity levels, average catches made, payment of crew and sale or consumption of the fish caught. The replacement costs of the different horsepower outboard motors and net types used by fishers were obtained from local suppliers. Daily petrol expenditure was calculated from the claimed litres used per trip multiplied by the 1999 petrol price of R 3 per litre. The average annual depreciation of fishing equipment was calculated as the current replacement cost divided by the average expected life of the item. The annual opportunity cost of permit holders' capital invested in fishing equipment was calculated as 7.5 % of the estimated replacement value (as if invested in a savings bank account at the current prime interest rate of 14.5 % less an inflation rate of 7 %). The opportunity cost of the permit-holders' own labour, when applicable, was estimated by calculating their potential net income if they had undertaken alternative fishing work.

It became apparent that the nature of the gill-net fishery varied greatly within the study region. Permit holders to the north of St Helena Bay (stratum 1) operated infrequently, and mostly on a subsistence level, with those further south (strata 2 &3) operated either recreationally, or in a part time commercial manner. Data obtained from gill-net permit holders during the survey were thus stratified spatially, in the same fashion as for catch and effort estimation, and the results are presented separately for three different regions of the West Coast and the Berg River (Fig 1.1). The beach-seine fishery was not stratified but certain data relevant to permit holders and crew is presented separately. A follow up telephone survey was also conducted (Appendix 2), primarily to obtain more accurate effort estimates (see Chapter 1 for survey design). During the telephone interview, respondents were asked whether they net-fished primarily for food, income or relaxation, if they had applied for commercial permits for the coming year and the amount they were prepared to pay for a net permit.

Results and Discussion

2.1 Demographics of the net permit holders

Response to the questionnaire was favorable with most fishers cooperating despite being initially suspicious. Certain questions, however, such as those about regulations, illegal activities and level of income were often not answered accurately, with many respondents declining to answer altogether. A total of 158 face to face interviews was conducted and a further 42 estuarine permit holders completed questionnaires at the Berg River Net-fish Association AGM. Coverage in the survey ranged from 26 % of the permit holders in Stratum 2 to 71 % in Stratum 1 being interviewed (Table 2.1).

Table 2.1: Demographic features of net-fishers interviewed.

Feature	Gill netters				Beach-seines
	Stratum 1: Doring-Elands + Yserfontein	Stratum 2: Dwarkersbos – North Head	Stratum 3: Saldanha-Langebaan	Berg River	
Permit holders	58	235	28	120	93
Interviews	41	61	16	42	40
Non–white (%)	54	23	50	9	24
Association members (%)	51	74	56	71	53
Average age	47	44	49	55	44
Over 60 (%)	20	18	13	31	6
Live within 5km (%)	90	95	100	82	50

Nearly all the net-fishers interviewed were male (99 %) and Afrikaans speaking, with approximately equal numbers of white and coloured permit holders in Strata 1 and 3. Due to the apartheid policies of the former government, South Africa has historically been divided along racial lines. It is widely accepted that non-whites were discriminated against under the apartheid system and the term "previously disadvantaged" is now often used to describe people from non-white race groups. In an attempt to rectify the wrongs of the past and ensure a more equitable distribution of marine resources, race has recently become a criterion in the allocation of fishing rights. The majority (76 – 91 %) of St Helena Bay (Stratum 2), Berg River and beach-seine permit holders, however, were white, with only one black beach-seine net permit holder (who was inactive) interviewed (Table 2.1). The racial composition of gill-net respondents from these areas is similar to that found for commercial skiboat operators (80 % white) by McGrath *et al.* (1997). The domination of the inshore net fishery by white males is further highlighted by the fact that the white population group only constitutes approximately 21 % of the population in the Western Cape (Statistics South Africa 1998). About half the gill net permit holders in Strata 1 and 3 and beach-seine permit holders claimed to be affiliated to some kind of fishers association (often not strictly net-fish) but stated that many of the associations had not had meetings for several years. Association affiliation was much higher (over 70 %) amongst St Helena Bay and Berg River permit holders, areas where well supported net-fish associations hold annual meetings.

The youngest net-fisher interviewed was 16 (using his fathers' nets) and the oldest was 78, with the average age of respondents being in the mid to late forties. In some areas net fishing is a traditional cultural activity, with skills and equipment passed from father to son. Considering that only 4.5 % of the population in the Western Cape is over the age of 65 (Sideropoulos *et al.* 1998), a disproportionate number of gill net permits are held by people over the age of 60. Nearly a third of the Berg River respondents were over 60 years of age. This is largely due to the Berg River Net-fish Association's policy to award permits to older fishers who can no longer fish in the sea (J. V. F. Heydenreich, Berg River Netfish Association, pers. com.).

By far the majority of gill-net permit holders live very close (less than 5 km) to the sites where they launch their boats, but only half beach-seine permit holders live within 5 km of where they usually fish. Commercial net-fishers, unlike commercial line-fishers, are restricted in terms of their permit conditions to specific areas where they may fish. As a result, the average distance traveled to launch sites, 4.8 km and 7.8 km for gill and beach-seine respondents respectively, is substantially less than that covered by commercial skiboat line-fishers, 44 km (McGrath *et al.* 1997). A large proportion of net-fishers do not transport their boats, but keep them moored in harbors or simply stored on the beaches from where they launch. Commercial skiboat fishers on average therefore have much higher travel costs than commercial net-fishers, but benefit from their mobility by being able to target aggregations of migrating species such as snoek *Thyrsites atun* and yellowtail *Seriola lalandi* (Penney *et al.* 1989).

2.2 Occupations of net-fishers

Approximately two thirds of the marine gill net permit holders interviewed worked in some other form of fishing, whilst a further *ca.* 20 % of beach-seine, Stratum 1 and St Helena Bay (Stratum 2) respondents are retired (Table 2.2). This is largely a result of a management policy implemented in 1975 to award permits preferentially to *bona fide* fishermen and pensioners (De Villiers 1987). Between 15-35% of the net fishers interviewed were not employed in fishing. Occupations listed included: fish factory owners, farmers, navy personnel, shop owners, teachers, electricians, builders and state employees. These permit holders often had worked in fisheries in the past, or had been involved in net fishing since childhood and felt they had traditional rights to be involved. Given that the majority of net permit holders are not reliant on the net fishery, there is no logical reason why those who do not work solely in other fishing sectors should be excluded from obtaining net permits.

Table 2.2: Occupations of net permit holders.

Occupation (% respondents)	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
Fishers (several sectors)	29	18	19	8	15
Retired	20	18	6	51	23
Pelagic fishers	12	30		10	15
Line-fishers	15	7			12
Rocklobster fishers	7				
Various jobs	17	15	25	31	35
Net-fishers	0	11	50	0	0
> 10yrs. Fishing industry	77	75	87	82	85
< 10yrs. Net-fishery	49	30	33	24	38

A large number of permit holders were employed in the pelagic fishery, which usually has a closed season over the summer months, a period when net fishing activity peaks. Of particular interest is that only 11 % of the gill net permit holders from Stratum 2, none from Stratum 1 and the Berg River nor any beach-seine respondents listed net fishing as their primary occupation. In contrast 50 % of the Saldanha-Langebaan respondents classified their work as net fishing (Table 2.2). Over 75 % of respondents from all areas had been involved in some form of fishing for more than ten years, whilst 24-49 % of respondents had entered the net fishery within the last 10 years. This indicates fairly low turnover of participants in this fishery, with approximately 70 % of the permit holders remaining in the fishery for longer than 10 years. Net license fees in the past have been particularly cheap (R 25 per net per year in 1998) and permit holders had little to lose by remaining in the fishery, even if mostly inactive and simply fishing during times of high fish abundance, or when other fisheries were not productive. On average, respondents had been net fishing for 20 years, a longer period than commercial skiboat skippers, who on average had fished for 15 years (McGrath *et al.* 1997), indicating greater turnover of participants in the skiboat line-fishery.

Table 2.3: Occupations of net-fish crew.

Occupation (% respondents)	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
Fishers (several sectors)	39	33			56
Retired	6	9		20	8
Pelagic fishers	9	18			
Line-fishers	12				21
Rocklobster fishers	18	3			6
Various jobs	16	31	14	80	9
Net-fishers	0	6	86		0

Between 82-100 % of gill net permit holders interviewed took 1-2 crew when fishing, whilst all beach-seine permit holders used 5-22 crew, with an average of 12. Over two thirds of net-fishers had regular crew who had fished with them for 5-13 years. In addition to crew who help with the fishing operation at sea, commercial gill net fishers from St Helena Bay (Stratum 2) usually employ 2-10 (average of 4) casual helpers to remove fish from the nets on shore. These casual helpers get paid R 5 per crate of fish (approximately 5 % of the value) and take most of the small by-catch as "fries", but only work for a few hours a day. Only 30 % of Berg River crew and one crewman from Saldanha had other work and as many as 70 % of beach seine crew were unemployed. In other areas, however, 60-90 % of crew had other work. Like permit holders, the majority of crew were employed in other fisheries, but a greater proportion had jobs outside of the fishing industry, mostly in the form of casual labour (Table 2.3). Only 6 % of crew from Stratum 2 worked solely in the net fishery but 86 % of Saldanha-Langebaan respondents claimed their crew only worked in the net-fishery.

A maximum estimate of the number of people obtaining part-time employment directly related to the catching of net-fish in the study area can be made by multiplying the number of permit holders by the average crew size and number of helpers employed. This calculation reveals that approximately 2 700 (640 permit holders, 2 060 crew) people could potentially derive some sort of income by catching net-fish. About half the crew are employed in the beach-seine fishery, but work less frequently and earn less than those working in the gill-net fishery. This figure is probably an overestimate as a large number (14 % of gill net and 23 % of beach-seine telephone survey respondents) admitted to being inactive for the 12 months preceding the interview. In contrast, an estimated 24 000 people are employed in the commercial skiboat fishery at a ratio of six employees per operator (McGrath *et al.* 1997). Although a large number of crew are temporally employed in beach-seine operations, gill-netting cannot be considered a labour intensive fishing method when compared to line-fishing.

2.3 Income distribution of net-fishers

It is well known that income from work in many fisheries is highly variable, fluctuating with the total allowable catches allocated annually and the availability of fish. In an attempt to better quantify the economic status of net permit holders, fishers were asked to estimate their approximate annual take home pay (after income tax) from all work. Naturally this is a sensitive subject and many respondents declined to answer. It became apparent that the more affluent respondents were the least inclined to answer, or obviously underestimated their income, thus the data presented below are biased towards the lower income brackets. With the exception of Saldanha Bay permit holders, more than half the gill-net respondents and all beach-seine crew claimed to take home less than R 20 000 per year. More than a third of these fishers claimed to earn less than R 10 000 per year (Table 2.4). Most respondents claimed to be the sole income earners in their households and supported an average of 2.8 dependents on their income. This indicates that the households of more than one third of the net-fishers in these areas have incomes of less than the household subsistence level which was estimated at R 12 362 for Cape Town households in 1997 (The Institute for Development Planning and Research at the University of Port Elizabeth 1997). In contrast the six gill-net permit holders from Saldanha-Langebaan who provided information on their income, and more than two thirds of the beach-seine permit holders interviewed, claimed to take home more than R 20 000 per year. More than half these fishers claimed net incomes of over R 60 000 per year. This is similar to the 1995 estimate of the average annual income in the Western Cape (R 53 000) but is substantially less than the annual average of R 98 000 earned by whites in the Western Cape in 1995 (Sideropoulos *et al.* 1998).

Table 2.4: Take home pay of net-fishers interviewed, from all types of work.
PH = permit holders

Income (Thousand Rands) (% respondents)	Gill netters				Beach-seines	
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	PH	crew
< 1	5	/		19		7
1 – 9	35	36		44	25	50
10 – 19	15	29		6	8	43
20 – 39	15	13	17	12		
40 – 59	10	10	33	12		
60 – 79	5	6	17	6	25	
80 – 99	10	6	17		8	
100 – 119	5		17		33	
No. respondents	33	31	6	16	12	14

For the majority of respondents, net fishing only contributed a small percentage of their income relative to other occupations. With the exception of Saldanha-Langebaan permit holders, 42-61 % of questionnaire respondents claimed to make less than 5 % of their income from net fishing (Fig. 2.1). It is clear that only in St Helena Bay (Stratum 2) and Saldanha-Langebaan, where 26 % and 81 % of respondents, respectively, claim to make more than half their income from net fishing, are a substantial number of participants truly reliant on commercial net-fishing.

Given that in most areas very few participants claim to make a substantial proportion of their income from net fishing, it is surprising that so many fishers waste a disproportionate amount of their fishing time in the fishery. In all areas over a quarter of respondents claim to spend more than 80 % of their fishing time in the net fishery (Fig. 2.2). Berg River respondents are excluded from the figure, as many are retired from other fisheries and thus allocate 100 % of their time to the net fishery, but live off their pensions. Only in Saldanha-Langebaan is the effort allocated to the net fishery comparable to the financial benefit the participants claim to derive from the fishery. It is highly likely, given the current review of access rights and the fishers uncertainty over their future status as permit holders, that many respondents overestimated their participation in the net-fishery for fear of been seen as inactive. Many may also have underestimated the contribution of the net fishery to their total income, either for tax evasion purposes, or in an attempt to influence management's perception of the value of the fishery and thus discourage the allocation of permits to new entrants.

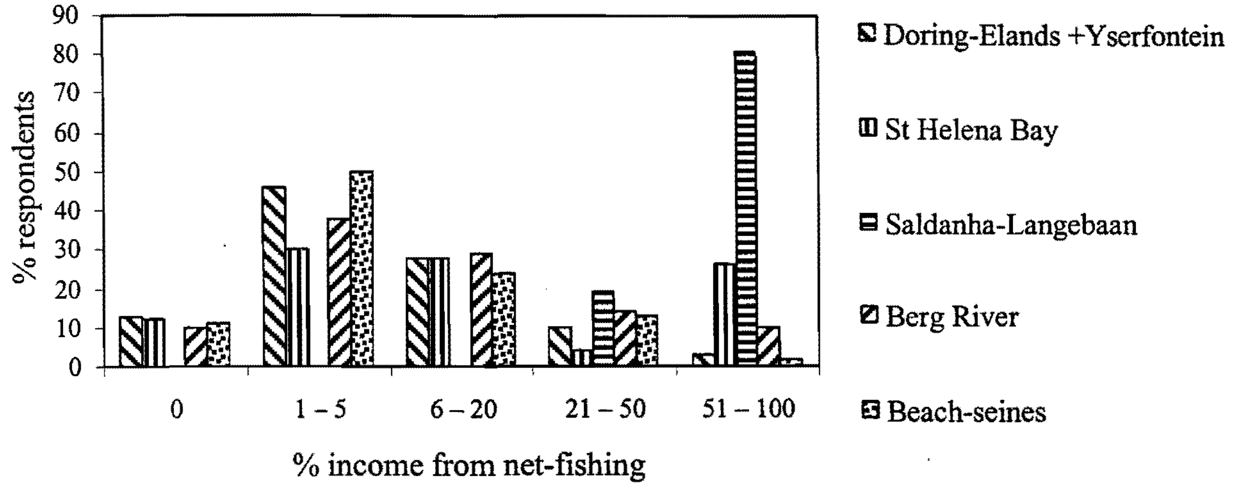


Fig. 2.1: Percent of respondents' total income from net fishing.

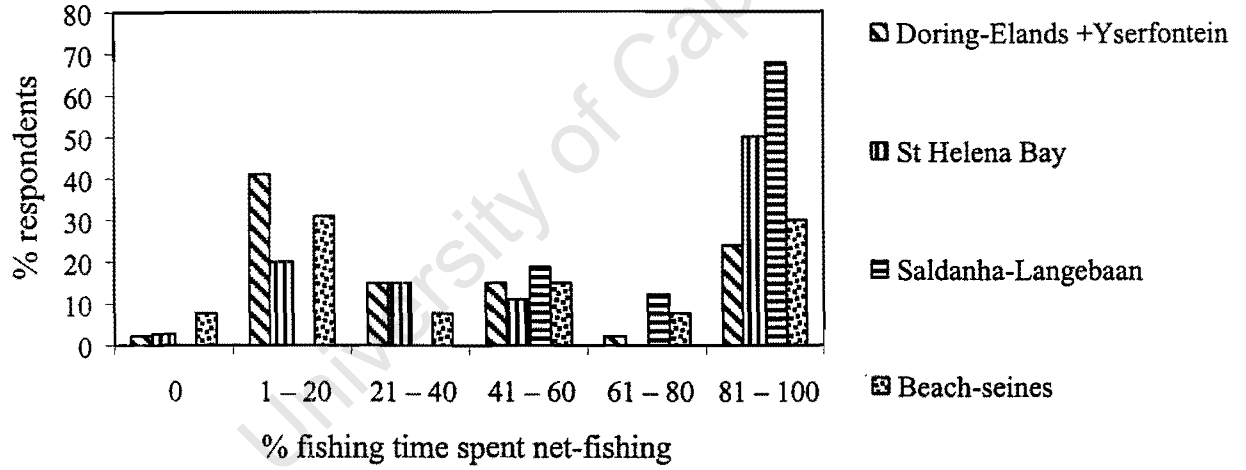


Fig. 2.2: Claimed proportion of fishing time spent net-fishing.

2.4 Costs and returns to net-fishers

(a) Investment costs

Despite the fact that most of the permit holders interviewed claimed to make only a small proportion of their income from the net fishery, they have invested a substantial amount in fishing gear, suggesting that catches and hence financial returns were greater in the past. Due to the difficulties of obtaining the cost of various items at the time when fishers had originally purchased them, all costs listed are the 1999 replacement costs obtained from local suppliers, or estimated by the fishers themselves.

To the north of Dwarskersbos (Stratum 1), harders seldom occur in sufficient densities, and the sea conditions are often too rough, to allow for commercial scale exploitation with gill nets. It is clearly not economically viable for fishers in these areas to invest in gear, or to go to sea solely for the purpose of gill-net fishing for *L. richardsonii*. Many Stratum 1 permit holders have only invested in the net and go to sea with other fishers who own the boat and outboard, or if they own all the equipment themselves, it is also used to harvest other resources. In these areas, long trips (where the fuel cost will be high) are often undertaken for the main purpose of catching rock lobster *Jasus lalandi* using hoop nets, or hottentot *Pachymetopon blochii* and snoek *T. atun* using hand lines and the gill net is taken along to supplement the day's catch. For these reasons, all costs to Stratum 1 permit holders are calculated as 30 % of the total costs, the average proportion of fishing time that these respondents claim to spend net-fishing.

The most common vessels used by respondents were dinghies – 3-5 m open, fiberglass boats, with a displacement hull design (Fig. 2.3). Purchase of boats and the associated safety and navigational equipment accounts for 30-40 % of gill-net fishers' investment costs (Table 2.5). Thirty-five percent of respondents from St Helena Bay (Stratum 2) fished from ski-boats – larger open boats with planing hulls. These fishers are those that operate commercially and often travel further in search of harder shoals. As a result, the average acquisition cost of a boat for St Helena Bay gill-net fishers was substantially more than that for gill-netters in other areas. Most of the Saldanha-Langebaan permit holders also fish commercially, but the shorter distances traveled and the sheltered nature of Saldanha Bay does not necessitate the use of more expensive skiboats and these fishers use motorized dinghies.

Fig. 2.3: Commercial gill-net fishing boats, with a large catch (± 1 ton) of *Liza richardsonii* (left) and *Callorhinchus capensis* (right).

The purchase of outboard motors accounted for the largest proportion (40-56 %) of gill-net respondents' investment costs (Table 2.5). The size of outboard motors used by gill-netters ranged from 5-85 horsepower. Nearly all the respondents from Stratum 2, Saldanha-Langebaan and the Berg River owned at least one outboard motor. The larger dinghies and greater proportion of ski-boats used by Stratum 2 net fishers necessitates the use of larger outboards (average = 25 hp), whereas fishers who operate in the more sheltered waters of Langebaan Lagoon and the Berg River use smaller (10-15 hp) motors. Less than half the permit holders interviewed from Stratum 1 used outboard motors (average 10 hp) when net fishing, but this item still accounted for 42 % of the average net-fishers investment costs.

On average, gill-net respondents from St Helena Bay (Stratum 2) used close to the maximum allowed four, 75-m "harder" nets (44-64 mm stretch mesh). Consequently, the average St Helena Bay net-fisher invested R 3 261 in nets, substantially more than gill net fishers from other regions. Several permit holders from Saldanha Bay and Langebaan Lagoon admitted to using more than the permitted maximum of two nets. In the less commercial areas to the north of Dwarskersbos (Stratum 1), respondents on average only used 1.3 nets although fishers may hold a maximum of four permits. None of the Berg River permit-holders admitted to using more than the allowed one net, probably because the width of the river prohibits the use of longer nets. Overall, purchase of nets accounted for 9-34 % of gill-net respondents' investment costs. Although 74 % of Stratum 2 permit holders had invested in "St Joseph" (178mm) nets, very little (only eight landings) St Joseph directed effort was observed during this study. Most respondents stated that they no longer targeted St Joseph, due to the low sale price (90c.kg $^{-1}$) and collapse of the central

African market for the fish. Lack of accurate data on St Joseph catch rates and effort levels precluded the incorporation of St Joseph gill netting in the cost - benefit analysis. If the St Joseph market were to recover, targeting this species could provide additional income to Stratum 2 permit holders with a relatively small increase in costs. Fifteen respondents out of the total of 118 (13 %) who used gill nets in the sea admitted to owning illegal nets, either unlicensed 44-64 mm gill nets, beach seine nets or gill nets with illegal mesh sizes (65-145 mm stretch mesh). Investment in these illegal nets was not included in analysis of costs and returns, as it was not possible to obtain accurate estimates of returns from illegal net fishing activities.

Although 30-58 % of gill-net respondents used vehicles to facilitate their fishing activities, none used their vehicles solely for net fishing. Purchase of a vehicle was therefore not considered as an investment in fishing gear and the investment costs of vehicles were not assessed for gill-net fishers. Vehicle fuel and maintenance costs were, however, taken into account in estimation of operating costs. Total investment in fishing gear by the average gill-net respondent varied considerably between areas (Table 2.5). Commercial net-fishers from Stratum 2 on average invest the most in fishing gear (R 30 461) whilst respondents from Saldanha-Langebaan and the Berg River had also made a substantial investment (R 18 400-21 100). Stratum 1 fishers on average invested much less in equipment than respondents from other areas (R 3 423). This is indicative of the more subsistence nature of the fishery, not by choice, but by low availability of fish in these areas and the shorter distances traveled. The fact that investment in boats and outboards by fishers in this area, unlike elsewhere, is also for harvesting other marine resources, means that investment costs directly applicable to net fishing are lower.

Entry into the beach-seine fishery requires the greatest investment, approximately R 77 000 (Table 2.5). The major investment cost is the purchase of the net. Although beach-seine nets were substantially cheaper in the past, due to decreases in demand the mesh size is no longer manufactured regularly and has become prohibitively expensive. A four-wheel drive vehicle is also required in most areas as fishers typically follow shoals of fish along sandy beaches. An increase in theft and vandalism of fishing gear has also become a problem for many beach-seine permit holders and equipment can no longer be left safely on site. A four-wheel drive vehicle is therefore seen as necessary part of beach-seine fishers' equipment and contributes on average 45 % of respondents' investment.

(b) Fixed costs

Capital invested in and the subsequent depreciation of fishing equipment accounts for the greatest proportion of net-fishers fixed costs. The average annual depreciation per respondent is a measure of the amount fishers must reserve annually for the eventual replacement of fishing gear (Table 2.5).

Average net life is inversely related to the amount that it is used. The most active Saldanha-Langebaan fishers, who on average claim to make 142 trips a year, replace complete meshes on average almost twice a year, whereas in Stratum 1 (where fishers claim around 33 trips per year) nets last nearly 4 years (Table 2.5). Fishers usually only need to replace the monofilament mesh of the nets, as the cork and lead-lines last substantially longer. Initial investment cost was therefore calculated using the price of the complete net, but depreciation of nets was calculated on the cost of replacement mesh alone. Beach-seine nets are essentially irreplaceable, given the prohibitive expense of the mesh, but most beach-seine nets last in excess of 20 years and all respondents said that with repairs they had never replaced the complete net.

The expected life of outboard motors is also directly related to the level of use and depreciation of this item accounts for the majority (80 % for Saldanha-Langebaan fishers) of the total annual depreciation costs for gill-net fishers. It was felt, that due to certain biases, questionnaire survey respondents had overestimated their activity levels and that the effort value obtained from the telephone survey were more realistic (Chapter 1). Average expected life and annual depreciation of outboard motors was therefore calculated using the lower telephone survey effort estimates (Table 2.5). Use of the activity levels claimed by questionnaire survey respondents in these calculations resulted in unrealistically low estimates of expected average outboard life and increased total annual depreciation by as much as 40 %.

Total average annual depreciation per respondent varies with the amount and type of equipment purchased and the level of use of the gear. Stratum 1 fishers who invest the least and operate infrequently need to, on average,.reserve R 259 per year for eventual replacement of fishing gear, whereas the more active, commercially orientated Stratum 2 and Saldanha-Langebaan fishers must set aside between R 3 000-4 000 annually.

Table 2.5: Average investment costs and depreciation of fishing gear used by respondents.

Item	Average number owned per respondent	Average 1999 cost per respondent (Rands)[1]	Average expected life (years)	Average annual depreciation per respondent (Rands)[2]
Stratum 1*				
Boat[3]	0.73	818	20[5]	41
Outboard[4]	0.48	1 440	15[6]	96
44-64 mm nets	1.3	1 165	3.8[7]	122[8]
Total		***3 423***		***259***
Stratum 2				
Boat	0.91	14 056	20	703
Outboard	1.06	13 144	9.6	1 367
44-64 mm nets	3.64	3 261	1.9	684
Total		***30 461***		***2 754***
Stratum 3				
Boat	1.13	7 425	20	371
Outboard	1.07	11 770	3.5	3 343
44-64 mm nets	2.13	1 904	0.7	531
Total		***21 099***		***4 245***
Berg River				
Boat	1	7 510	20	375
Outboard	0.92	9 200	9	1 012
44-64 mm nets	1	896	3.4	105
Total		***18 406***		***1 492***
Beach-seines				
Boat	0.81	2 855	20	218
Net	1.2	39 600	30	1 320
Vehicle	0.85	34 446[9]	20	1 722
Total		***77 050***		***3 260***

1 = Average cost per item x average number owned per respondent.
2 = Average cost per respondent ÷ average expected life
3: As estimated by respondents, including accessory equipment (navigational, safety and fish finding equipment etc.).
4: Based on 1999 supplier value of average size (horsepower) motor used by respondents in that Stratum.
5: Based on maximum age of boats used.
6: Based on an outboard life span of 1 250 hours ÷ (average claimed effort x 2.5 hrs running per trip).
7: As claimed by respondents.
8: Calculated using replacement cost of mesh alone.
9: As estimated by respondents.
* Stratum 1 investment in boat and outboard calculated at 30 % of total, as equipment is not used solely for net fishing

Although beach-seine respondents had made the greatest initial investment, the average annual depreciation of their gear was slightly less than for commercially active gill-netters (Table 2.5). This is a result of the relatively low acquisition cost and long life span of rowing boats used and the fact that beach-seine fishers do not need outboard motors. Depreciation of the four-wheel drive vehicle contributed over 50 % of the total annual depreciation costs, even using an optimistic expected life span of 20 years. Although no respondents had replaced their complete beach-seine net, it would eventually wear out and this item amounts to 40 % of the total annual depreciation costs.

Additional fixed costs to net-fishers include an annual boat safety survey fee and annual net permit fees. The cost of a safety survey for motorized commercial fishing vessels that operate less than 10 nautical miles from the shore is R150 for a 4.2 m (the average size boat used by gill-net respondents) vessel. This fee is applicable to most gill-netters operating in Stratum 2, the Berg River, Saldanha Bay and Langebaan Lagoon. The survey fee for non-motorized rowing boats is slightly cheaper (R 90) and as only half the Stratum 1 fishers used outboard motors and the boats are also used for line and rock lobster fishing, an average safety survey cost of R 38 is applicable to these fishers. Although beach-seine fishers normally operate within one nautical mile of the shore, they also require safety certificates for their rowing boats (R 90). Each individual net owned by permit holders requires a separate annual permit issued by the licensing authority (MCM). Permit costs during 1999 were R 30 per net. St Helena Bay (Stratum 2) and Berg River fishers who moor their boats at jetties within the harbour area also have to pay annual harbour fees of approximately R 168 (for a 4 m boat). Not all permit holders moor their boats within the harbour area and pay harbor fees, so these have not been included in the total fixed costs for the average net-fisher.

(c) Variable/operating costs and sharing systems

Daily petrol expenditure (boat and vehicle fuel) was greatest for fishers operating in St Helena Bay, due to the greater number of skiboats used and the distances covered when fishing (Table 2.6). Annual maintenance costs (for repairs and services to all fishing gear including vehicles and trailers) increased from Stratum 1 to Stratum 3. This is a result of the equipment used (a dinghy has very low maintenance compared to a skiboat), the number of nets owned and the average annual effort expended by fishers. Beach-seine permit holders could not put a figure on annual maintenance related directly to the fishing operation, as no outboards are used and boats and nets are usually repaired by hand at little expense. Wear and tear on four wheel drive vehicles used by beach-seine operators during fishing is obviously significant, but no respondents used their vehicles solely for beach-seining and could not value this expense.

Table 2.6: Daily fishing expenditure.

Expense (Rands)	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North head	Stratum 3 Saldanha-Langebaan	Berg River	
Ave. petrol cost per trip	6	93	51	30	50
Ave. annual maintenance	351	2 876	3 650	1 413	/
Crew share (%)	49	33	32	33	60

Beach-seine respondents on average claimed to pay their crew 60 % of the value of the catch (Table 2.6). This could, however, be an attempt by permit holders to convince management that they are distributing the catch fairly. In contrast to claims by permit holders, some of the crew interviewed claimed to only get R 25 per man and 20 fish out of a catch of fish valued at R 2 500 (approximately 1 ton). For all the crew combined this amounts to only 15 % of the value of the catch with the permit holder pocketing 85 %. Fishers from Stratum 1 claimed to split the catch equally amongst the crew, but usually also share the daily fuel costs. Crew working on the commercial boats received on average a third of the catch with a third traditionally going towards equipment maintenance and daily expenses and the remaining third to the permit holder. The sharing systems used by net permit holders mean that they incur no fixed labour costs, with crew only receiving pay in proportion to the amount of fish caught. This obviously results in little financial security for labour, but given the sporadic availability of fish and the high-risk nature of the fishery it is the only viable way in which permit holders can employ crew.

(d) Sale of fish

On average, respondents from St Helena Bay (Stratum 2) and Saldanha-Langebaan sold more than 90 % of their catch, whereas Stratum 1, Berg River and beach-seine fishers kept 21-30 % of the catch for their own consumption (Table 2.7). Generally, the price obtained for the fish was inversely proportional to the amount sold to dealers and to the size of the catch. Fishers who sell a greater proportion of the catch directly to the public obtain a higher price on average than fishers who sell large catches to dealers. The exceptions are beach-seine permit holders, who often operate in areas where no formal market specifically for harders exists and who retain a large proportion of the catch to sell to farm labourers or other employees at a low price.

Table 2.7: Sale of fish caught by net-fishers.

Value	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
Amount sold (%)	70	91	99	79	75
Average price (R/kg)	3.24	2.40	3.00	2.00	2.00
Dealers/factories (%)	25	80	69	90	54
Out of hand (%)	75	20	25	10	46
Process own fish (%)	12	11	19	55	38

Berg River permit holders sell their fish for slightly less on average than fishers from St Helena Bay, who usually sell to the same buyers. This is probably related to the average size of the fish caught in the Berg River, where a large proportion of the catch is small fish or "bokkoms", which is only suitable for salting and drying (Fig. 2.4) and not for the more lucrative fresh fish or bait markets. The relatively good price obtained by Saldanha-Langebaan permit holders compared to that obtained by fishers from nearby St Helena Bay is also related to the size and quality of the fish caught. Fish caught in Langebaan Lagoon are particularly large are highly sought after as fresh fish and as bait for tuna longline operations. One local factory packs in the region of 20 tons per month for this bait market. Between 10-20 % of the marine gill net fishers interviewed processed a small proportion of their catch, usually into "bokkoms", but this was for own consumption and not for sale. A fairly high proportion of beach-seine and Berg River fishers interviewed however, claimed to make "bokkoms", either for sale to the public, or to their own employees.


Fig. 2.4: "Bokkoms" – dried and salted *Liza richardsonii* being hung out to dry after salting (left) and stored in a "factory" (right).

(e) Returns to net permit holders

Based on claimed daily catches, annual effort levels, and the calculated fixed and variable costs, permit holders returns to capital and average annual profits were estimated (Table 2.8). The proportion of the catch retained for own or crew consumption, although not sold, was valued as if it had been. The average daily catch was multiplied by the average sale price and the daily expenses of fuel and crew pay were subtracted, giving a net trip income for each area. Annual net income was calculated by multiplying the net trip income by the claimed average number of days fished per year. The annual accounting profit or loss for the average permit holder was calculated by subtracting the relevant fixed and variable costs. Permit holders' annual excess profits or losses were calculated by subtracting the opportunity costs of investment capital and own labour (when applicable) from annual accounting profit. For this analysis, the most realistic telephone survey effort values and catch rates based on monitored or factory sales records were used (Chapter 1). Only eight landings were monitored from Stratum 1 (Ave. = 9.78 kg) and no factory records were available, so the average daily catch rate claimed by telephone survey respondents (26 kg) was used. When the calculations were made simply using the effort levels and catch rates claimed by questionnaire survey respondents, accounting profits (excluding opportunity costs) were unrealistically negative (as much as R 5 000) for St Helena Bay and Berg River fishers.

The opportunity cost of permit holders' capital was calculated as 7.5 % of the investment costs, a realistic rate of return if net-fishers had invested their money in a savings account with a local bank rather than in fishing gear. The opportunity cost of permit holders' own labour was calculated based on the amount they would have earned if they had spent their time fishing as crew on a commercial line-fishing boat rather than net-fishing. In reality, permit-holders are skilled and qualified seamen and could earn more as skippers on commercial ski-boats. If this opportunity existed, the opportunity cost of the permit holders' labour would be greater, as ski-boat skippers earn substantially more (at least double) than crew. Commercial line fishing is a likely alternative source of employment for net fishers. Retired fishers are no longer economically active and the opportunity cost of the average net fisher was adjusted accordingly. Calculation of the opportunity cost of labour does, however, assume that alternative employment is available during the periods when net-fishers are active. This assumption is not always valid and the inclusion of labour opportunity costs in determining economic profit is debatable.

It is clear, based on accounting profit, that on average, only gill-netters from Saldanha-Langebaan and possibly beach-seine fishers are potentially making a living out of net fishing (Table 2.8). The rate of return on investment, for areas where the average fisher achieved a positive residual return that was greater than the opportunity cost of his labour was calculated using the method recommended by Yater (1982) as:

$$\text{Rate of return} = (\text{accounting profit} - \text{labour opportunity cost}) \div \text{acquisition cost}$$

Saldanha-Langebaan permit holders, even when using 1999 acquisition costs, achieved a very favorable rate of return, substantially more than the opportunity cost of their capital investment and made a reasonable pure profit. The average beach-seine permit holder also achieves a positive rate of return on their investment, and makes a small pure profit. Stratum 2 permit holders just cover the opportunity cost of their labour, but their rate of return is much less than the opportunity cost of their capital and they make a pure loss. The average Stratum 1 and Berg River permit holder does not cover the opportunity cost of own labour and has a negative rate of return on investment (i.e. loses money).

The average gill-net permit holder in most areas is currently barely covering total costs, or if the claimed daily expenses of Berg River fishers are to be believed, is running at an annual loss. At current effort levels, it appears that gill netting in the Berg River is a recreational pastime for pensioners rather than a commercial operation. Berg River fishers however, feel very strongly that they have a historical right to participate in the fishery and appear willing to accommodate annual losses to remain in the fishery. Berg River fishers do retain a sizable proportion of their catch for own consumption and many process their own catch into "bokkoms". This will increase their returns relative to those shown in Table 2.8. Even for the average St Helena Bay permit holder, accounting profit was less than the opportunity costs of their labour and capital.

The current costs and returns to net-fishers make it hard to believe that these fisheries continue to exist. Investment costs and depreciation of equipment were, however, calculated using current replacement costs and fishing equipment was relatively cheaper in the past. The fall in the international value of the South African Rand over the last decade has resulted in drastic increases in the costs of imported equipment, particularly monofilament gill net mesh and outboard motors. The value of by-catch was also not included in the analysis. By-catch in the legal gill net fishery, however, is usually low-value species that contribute less than 5 % of the total catch (Chapter 1) and represents little in the way of a financial return to gill-net permit holders. On the other hand, by-catch of "angling" fish provides over 60 % of the total value of the False Bay beach-seine catch (Lamberth 1994). Although not quantified in this study, the illegal sale of by-catch could represent a significant return to beach-seine permit holders, particularly along the Southwest Coast. The *L. richardsonii* stock appears overexploited in areas with high effort levels (Chapter 1), it is likely therefore that catches and hence returns were substantially greater when fishers originally entered the fishery. As there are limited alternative opportunities or resources that net fishers can exploit using their fishing gear, they can not simply leave the fishery without losing the capital that they have "sunk" into fishing equipment. Most permit holders probably recovered their investment costs during better years in the past and subsidize their continued participation in the fishery with income from other employment in the hope that things will improve in the future. Equipment will, however, eventually wear out and in most areas at current effort levels, the net fishery, is not economically sustainable as a commercial operation in the long term.

Table 2.8: Average income and returns to net permit holders, based on *Liza richardsonii* directed catch and effort only.

Value (Rands)	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	Beach-seines
Daily catch					
Average catch (kg)	26	183	136	37	795
Value of fish sold	***84***	***439***	***408***	***74***	***1 590***
Daily operating costs					
Fuel	6	93	51	30	50
Crew pay	39	146	136	25	954
Total	***45***	***239***	***187***	***55***	***1 004***
Income					
Net trip income	39	200	221	19	586
No. trips per year	33	52	142	40	24
Annual net income	***1 287***	***10 400***	***31 382***	***760***	***14 064***
Annual fixed costs					
Net license fee	39	186	64	30	36
Boat survey fee	38	150	150	150	90
Depreciation	259	2 754	4 245	1 492	3 260
Total annual fixed costs	***336***	***3 090***	***4 459***	***1 672***	***3 386***
Annual variable cost					
Maintenance	351	2 876	3 650	1 413	NA
Total annual costs	***687***	***5 966***	***8 109***	***3 085***	***3 386***
Annual accounting profit or loss	***600***	***4 434***	***23 273***	***- 2 325***	***10 678***
Annual opportunity costs					
Of investment capital[1]	257	2 285	1 582	1 380	5 779
Of own labour[2]	2 508	4 051	12 681	1 862	1 663
Total	***2 765***	***6 336***	***14 263***	***3 242***	***7 442***
Annual excess profit or loss	***- 2 165***	***- 1 901***	***9 010***	***- 5 567***	***3 236***
Rate of return (%)	***- 56***	***1.25***	***50***	***- 23***	***12***

1: Based on 7.5 % of acquisition cost.
2: Valued at R 95 per day, the average daily crew wage earned on commercial skiboats in 1995was R 65 per day (McGrath *et al.* 1997).

The above costs and returns are based on a hypothetical "average" commercial net-fisher. In reality there is a limited number of permit holders who do make substantially more by operating more often and efficiently than the "average" net-fisher. There is also a substantial number of permit holders who do not operate commercially at all, but are inactive or fish recreationally only a few times per year. The general feeling of most net-fishers interviewed was that net fishing as a source of income was no longer economically viable due to decreased catches rates, low and sporadic availability of fish and increases in costs, particularly the fuel price in recent years. Indeed, 10 % of Stratum 2 and 42 % of Stratum 1 respondents admitted to being inactive for the 12 months preceding the interview, citing the high risk of running at a loss as the main reason for not fishing.

The glaring exception in the West Coast gill net fishery is the Saldanha-Langebaan fishery, where respondents spent more of their time, made a larger proportion of their income, invested more and could make a living from the fishery. The reasons for net fishers in this area doing exceptionally well compared to other regions is partly due to the year-round availability of fish, but due to a failure by management to effectively reduce net-fishing effort in other areas. The large proportion of *L. richardsonii* retained by Stratum 1 permit holders for their own consumption (30 %) underlies the importance of gill-netting to meet food requirements, rather than as a commercial enterprise. Furthermore, the market for fish in these areas is limited, and the low value of the fish makes it uneconomical to transport catches by road to the "bokkom" factories at Veldrift. In remote areas, demand is often so low that it is uneconomical to harvest fish other than for household consumption or small local markets (Ruddle 1996).

The St Helena Bay (Stratum 2) annual catch is estimated to be around 2 000 tons, substantially more than the 500-600 tons estimated for Saldahna-Langebaan (Chapter 1). Absolute fish abundance is therefore not the reason for St Helena Bay permit holders not deriving the same economic benefit from the net-fishery as Saldanha-Langebaan fishers. The St Helena Bay catch is, however, shared between 235 permit holders, most using the maximum allowed four nets. By contrast only 28 permit holders are permitted to fish in Saldanha-Langebaan, using a maximum of two nets in the Bay area and only one in the Lagoon. Saldanha-Langebaan permit holders also use larger mesh nets than St Helena Bay permit holders (51-64 mm cf. 44-51 mm stretch mesh) and catch a larger class of fish, that fetches a correspondingly higher price. The availability of fish to individual St Helena Bay fishers is much lower than to individual Saldanha-Langebaan fishers who make many more trips per year. This is not only a result of fewer fishers competing for the available fish, but also of the more sheltered sea conditions and less marked seasonality in the occurrence of harder shoals in Saldanha-Langebaan compared to St Helena Bay. Furthermore, the majority of Saldanha-Langebaan fishers are not involved in other fishing sectors which prevent them from net fishing for much of the year.

The gill-net fishery in the Berg River and St Helena Bay is ridiculously oversubscribed with a large amount of latent and recreational effort making the fishery economically inefficient. The lack of pure profits, or even positive accounting profits, to permit holders in some areas is compelling evidence that the fishery is indeed at or beyond the open access equilibrium point. This suggests, in terms of an open access bio-economic model, that an effort reduction in the region of 60 % is required in order to obtain Maximum Economic Yield from the fishery (McManus 1996). Catch per unit effort almost always declines with increasing effort (McManus 1996). It is, however, unlikely that a reduction in the number of Stratum 1 fishers would result in increased catches for the remaining permit holders in this area. Many of these permit holders are inactive (40 %) anyway and catch rates are still low. Natural low densities of *L. richardsonii*, an exposed coastline and lack of local markets make this area unsuitable for commercial gill-netting. A reduction in the number of St Helena Bay and Berg River fishers would certainly improve catch rates for the remaining fishers, even at the current overexploited stock size, simply through less competition for the available fish.

The 60 % effort-reduction mentioned above also predicts improved catches due to assumed increased recruitment via a positive stock-recruitment relationship, i.e. greater economic yields due to the recovery of an overexploited stock. The assumption that a positive stock-recruitment relationship exists and will continue to exist at greater stock sizes needs to be true if the benefits of reducing fishing effort are to be realized (Milliman *et al.* 1987). Due to increased intraspecific competition for resources at higher population levels, growth rates may also decrease, resulting in decreased yield-per-recruit (Milliman *et al.* 1987). Furthermore, unfavorable environmental conditions or other extraneous factors may suppress stock recovery even when fishing effort is reduced. These biological uncertainties mean that the degree of, or time period for, recovery of the *L. richardsonii* stock at lower levels of gill netting effort cannot be accurately known. For stock recovery to occur, effort would initially have to be reduced to a level that results in a catch smaller than the productivity of the stock. During this period the cost of the forgone catch may equal any future returns (which will have a relatively lower present value due to discounting), resulting in zero long term economic gains (Anderson 1986, Milliman *et al.* 1987). Even under an optimistic scenario, where stock recovery occurs rapidly, effort, in terms of the number of permit holders, could never be increased to the obviously unsustainable current level.

Annual gross income (value of catch minus crew share) from net fishing for permit holders from most areas in 1998/99 (R 1 386-17 992) was much lower than the R 54 600 estimated for commercial skiboat line-fishers in 1995 (McGrath *et al.* 1997). Most netfishers are, however, part time participants and claim to make less than 5 % of their total annual income from the fishery. A large proportion of Saldanha-Langebaan permit holders do qualify themselves as full time commercial net-fishers and have similar annual effort levels to commercial skiboat line-fishers (119 and 142 trips per year respectively). These fishers had an average gross annual income in 1998/99 of R 50 694, which is also less than the gross that the average commercial skiboat operator made in 1995. Details of the total fixed and variable costs for commercial skiboat operators are not given in the study by Mc Grath *et al.* (1997) and it is not possible to compare pure profits or rates of return to owners in the two fisheries.

(f) Returns to crew

Crews in net-fishing operations are not (usually) assured of a standard daily wage. The sharing systems in place essentially force crew to become partners with the permit holder, sharing the risk of making a catch on any day and hence the resultant income. Crew members do not, however, have to cover any of the fixed or running costs of the outfit and only have to cover the opportunity cost of their own labour. Once again, this should only be considered if alternative employment is available during the periods that they spend net fishing. This is seldom true along the West Coast, where unemployment levels are high and much of the crew is not equipped with the skills necessary to undertake alternative non-fishing/formal sector work. Daily and annual income for the average crewman are shown in Table 2.9. The opportunity cost of labour is calculated as if the crewman had fished on a commercial skiboat and made R 90 per day, rather than net fishing. Beach-seine crew earns a comparable amount to commercial skiboat crew and fishers who worked on St Helena Bay and Saldanha-Langebaan gill-net boats made slightly more. These fishers make a small annual pure profit or loss and would do equally well working in either sector. Stratum 1 and Berg River crews on average make less than they would by commercial line fishing. In these areas, there is therefore strong economic motivation for crew to target line-fish when this opportunity exists, rather than to net-fish. This is borne out in practice with net-fishing activity only taking place when alternative fishing activities are less productive.

Table 2.9: Daily and annual income and returns to net-fish crew.

Rands	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
No. trips per year	33	52	142	40	24
Daily income	39	146	136	25	79
Annual net income	1 287	7 592	19 312	1 000	1 896
Less opportunity cost	3 135	4 940	13 490	3 800	2 160
Pure profit or loss	- 1 848	2 652	5 822	- 2 800	- 264

2.5 Contribution of net fishing to the regional economy

The landed wholesale value of the harder catch in the study area (estimated at around 5 000 tons) is approximately R 12.5 million. Additional economic benefits and employment directly related to fishery in the form of equipment purchases made by fishers and the sale of value-added products produced by the buyers of net fish exist. The 481 permit holders who claim to be active within the study area have invested a total of approximately R 16.6 million (1999-replacement values) in fishing gear. They spend approximately R 1. 07 million on maintenance of fishing equipment and R 1. 48 million on fuel annually. Approximately 580 monofilament gill nets with a value of nearly R 200 000 are sold annually. In Laaiplek and Veldrif, nine "vis winkels" that buy fish and produce "bokkoms" for sale rely exclusively on the net fisheries for their business. Although farmers are still the main buyers, "bokkoms" are now regarded as a West Coast delicacy and are finding an increasing market amongst tourists. These businesses are usually owner-run, but do employ 1-5 full time workers and take on additional temporary help during times of high fish abundance. Other larger fish processors in St Helena Bay, Saldanha and Langebaan also deal in net-caught fish, packing blast-frozen harders for longline bait and producing dried or frozen St Joseph and hound shark fillets for export. These factories employ substantial numbers of workers, but do not deal exclusively with net-caught fish, also buying and processing line and trawl-caught fish.

With the exception of a few beach-seine operations (at Elands Bay, St Helena Bay, Paternoster, Struisbaai and Arniston), very few previously disadvantaged permit holders appeared to rely on the net fishery as an alternative source of food or income when other fisheries were not productive (pers. obs.). For example, although there are over 40 gill-net permit holders in Lamberts and Doring Bay, only one (a local restaurant owner) was seen to work regularly with his nets. Part of the explanation for the apparent lack of activity by poor permit holders may be their inability to purchase or maintain the equipment needed, or their choice not take the risk of having their nets damaged by seals for a small catch. It is clear that the simple allocation of net permits will not relieve hardship amongst poor communities. Financial assistance to the permit recipient and the innovative development of new markets, more lucrative than "bokkoms" – for example fresh iced fish, smoked fish or pickled "rolmops" – need to occur at the same time.

2.6 Attitudes and responses to management

(a) Respondents' perceptions of the resource status

Over 70 % of gill net fishers operating outside of Saldanha-Langebaan felt that their catches had declined since they had entered the fishery (Table 2.10). Although only 56 % of Saldanha-Langebaan respondents and less than half the beach-seine fishers interviewed felt that their catches had declined, the majority felt that no more permits should be issued for the area where they operated and many complained that there were already too many. It is surprising that majority of fishers interviewed from the Doring-Elands Bay area felt that more permits could be issued, despite the fact that they felt their catches were declining and at least 42 % admitted to being inactive. When questioned about their reasons, many felt that they did not want to deprive others from attempting to make a living catching *L. richardsonii*, even if they were not being successful themselves.

Table 2.10: Questionnaire respondents' perception of the resource status and opinions on increased participation in the net fishery.

% respondents	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
Catches declining	76	70	56	74	42
No more permits	42	66	66	62	72

When asked for the reasons they felt their catches had declined, with the exception of Berg River fishers, very few respondents blamed the number of participants in the fishery. Rather a host of other factors were cited, including animal competitors (birds and seals), human interference (other fishers, recreational watercraft) and environmental changes and degradation (Table 2.11). A large proportion of respondents felt that the numerous severe black tides (low oxygen conditions associated with the decay of plankton blooms) that have occurred along the West Coast in the last decade (which resulted in large fish kills) were the cause of the catch declines experienced. Several of the reasons provided by respondents have almost certainly played a role in making the *L. richardsonii* stock vulnerable to overexploitation, whereas others are obviously attempts to apportion blame elsewhere. Whatever the reasons for the catch declines experienced by net fishers, it is clear that there is no justification for increasing the number of participants in the areas where these fisheries currently operate.

Table 2.11: Questionnaire respondents' perceived reasons for catch declines.

Reason (% respondents)	Gill netters				Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha-Langebaan	Berg River	
Pelagic by-catch	20	10	*		
Environ. Changes	19	3	*	9	*
Reduced estuary flow	13	5		27	
Black tides	10	38	*	9	*
Seals, cormorants	10	7	*		
Too many nets	6	19		54	
No idea		19	*		

*reasons were mentioned by fishers as possible causes of catch declines.

(b) Factors driving effort in the net fisheries

In light of the low or negative financial returns to net permit holders, other social rather than economic factors must be driving some of the effort in the fishery. In an attempt to better understand these factors, telephone survey respondents (marine net permit holders) were asked whether they fished primarily for food (i.e. subsistence), income (i.e. commercial) or relaxation (i.e. recreational). Respondents' answers to these questions are summarized in Table 2.12.

It is not surprising, given that commercial gill netting does not appear viable in the region, that 75 % of Stratum 1 respondents claimed that obtaining food, or a combination of food and income, were the main reasons that they participated in net fishing. Forty-two percent of respondents in this area admitted to having been inactive in the 12 months preceding the interview and a third stated that they had not reapplied for commercial permits in the coming year. Most also expressed an interest in obtaining a cheaper subsistence net permit, if they became available, even if this restricted the length of net they would be permitted to use and the sale of fish they caught. Recreation does not feature as a motivation for net-fishers in this area.

The majority of St Helena Bay (Stratum 2) respondents claimed that income was the primary reason they fished, whilst some felt that obtaining food and relaxation played a role. A few St Helena Bay permit holders admitted to being inactive and 15 % would like to be classified as subsistence rather than commercial. All Saldanha-Langebaan respondents participated in net fishing for commercial reasons, although a few claimed that meeting food requirements was also important. Understandably, no Saldanha-Langebaan respondents were interested in being classified as subsistence if this would restrict the sale of fish. Beach-seine respondents fished both for financial gain and to obtain food for own consumption or for their employees (usually farm workers). Nearly a quarter of the beach-seine permit holders who were contacted admitted to having been inactive and said that they were not reapplying for permits.

Table 2.12: Factors driving effort in the marine gill and beach-seine fishery.

Reason for fishing (% respondents)	Gill netters			Beach-seines
	Stratum 1 Doring-Elands + Yserfontein	Stratum 2 Dwarkersbos – North Head	Stratum 3 Saldanha- Langebaan	
Income	25	52	80	21
Food	42	15	0	16
Relaxation	0	4	0	10
Income & food	33	17	20	47
Income & relaxation	0	4	0	5
Food & relaxation	0	8	0	0
Inactive	42	10	0	23
Reapplied for permits	66	88	100	82
Interested subsistence	66	15	0	0
Prepared to pay (Ave.)	R 222 ± 57	R 119 ± 21	R 59 ± 11	R 185 ± 61

A large proportion of Stratum 1 and beach-seine respondents, claimed that obtaining food from net fishing was important, and were willing to pay more on average for a permit than the more commercially orientated St Helena Bay and Saldanha-Langebaan fishers. For all respondents combined, 46 % claimed that obtaining food was one of the reasons they participated in the net fishery. This is probably one of the main reasons why many net fishers remain in the fishery despite the limited economic benefits.

(c) Respondents' knowledge and support for management regulations

Knowledge of the catch restrictions relevant to fish caught in nets amongst fishers interviewed was disturbingly low (Table 2.13), considering that the people interviewed are permit holders with commercial fishing rights and have presumably been informed of the conditions under which they may operate. This clearly indicates a lack of communication between management and the fishers and the lack of enforcement of these regulations. As many as 70 % of respondents in some areas had never had their catch inspected and the likelihood of being apprehended for contravening a regulation is so low that many fishers simply do not bother to learn the regulations. Commercial skiboat fishers generally have a slightly better knowledge (63-83 % of respondents) of management regulations than commercial net fishers (Sauer *et al.* 1997). Commercial linefishers on the West Coast on average have their catches inspected 12 times per year, indicating a direct link between the level of enforcement and the fishers' knowledge of regulations. It is ironic that the majority of recreational skiboat fishers (41-74%) and shore anglers (75-67 %) on the West Coast, who are the most vociferous opponents of commercial net-fishing, do not know the current management regulations (Brouwer *et al.* 1997, Sauer *et al.* 1997). Inspection rates in the recreational line-fishery, particularly for shore anglers on the West Coast, is very low, with less than 2 % of anglers ever having had their catch inspected (Brouwer *et al.* 1997).

Table 2.13: Knowledge of regulations amongst net-fishers interviewed.

% respondents	Size limits	Bag limits	Closed seasons	Sales ban
Know	60	59	72	53
Do not know	17	19	10	30
Would not answer	23	22	18	17

Support for gear restrictions amongst permit holders was fairly high (these are not really restrictive), but approximately half the fishers interviewed did not support restrictions on type and quantity of by-catch species they may retain (Table 2.14). This is understandable, as many net-fishers have traditionally caught valuable line-fish species and feel it is unfair that they are now restricted to catching relatively low value *L. richardsonii* and *Callorhinchus capensis*. Current catches of large line-fish are sporadic and fishers feel that when they do manage to catch these fish they should be allowed to retain and sell them as many are struggling to remain economically viable on catches of the legal target species alone. Support for catch restrictions amongst West Coast commercial (60-91 %) and recreational line-fishers is greater than amongst net-fishers. Line-fishers are not, however, restricted to only two species and a substantial proportion (as many as 50 %) admitted to having contravened the regulations despite claiming to support them (Sauer *et al.* 1997, Brouwer *et al.* 1997).

Table 2.14: Net-fish respondents support for restrictions.

% respondents	Gear (net) restrictions			Catch restrictions		
	Length	Depth	Mesh size	Target spp.	Size limits	Bag limits
Support	71	89	89	52	76	48
Do not	27	9	8	40	13	42
Would not answer	2	2	3	8	10	10

Conclusion

This study has highlighted the socio-economic complexities of the inshore net fisheries. It is clear that the importance of the fishery, as a source of income, recreation or food, for permit holders and crew varies greatly between and within different areas. On average, net permit holders are not an affluent group and net fishing cannot be considered a particularly lucrative activity. The limited economic analysis that was conducted suggests that at current effort levels, commercial net fishing is not viable in most areas. In the past, net fishing undoubtedly has played an important role in supplementing income from other sources for a small proportion of the current participants, and continues to do so.. For the majority of permit holders, however, it only constitutes a small proportion of earnings, or in some cases represents a cost. The social and cultural importance of the fishery for participants should not be underestimated and they will vigorously defend their perceived traditional right to continue fishing. The fishery, as a whole, plays an important role in supplying cheap protein to rural communities and as a source of work in areas where employment of any type is rare. Equipment and fuel purchased by net fishers and the sale of fish caught also make a substantial contribution (approximately R 15 million annually) to the regional economy. Management faces a difficult task of reducing effort to a more sustainable level, at the same time maintaining the positive socio-economic aspects of the fishery and improving cooperation with fishers and their compliance with regulations.

In order to reduce effort in a fair and equitable fashion, it is suggested that current and potential new permit holders should be assessed on an individual merit basis. In terms of criteria, net permit holders should:

- be able to prove some past involvement in the net fishery, either having worked as crew for current permit holders, or having operated their own equipment; this would ensure that they have the skills and experience necessary to be successful net fishers
- have the financial means to afford the initial capital outlay for the equipment needed (if they do not already have access to it) and be able to afford the daily running and maintenance expenses
- motivate that they have the time available, in that they do not have other work or fishing obligations, and the economic need to net-fish regularly
- demonstrate that they have the business skills required to fish in an economically viable manner
- show that a market is available for the fish they catch or provide information on how they process and market their own catches
- demonstrate a knowledge of and respect for the regulations relevant to net fishing and a concern for the sustainability of the resource

There is no logical reason to revoke the permit of a successful, active fisher who has already invested time and money in the net fishery and who provides employment for others in order to award it to someone else, particularly if they do not meet the above criteria. The most likely outcome of such an action would be equivalent to a "handout" in that the new recipient would likely just sell the permit back to an established net-fisher. Government funding and resources should rather be allocated to training, education and the development of alternative, sustainable livelihoods for poor and redundant fishers. The solution does not lie in allowing increased access to overexploited natural resources.

CHAPTER 3

THE LIKELY IMPACTS OF AN EASTWARD EXPANSION OF THE GILL-NET FISHERY IN THE WESTERN CAPE, SOUTH AFRICA

Introduction

Gill nets were introduced to South Africa by Italian and Portuguese fishermen during the 1860's (Thompson 1913). Conflict between gill-net fishermen and other sectors occurred as early as 1905, when: "It was found that their nets extended uninterruptedly from Robben Island northwards to the mainland," and " The provisions of the Fish Protection Act had, therefore, to be invoked to regulate netting in the locality, and further steps have had to be taken at a recent date" (Thompson 1913). Gilchrist (1914) also investigated angler and commercial fisher complaints that gill and beach-seine netters in the Berg River and Knysna Lagoon were catching large numbers of juvenile fish and depleting stocks. Further complaints from anglers and conservation bodies over net catches of line-fish and conflict with other sectors during the next 100 years has resulted in the implementation of various management measures aimed at reducing this conflict (De Villiers 1987, Penney 1991, Lamberth 1994, Lamberth *et al.* 1997).

The licensing of gill nets became compulsory in 1973 and fishers are required to submit daily catch returns to Marine and Coastal Management (MCM) (Theart *et al.* 1983, De Villiers 1987, Stander 1991). Gill-net fishing effort was reduced and largely confined to the West Coast and various gear restrictions, particularly limits on net length and mesh size were implemented in an attempt to reduce line-fish by-catch. In 1984 gill-net permits for the capture of galjoen *Dichistius capensis* were cancelled (Bennett 1988), and exchanged for permits for 178 mm stretched-mesh gill-nets intended for the capture of St Joseph sharks *Callorhinchus capensis* (De Villiers 1987, Freer & Griffiths 1993). Harders, *Liza richardsonii*, and St Joseph are now the only legal target species of the gill-net fishery. The landing of line-fish species is limited to 10 individuals per permit holder, per day, subject to the usual line-fish regulations.

One of the main aims of South Africa's new Living Marine Resources Act (implemented in 1998) is to create more equitable access to marine resources. Consequently, there has been increasing pressure on management to provide net permits to those fishers who claim to have been historically excluded from, or have operated illegally in, the fishery and to permit the catching of line-fish by this sector. Gill nets have been regarded as an ideal solution for developing inshore fisheries in impoverished countries, requiring little capital investment and low operating costs relative to other more technologically demanding fishing methods (Grant 1981). The West Coast commercial gill-net fishery, however, is currently oversubscribed with little potential for more entrants (Chapters 1 & 2).

Another option for increased participation in the gill-net fishery is a geographical expansion of the area where the fishery currently operates. The rationale for the spatial restriction of the fishery in the past has been based on concerns that by-catch, particularly of line-fish, in areas further south and east is too great. It was argued that the benefits of allowing gill nets in these areas are far outweighed by the problems of increased user conflict with other sectors and conservation and angler concern over the sustainability of line-fish stocks (De Villiers 1987, Stander 1991). This restriction in the areas where gill nets may be used was thus based on opinion and political pressure from other users groups. The well documented marine biogeographical trend of increasing species richness of fish from west to east around the South African coast (van der Elst & Adkin 1991, Bennett 1994, Turpie *et al.* 1999), appears to lend support to this decision. No scientific studies, however, were undertaken to quantify the actual gill-net catch composition or catch rates along the currently closed Southwest Coast, relative to the West Coast, where gill netting is allowed. This study investigated the potential impact on non-target species if the gill-net fishery was allowed to expand along the Southwest Coast.

Methods

Sampling methods

Experimental fishing, using a range of gill nets commonly used in the commercial fishery (Table 3.1), was conducted at bi-monthly intervals from September 1997 - July 1999 at various marine and estuarine sites throughout the study area (Fig. 3.1). The three different net types provide information on the current or potential catches of three different gill-net fisheries, namely, a fishery primarily targeting mullet, (using 44-51 mm nets), a currently illegal fishery targeting line-fish (using 145 mm nets) and one targeting St Joseph sharks (using 178 mm nets). In order to assess the potential impact of an expansion of any one, or a combination of, these fisheries, data for each net type are analyzed and presented separately. Sampling was concentrated along the southwest Cape Coast, where only an illicit gill net fishery exists. Gill-nets were deployed from a 4 m rowing boat, which is similar to the vessels used by many artisanal netfishers around the coast, but vastly inferior to the electronically equipped motorized boats used by the more commercial net-fishers in the St Helena and Saldanha Bay areas. Nets were set for at least 1 hour and often for longer periods in order to gain a sufficient sample. Overnight sets were also made on several occasions on the Southwest Coast, as anecdotal evidence suggested that much of the illegal gill netting occurred at night. Overnight sets were attempted on the West Coast, but resulted in theft of our sampling nets. All fish caught were identified, counted and measured to the nearest millimeter total length.

Table 3.1: Dimensions of gill nets used during experimental netting.

Net type	Stretched mesh (mm)	Length (m)	Depth (m)	Hanging ratio (%)	Buoyancy
"harder"	44-51	75	6	50	Positive
"galjoen"	145	60	2	60	Negative
"St Joseph"	178	75	3	60	Negative

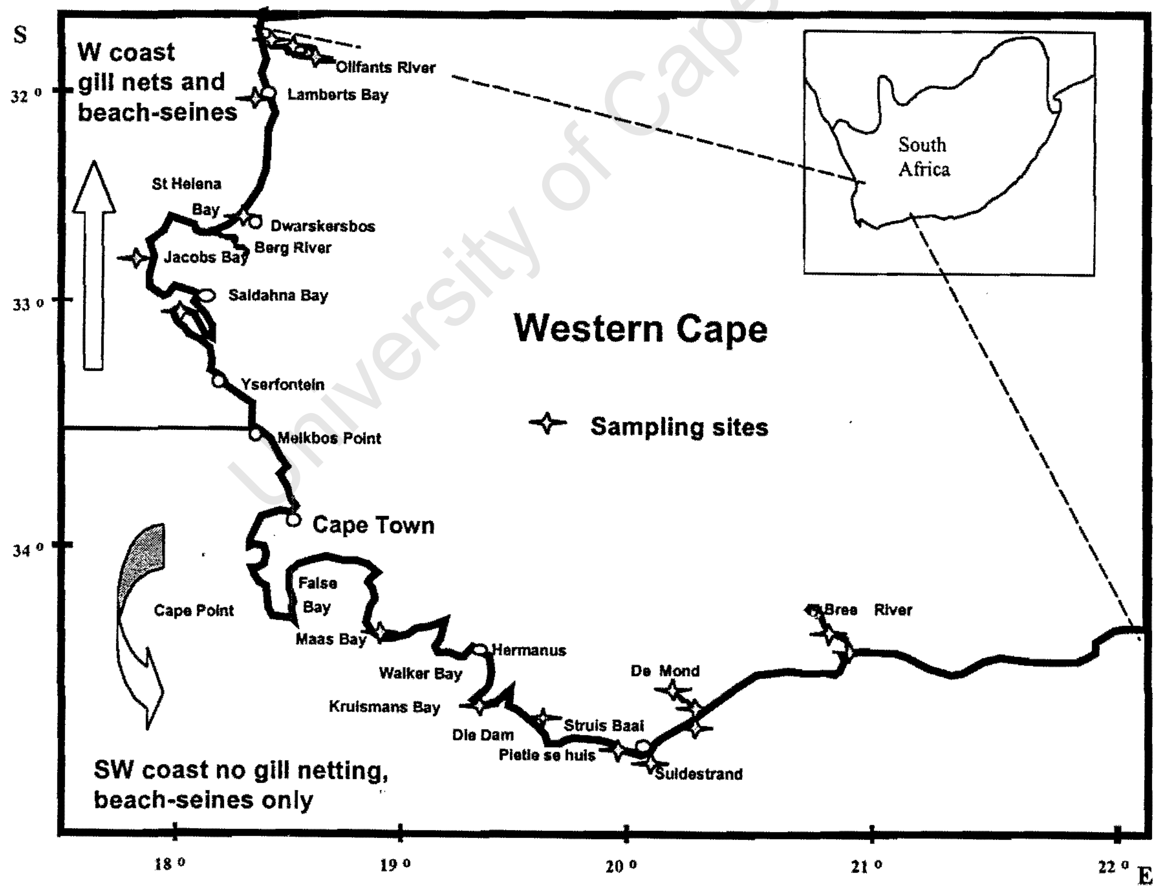


Figure 3.1: Map of the western Cape showing the study area and experimental netting sites.

Data analysis

Catch rates for all species caught in each net type in areas currently open to legal gill netting (West Coast estuaries and West Coast marine) and closed to gill netting (Southwest Coast estuaries and Southwest Coast marine) were calculated as:

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

Where c_i is the number of fish caught in the ith set and e_i is the soak time of the net for the ith set in hours. *Cpue* is thus expressed as number of fish.standard net-hour^{-1}.

The Kruskal-Wallis ANOVA by ranks (STATSOFT 1999) was used to test for significant differences in total (all species), target (mullet or St Joseph) and by-catch (all species excluding mullet and St Joseph) *cpue* between the four areas. When the Kruskal-Wallis test indicated significant differences between means, nonparametric multiple comparison tests (equations 11.26 & 11.27 in Zar 1996) were used to determine where significant differences in *cpue* occurred. Essentially this represents a univariate method where the full set of species caught were lumped together (total *cpue*), or certain species excluded (target and by-catch *cpue*), and the statistical tests were performed on the single variable. Although this provides a useful summary for management purposes, much more detailed information on the species responsible for differences in the catch composition and catch rates between areas can be obtained by the use of multivariate methods.

Multivariate methods based on triangular matrices of similarities between every pair of samples are commonly used for analysis of community structure between sites, at different times, or to assess the effects of pollutants or other impacts on communities (Clarke & Warwick 1994). These methods do not require data to be normally distributed or homoscedastic and are therefore ideally suited for the analysis of the catch data obtained during this study, with many fish species absent from most samples and highly variable in abundance when they were caught. Catch data for each net type from each of the regular sampling sites were grouped and transformed into catch rates (as above) to standardize for differing set times and to include in the analysis sets where no fish were caught. In order to assess any differences between diurnal and nocturnal catches, overnight sets made in the sea or in estuaries along the Southwest Coast were grouped separately. As the main aim of the study was to assess the potential impact of an expanding commercial or subsistence gill net fishery, which would have substantially greater effort levels than experimental netting, *cpue* data were root-root transformed. This transformation allows rare species, that were caught only occasionally during experimental netting, but are likely to be caught much more frequently in a commercial fishery, to make a greater contribution to the measure of similarity between samples (Clarke & Warwick 1994).

Using the Bray-Curtis similarity index (unweighted group-average method), similarities between samples (sites) were displayed on dendrograms and two-dimensional ordination plots, using Multi-Dimensional Scaling (MDS). Statistical differences in catch rates and composition between groups of sites, defined *a priori* as being representative of West Coast estuarine, West Coast marine (exploited sites) and Southwest Coast estuarine and marine (unexploited sites), were tested for by Analysis of Similarities (ANOSIM) (Clarke & Green 1988). The species primarily responsible for similarities within these groups and dissimilarities between groups were identified using Simper analysis (Clarke 1993). All of the above multivariate analyses were conducted using the CLUSTER, MDS, ANOSIM and SIMPER modules on the PRIMER computer package, version 4.0 (Plymouth Marine Laboratory, Plymouth, UK).

Results

3.1 Composition of experimental catches

(a) Marine sets

A total of 4 655 fish representing 40 species and 25 families were caught in 287 experimental gill net sets in the sea along the West and Southwest Coasts (Table 3.2). On the currently open West Coast, the legal target species *L. richardsonii* dominated the 48-51 mm net catches, numerically contributing 82.4 %. A further six species, hound shark *Mustelus mustelus* (6.4 %), maasbanker *Trachurus trachurus* (3 %), white stump *Rhabdosargus globiceps* (1.5 %), St Joseph shark *Callorhinchus capensis* (1.3 %), elf *Pomatomus saltatrix* (1 %) and strepie *Sarpa salpa* (1 %) contributed the majority of the by-catch. *Liza richardsonii* only contributed 43 % numerically to the 48 mm net catch along the currently closed Southwest Coast, with the most numerous by-catch species being *S. salpa* (25.5 %), *P. saltatrix* (10.9 %) and *R. globiceps* (5.9 %).

Table 3. 2: Summary of information on species composition and abundance of all fish caught in 287 gill-net sets (44-51 mm, 145 mm and 178 mm stretch mesh) along the southwest and west Cape coast (**marine environment**) during the period September 1997 to July 1999.

		Total Catch	S. W. Coast (marine)			W. Coast (marine)		
			48 mm	145 mm	178 mm	48 mm	145 mm	178 mm
OSTEICHTHYES			*Cpue:* fish.net-hour^{-1}					
Ariidae	*Galeichthyes feliceps*	53	0.38	0.01	0.01	0.07	< 0.01	
Carangidae	*Gnathanodon speciosus*	4	0.04					
	Trachurus trachurus	84	0.13			0.47		
Cheilodactylidae	*Chirodactylus brachydactylus*	5	0.02	< 0.01		< 0.01		
Clinidae	*Clinus superciliosus*	6	0.03			0.01		
Coracinidae	*Dichistius capensis*	159	0.14	0.58	0.12		0.08	
Gempylidae	*Thyrsites atun*	1					< 0.01	
Haemulidae	*Pomadasys olivaceum*	27	0.23					
Mugilidae	*Liza dumerilii*	2	0.01					
	Liza richardsonii	2 628	5.49			12.71		
	Liza tricuspidens	32	0.21					
Pomatomidae	*Pomatomus saltatrix*	340	1.39	0.10	0.06	0.15		
Sciaenidae	*Argyrosomus inodorus*	27	0.13	0.03	0.02	< 0.01		
	Umbrina canariensis	11	0.04	0.01	0.01			
Sparidae	*Diplodus sargus*	15	0.01	< 0.01		0.06		
	Diplodus cervinus	12	0.03	0.03				
	Lithognathus lithognathus	31	0.05	0.07	0.05			
	Rhabdosargus globiceps	150	0.76			0.23		
	Rhabdosargus holubi	2	0.01					
	Sarpa salpa	460	3.26			0.16		
	Sparadon durbanensis	30	0.02	0.03	0.11			
	Spondyliosoma emarginatum	3				0.02		
Soleidae	*Austroglossus microlepis*	3				0.04		
Triglidae	*Chelidonichthys capensis*	12				0.08	< 0.01	
Subtotal	Osteichthyes	4 097	12.37	0.86	0.37	14.02	0.11	0
No. of species		24	20	10	7	13	4	0
CHONDRICHTHYES								
Alopiidae	*Alopias vulpinus*	1					< 0.01	
Callorhinchidae	*Callorhinchus capensis*	84	0.01			0.20	0.35	0.39
Carcharhinidae	*Carcharhinus brachyurus*	1			< 0.01			
Dasyatidae	*Dasyatis chrysonata*	1			< 0.01			
Hexanchidae	*Notorynchus cepedianus*	2						0.03
Mylobatidae	*Myliobatis aquila*	103		0.03	0.13	0.01	0.21	0.59
	Pteromylaeus bovinus	4	0.01	< 0.01	0.01			
Odontospidae	*Carcharias taurus*	9		< 0.01	0.04			
Rajidae	*Raja straeleni*	10				0.04	0.03	< 0.01
Rhinobatidae	*Rhinobatos annulatus*	25	0.03	0.04	0.02	0.06	0.03	
Scyliorhinidae	*Haploblepharus edwardsii*	50	0.27		0.03			
	Haploblepharus pictus	13				0.09		
	Poroderma africanum	17	0.03	0.06		0.01		
Squalidae	*Squalus megalops*	1						< 0.01
Triakidae	*Mustelus mustelus*	197	0.01	0.05	0.09	0.98	0.32	0.20
	Triakis megalopterus	30	0.02	0.03	0.11			
Subtotal	Chondrichthyes	558	0.39	0.21	0.42	1.40	0.95	1.23
No of species		16	7	7	9	7	6	6
TOTAL	Overall	4 655	12.76	1.06	0.79	15.43	1.06	1.23
	No. of sets	287	63	46	49	59	40	30
	Minimum		0	0	0	0	0	0
	Maximum		186	11.5	16	2 448	8	13.33
	Average		21.34	1.45	1.34	54.74	1.14	1.32
	Standard error		4.28	0.35	0.40	41.37	0.34	0.40

The 145 mm net catch along the Southwest Coast was numerically dominated by osteichthyes, *D. capensis* (55 %), *P. saltatrix* (9.4 %) and white steenbras *Lithognathus lithognathus* (6.6 %). The most numerous species caught along the West Coast however were chondrichthyes, *Callorhinchus capensis*, (33 %), *M. mustelus* (30 %) and the stingray *Myliobatis aquila* (19.8 %).

The 178 mm net catch made along the Southwest Coast contained both osteichthyes and chondrichthyes with four species *D. capensis* (15 %), musselcracker *Sparadon durbanensis* (14 %), *M. aquila* (16 %) and gully shark *Triakis megalopterus* (14 %) making up nearly 60 % of the catch. No teleosts were caught in the 178 mm net on the West Coast. Numerically, the legal target species *Callorhinchus capensis* contributed 32 % of the total catch, whilst *M. aquila* (48 %) and *M. mustelus* (16 %) were the most common by-catch species.

In all mesh size nets, a total of 31 species were caught in sets along the currently closed Southwest Coast and 25 species on the open West Coast. Sixteen of the species caught in experimental sets in the sea occurred in catches along both coasts, 14 were caught only on the Southwest Coast, whereas nine were caught only on the West Coast (Table 3.2).

(b) Estuarine sets

Three thousand seven hundred and twenty-one fish representing 27 species and 14 families were caught in 257 experimental estuarine sets (Table 3.3). Species of the family Mugilidae dominated the 48-51 mm net catches in estuaries on both coasts. In the Olifants River estuary, the target species *L. richardsonii* numerically contributed 84 % to the 48-51 mm net catches and the most common by-catch species was flathead mullet *Mugil cephalus* (14 %). A further three species were caught in low numbers in the 48 mm net. *Liza richardsonii* numerically contributed 68 % of the total Southwest estuarine 48 mm net catch with three other mullet species *L. dumerilii, L. tricuspidens* and *M. cephalus* together contributing a further 21 %. Sixteen other species were caught in the 48 mm net sets in Southwest Coast estuaries, the most numerous being barbel *Galeichthyes feliceps*, leervis *Lichia amia*, spotted grunter *Pomadasys commersonnii*, moony *Monodactylus falciformis*, dusky kob *Argyrosomus japonicus*, Cape stump *R. holubi* and *L. lithognathus*.

Table 3.3: Summary of information on species composition and abundance of all fish caught in 257 gill-net sets (44-51 mm, 145 mm and 178 mm stretch mesh) in **estuaries** along the southwest and west Cape coast during the period September 1997 to July 1999.

			Cpue: fish.net-hour^{-1}					
		Total	S. W. Coast estuaries			W. Coast estuaries		
Net mesh size		Catch	48 mm	145 mm	178 mm	48 mm	145 mm	178 mm
OSTEICHTHYES								
Ariidae	*Galeichthyes feliceps*	27	0.41				0.02	
Carangidae	*Lichia amia*	61	0.53	0.04	0.10			
Clupeidae	*Sardinops sagax*	1				<0.01		
Cyprinidae	*Cyprinus carpio*	6	0.05	0.03				
Haemulidae	*Pomadasys commersonnii*	142	0.24	0.91	0.15			
Monodactylidae	*Monodactylus falciformis*	13	0.20					
Mugilidae	*Liza dumerilii*	418	4.31					
	Liza richardsonii	2 445	23.81			7.06		
	Liza tricuspidens	239	2.59	0.09	<0.01			
	Mugil cephalus	86	0.50	0.04		1.26	0.02	
	Myxus capensis	6	0.05					
Pomatomidae	*Pomatomus saltatrix*	9	0.04	<0.01		0.05	0.02	0.04
Sciaenidae	*Argyrosomus japonicus*	32	0.18	0.10	0.05			
Sparidae	*Diplodus sargus*	4	0.04					
	Diplodus cervinus	2	0.01	0.01				
	Lithognathus lithognathus	23	0.24	0.02	<0.01			
	Sparodon durbanensis	1		<0.01				
	Rhabdosargus globiceps	1	0.02					
	Rhabdosargus holubi	127	1.48					
	Sarpa salpa	5	0.05					
Subtotal	Osteichthyes	3 649	34.74	1.30	0.34	8.38	0.06	0.04
No. of species		20	18	10	5	4	3	1
CHONDRICHTHYES								
Dasyatidae	*Dasyatis chrysonota*	1			<0.01			
	Gymnura natalensis	1		<0.01				
Myliobatidae	*Myliobatis aquila*	11		0.02	0.10		0.02	
	Pteromylaeus bovinus	2			0.03			
Rhinobatidae	*Rhinobatos annulatus*	7	0.02	<0.01	0.04		0.02	
	Rhinobatos blochii	47					0.39	1.09
Scyliorhinidae	*Haploblepharus pictus*	3				0.05		
Subtotal	Chondrichthyes	72	0.02	0.04	0.17	0.05	0.43	1.09
No. of species		7	1	3	4	1	3	1
TOTAL	Overall	3 721	34.76	1.34	0.51	8.43	0.49	1.13
	No. of sets	257	91	53	44	40	23	6
	Minimum		0	0	0	0	0	0
	Maximum		1 008	14	6	76	4	13
	Average		51.05	1.60	0.62	10.21	0.38	3.01
	Standard error		11.97	0.40	0.20	2.75	0.19	2.08

The 145 mm net estuarine catch was numerically dominated by *P. commersonnii* (67 %) and *A. japonicus* (7.5 %) in Southwest Coast estuaries and by the bluntnose sandshark *Rhinobatos blochii* (79 %) in the Olifants River estuary. The 178 mm net Southwest Coast estuarine catch was numerically dominated by *P. commersonnii* (29 %), *L. amia* (19 %) and *M. aquila* (19 %). *Rhinobatos blochii* (96 %) dominated the 178 mm West Coast estuarine catch, although due to operating difficulties only six sets were made with this net in the Olifants River. In all nets combined, only nine by-catch species were caught in West Coast estuaries, although 12 additional species that are vulnerable to capture in the mesh size gill nets used during this study were previously recorded in the Berg (Bennett 1994) and Olifants estuaries (Lamberth & Whitfield 1997). In contrast, 22 by-catch species including at least 13 "linefish" species were caught in Southwest Coast estuaries during this study.

3.2 Univariate comparisons between areas

Due to fluctuating weather and oceanographic conditions, which affect both fish availability and the catch efficiency of the nets; catches made during experimental netting were highly variable, ranging from 0 - >2 000 fish per net-hour^{-1}. This resulted in *cpue* data that were not homoscedastic (Levene Test of Homogeneity of Variances, $p < 0.05$, STATSOFT 1999) or for some areas normally distributed (Normal Probability Plots STATSOFT 1999). A number of different data transformations, including logarithmic, square root, root-root and inverse, were conducted in an attempt to stabilize the variances and correct for non-normality. Although some of these transformations were moderately successful with respect to normality, none were successful in reducing variance heterogeneity. Day and Quinn (1989) caution against the use of standard nonparametric tests as a simple means to avoid the problem of variance heterogeneity, but do state that these tests are more robust than parametric tests in this regard. Zar (1996) recommends the non-parametric Kruskal-Wallis test, which may be more powerful for cases where the assumptions of a parametric ANOVA are not met.

(a) "Harder nets" (44-51 mm stretch mesh)

The relationship between total, target and by-catch *cpue* and the number of species caught in experimental gill net sets in the four areas sampled is shown in Figure 3.2. The number of species caught in 44-51 mm nets was greatest in Southwest Coast marine sets (27), similar in West Coast marine (20) and Southwest Coast estuarine sets (19) and lowest for West Coast estuarine sets (5). More chondrichthyian species were caught in West Coast estuarine and marine sets than in Southwest Coast sets.

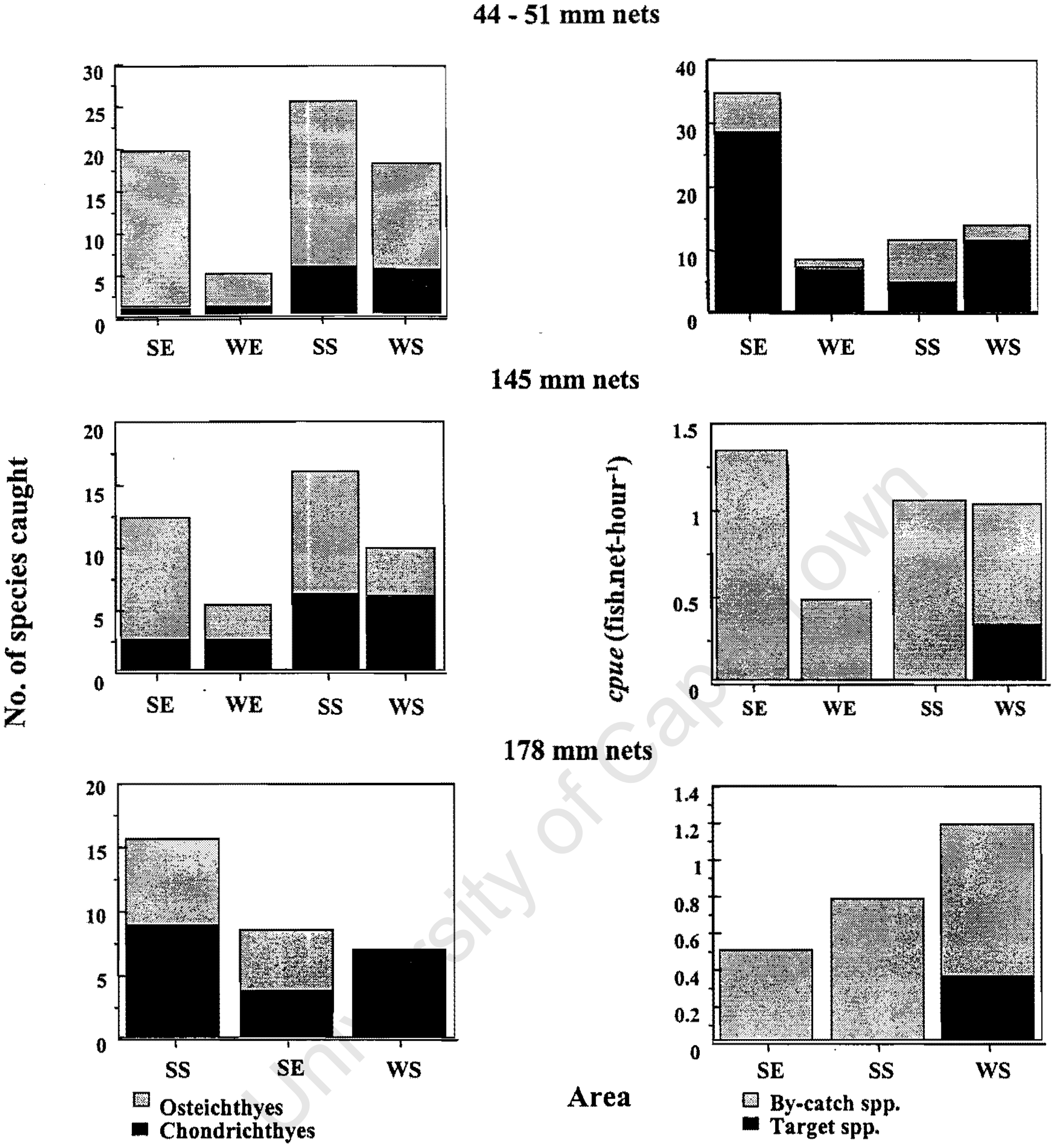


Fig. 3.2: Comparative number of species and *cpue* of target and by-catch species caught in 544 experimental gill net sets.

Areas are coded as:

SE = Southwest Coast estuaries - currently closed to all netting,

WE = West Coast estuaries – open to commercial gill netting by ± 185 permit holders,

WS = West Coast sea – open to commercial gill netting by ± 321 permit holders,

SS = Southwest Coast sea – 4 "experimental" gill net permits

Total cpue

The null hypothesis that total 44-51 mm net catch rates are the same in all four areas was rejected ($H_{3,\ 253}$ = 36.78, $p < 0.001$, Kruskal-Wallis test). Total *cpue* recorded in Southwest estuaries (34.76 fish.net-hour^{-1}) was significantly greater than that recorded in West Coast estuarine (8.43 fish.net-hour^{-1}) and marine sites (15.43 fish.net-hour^{-1}), but not significantly different to the total *cpue* recorded in the sea on the Southwest Coast (12.76 fish.net-hour^{-1}), (Table 3.4). No significant differences were found between total estuarine and marine *cpue* recorded on the West Coast or between West Coast and Southwest Coast marine sets. Total Southwest Coast marine *cpue* was, however, significantly greater than that recorded for West Coast estuaries (Table 3.4).

The results of the non-parametric multiple comparison tests appear inconsistent with the actual catch rates, calculated as the total number of fish caught divided by the total set time. This can be explained by the fact that the variables used for statistical tests are the ranks of the individual sets. Therefore, although the overall catch rate recorded for an area may be greater than in another, the mean rank may be less due to inconsistent large catches and many small or zero catches.

Target cpue

The null hypothesis, that target 44-51 mm catch rates are the same in all four areas was rejected ($H_{3,\ 253}$ = 17.044, $p < 0.001$, Kruskal-Wallis test). Target *cpue* recorded for Southwest Coast estuaries (28.12 fish.net-hour^{-1}) was significantly greater than that recorded for all other areas. No significant differences in target *cpue* were found between Southwest Coast marine (5.50 fish.net-hour^{-1}), West Coast marine (12.71 fish.net-hour^{-1}) and West Coast estuarine samples (7.06 fish.net-hour^{-1}), (Table 3.4).

By-catch cpue

The null hypothesis, that by-catch *cpue* is the same in all four areas was rejected ($H_{3,\ 253}$ = 43.844, $p < 0.001$, Kruskal-Wallis test). By-catch *cpue* recorded for Southwest Coast marine and estuarine sets (6.64 and 7.26 fish.net-hour^{-1} respectively) was significantly greater than that recorded for both West Coast marine and estuarine sets (2.71 and 1.37 fish.net-hour^{-1} respectively), but not significantly different from each other. West Coast marine by-catch *cpue* was significantly greater than that recorded for West Coast estuaries (Table 3.4).

Table 3.4: Results of the multiple comparison tests between 44-51 mm net total, target and by-catch *cpue* recorded for four different areas of the Southwest Cape Coast.
Bold font indicates significant statistics

Comparison	Total *cpue*		Target *cpue*		By-catch *cpue*	
	Q statistic	P value	Q statistic	P value	Q statistic	P value
SW estuarine vs. W estuarine	**5.33**	**P < 0.001**	**3.16**	**P < 0.01**	**5.25**	**P < 0.001**
SW estuarine vs. W marine	**4.54**	**P < 0.001**	**3.30**	**P < 0.01**	**2.71**	**P < 0.05**
SW estuarine vs. SW marine	2.49	P > 0.05	**2.85**	**P < 0.05**	0.99	P > 0.05
SW marine vs. W estuarine	**2.98**	**P < 0.02**	0.64	P > 0.05	**5.72**	**P < 0.001**
SW marine vs. W marine	1.93	P > 0.05	0.47	P > 0.05	**3.40**	**P < 0.005**
W marine vs. W estuarine	1.24	P > 0.05	0.22	P > 0.05	**2.64**	**P = 0.05**

(b) "Galjoen" nets (145 mm stretch mesh)

The use of this mesh size net has been illegal since 1984 and as such there is no legal target species, although the colloquial name for the net type indicates the former target species. As with the 48-51 mm nets, a greater number of species were caught in Southwest Coast estuarine and marine sets (13 and 17 respectively) than in West Coast estuarine and marine sets (6 and 10 respectively), (Fig. 3.2). Total *cpue* was similar for marine sets on both coasts, but separation of *C. capensis* catches, the legal target species for the 178 mm net fishery, shows that the catch rate of other species is greater along the Southwest Coast. *Cpue* recorded for Southwest Coast estuarine sets was nearly three times that recorded in West Coast estuaries.

The null hypothesis, that 145 mm net by-catch rates are the same in all four areas was rejected (Kruskal-Wallis test: $H_{3,\ 162} = 16.48$, $p < 0.001$, STATSOFT 1999). Non-parametric multiple comparison testing indicated that Southwest Coast marine by-catch *cpue* is significantly greater than that recorded for West Coast estuarine and marine sets (Table 3.5). No significant differences in by-catch rates were found for pairwise comparisons between the other areas.

(c) "St Joseph" nets (178 mm stretch mesh)

As only six sets were made with 178 mm nets in West Coast estuaries, this area was excluded from further analysis. Many more species, particularly teleosts, which were absent from West Coast marine catches, were caught in the 178 mm nets during experimental netting in Southwest Coast marine and estuarine habitats. (Fig. 3.2). The target species *Callorhinchus capensis*, was only caught in sets made along the West coast.

Table 3.5: Results of pairwise comparisons between 145 mm net by-catch *cpue* recorded in different areas. **Bold font indicates significant statistics.**

Comparison	Q statistic	Probability value	Conclusion
SW estuarine vs. W estuarine	2.48	$P > 0.05$	Accept H_0
SW estuarine vs. W marine	2.28	$P > 0.05$	Accept H_0
SW estuarine vs. SW marine	0.71	$P > 0.05$	Accept H_0
SW marine vs. W estuarine	**2.99**	**$P < 0.02$**	**Reject H_0**
SW marine vs. W marine	**2.87**	**$P < 0.05$**	**Reject H_0**
W marine vs. W estuarine	0.54	$P > 0.05$	Accept H_0

The null hypothesis, that total 178 mm net *cpue* is the same in all four areas was accepted (Kruskal-Wallis test: $H_{2,\ 123} = 4.53$, $p > 0.05$, STATSOFT 1999). By-catch (excluding *Callorhinchus capensis*) *cpue* did, however, differ significantly between areas (Kruskal-Wallis test: $H_{2,\ 123} = 8.07$, $p < 0.05$, STATSOFT 1999). Post-hoc pairwise comparisons indicated that Southwest marine by-catch *cpue* was significantly different from that recorded for West Coast marine sets ($Q = 2.34$, $p < 0.05$).

3.3 Multivariate comparisons between areas

(a) "Harder nets" (44-51 mm stretch mesh)

Based on similarities in the 44-51 mm net catch rate and composition, cluster analysis separated the 18 sampling sites into three major groups and three outliers at the arbitrary 50 % level of similarity (Fig. 3.3). The top group comprised exclusively the Southwest estuarine sites in the Breede and De Mond Rivers. The middle group included the three Olifants River sites (West Coast estuarine) closely linked to one West Coast marine site (Lamberts Bay) and less closely linked to one Southwest Coast marine site (Kruismans Bay). Catches at these five sites were dominated by *L. richardsonii*, caught at a similar rate (3-7 fish.net-hour^{-1}) with only 1-3 by-catch species caught at low rates. The lower group was composed of exclusively Southwest Coast marine sites and included the combined overnight sets made in this area. The three outliers were all West Coast marine sites.

The separation of sampling sites on the two-dimensional ordination plot by MDS analysis agreed closely with the grouping pattern of the dendrogram (Fig. 3.3). This suggests that both methods are adequate representations of the actual similarities between sites, despite the moderate level of stress (0.15) for the MDS plot. The three West Coast marine sites that were outliers in the dendrogram form a loose group in the MDS ordination and of interest is the close placement of the Saldanha Bay site (12), a sun warmed embayment/lagoon on the West Coast, to the Southwest Coast marine sites.

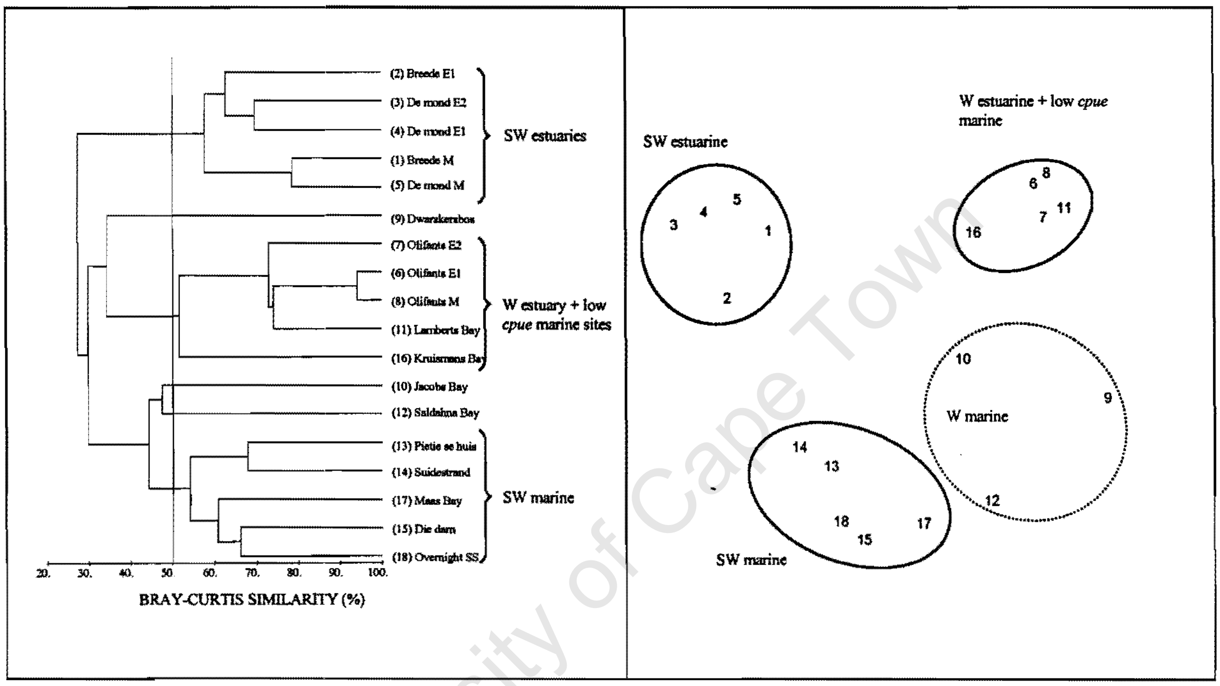


Fig. 3.3: Dendrogram and MDS ordination showing similarities between sites based on the composition and catch rates of fish species in experimental 44-51 mm gill net sets. Groups of sites identified at the 50 % level of similarity in the dendrogram are circled with solid lines and the West Coast marine sites that were outliers in the dendrogram are circled with a dotted line in the ordination plot. MDS plot stress = 0.15.

A one way ANOSIM rejected the null hypothesis that there are no significant differences in the experimental 44-51 mm net catch rates and composition between the groups of sites defined *a priori* as been representative of the four different areas (Global R = 0.773, P < 0.05). Multivariate pairwise tests indicated significant differences between all areas except between groups of sites from the two currently exploited West Coast marine and estuarine areas (Table 3.6).

Table 3.6: Results of the multivariate pairwise tests between groups of sites from the four areas where experimental 44 – 51 mm gill net sets were made.

Comparison	Significance level (%)	Conclusion
SW estuarine vs. W estuarine	1.8	Reject H_o
SW estuarine vs. W marine	0.8	Reject H_o
SW estuarine vs. SW marine	0.2	Reject H_o
W estuarine vs. W marine	22.9	Accept H_o
W estuarine vs. SW marine	1.2	Reject H_o
W marine vs. SW marine	1.9	Reject H_o

The SIMPER program was used to calculate the contribution of each species to the average dissimilarity between the *a priori* defined groups of sites from each area that were found to be significantly different by ANOSIM. The low catch rates and few by-catch species caught at West Coast estuarine sites are the main causes of dissimilarity between this area and sets made in the Southwest estuarine and marine sites. Much (> 60 %) of the dissimilarity between Southwest Coast estuarine sets and marine sites on both coasts is due to large catches of estuarine opportunist and/or dependent species (e.g. *L. dumerilii, L. amia, L. tricuspidens, R. holubi, P. commersonnii, M. cephalus* and *L. lithognathus*) and the absence of, or low catches of, more marine-associated species such as *S. salpa, R. globiceps, A. inodorus, T. trachurus* and *P. olivaceum* in estuaries (Wallace *et al.* 1984, Smith & Heemstra 1986). The top five species responsible for over 30 % of the dissimilarity between West Coast and Southwest coast marine sites occurred in sets made on both coasts (Table 3.7, see p. 110). It is a combination of differences in catch rates and presence or absence that is responsible for the dissimilarity between these two areas.

(b) "Galjoen" nets (145 mm stretch mesh)

The grouping of samples into sites was done slightly differently to the 44-51 mm net site grouping. An extra "site" of overnight sets that were made in the De Mond estuary was created, Olifants River sets were grouped into only two sites, rather than three, and one West Coast marine site, Jacobs Bay, was excluded as no fish were caught in the 145 mm net at this site. Cluster analysis separated the 17 sampling sites into four major groups at the arbitrary 25 % level of similarity (Fig. 3.4). These four groups correspond to the four *a-priori* defined areas and are also reflected in the two-dimensional ordination plot derived by MDS analysis. In the ordination plot, West Coast marine sites are less tightly grouped than sites from the other areas, and the Saldanha Bay site is once again situated closest to the Southwest Coast marine group. The low stress value for the MDS ordination and the similar grouping of sites in the dendrogram and ordination plot suggests that both methods are valid representations.

The one way ANOSIM test indicated significant differences between the *a priori* defined groups of sites (Global R = 0.975, $p < 0.05$). The results of the multivariate pairwise comparison tests are shown in Table 3.8. In contrast to the results of the pairwise comparisons of the univariate by-catch *cpue*, where only Southwest Coast marine sets were found to be significantly different to West Coast sets, multivariate testing showed Southwest Coast marine and estuarine groups to be significantly different from each other and from West Coast marine and estuarine groups. West Coast marine and estuarine groups were not significantly different from each other at the 5 % level. This is, however, due to insufficient replicates in these two habitats, resulting in too few permutations used in the ANOSIM procedure to resolve differences at less than the 10 % level. The clear separation of these two groups in the MDS ordination plot and the obvious lack of overlap in catch composition suggests that the catches from these two areas are indeed different.

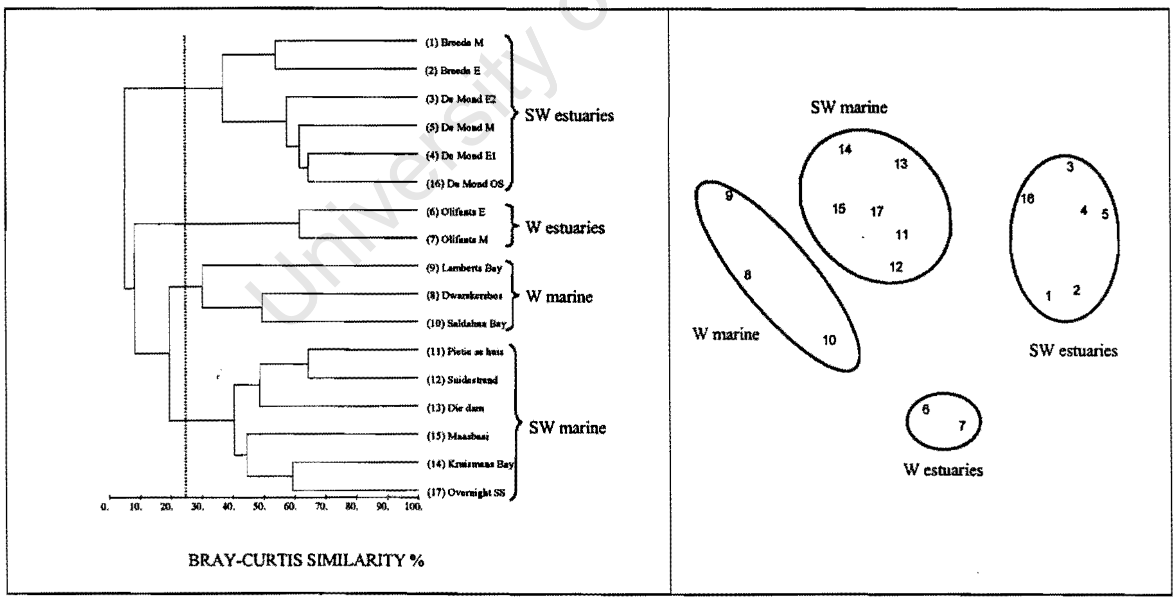


Fig: 3.4: Dendrogram and MDS ordination showing similarities between sites based on the composition and catch rates of fish species in experimental 145 mm gill net sets. Groups of sites identified at the 25 % level of similarity in the dendrogram are circled in the ordination plot. MDS plot stress = 0.09.

Table 3.8: Results of multivariate pairwise tests between groups of sites from the four areas where experimental 145 mm gill net sets were made.

Comparison	Significance level (%)	Conclusion
SW estuarine vs. W estuarine	3.6	Reject H_o
SW estuarine vs. W marine	1.2	Reject H_o
SW estuarine vs. SW marine	0.2	Reject H_o
W estuarine vs. W marine	10	Accept H_o
W estuarine vs. SW marine	3.6	Reject H_o
W marine vs. SW marine	1.2	Reject H_o

The average *intra*-group similarity calculated by the SIMPER program, ranged from 36.7 % (West Coast marine) to 47.3 % (Southwest estuarine). The average similarity for the two Olifants River sites was higher, 61.6 %, but only one species (*R. blochii)* was caught at both sites. Estuarine opportunists (Wallace *et al.* 1984), *P. commersonnii* (63 %), *L. tricuspidens* (12.5 %) and *M. cephalus* (6.6 %) were responsible for more than 80 % of the average similarity within the Southwest estuary group. *Callorhinchus capensis* (52.3 %), *D. capensis* (19.7 %) and *M. mustelus* (17.3 %) contributed 89.3 % to the average similarity within the West Coast marine group. Similarity within Southwest coast marine group was largely due to catches of *D. capensis* (43.9 %), *L. lithognathus* (18.6 %) and *D. cervinus* (7.8 %).

Average dissimilarity between groups (80.5-98.5 %) was much greater than the *intra*-group similarity. Once again, dissimilarity between the Southwest estuarine group and the marine groups from both coasts was largely due to catches of estuarine dependants or opportunists, such as *P. commersonnii*, *L. tricuspidens* and *A. japonicus,* and the absence of marine species such as *D. capensis, C. capensis* and *M. mustelus* in estuaries (Wallace *et al.* 1984, Smith & Heemstra 1986). Dissimilarity between West Coast and Southwest Coast marine groups was mostly due to the absence of particular species in one of the areas (Table 3.7). Of the top 12 species that contribute 80.8 % to the dissimilarity between these two groups, five were caught only in Southwest Coast experimental sets (although two, *L. lithognathus* and *A. inodorus,* have been recorded in West Coast commercial gill net landings), whilst three only occurred in West Coast sets (Chapter 1).

(c) "St Joseph" nets (178 mm stretch mesh)

Cluster analysis separated the 15 sampling sites (178 mm net sets were grouped into fewer sites to achieve similar sampling effort at each site) into four major groups at the 20 % level of similarity (Fig. 3.5). West Coast marine sites separated into two groups of two sites each, with the more exposed Jacobs Bay and Lambert's Bay sites grouping separately from the more sheltered, relatively warmer water Dwarskersbos and Saldanha Bay sites. Southwest Coast marine and estuarine sites once again formed cohesive groups and the six sets that were made in the Olifants River grouped out separately. As with the other mesh size nets, overnight sets made at marine sites along the Southwest Coast linked to the sites where only daytime sets were made, suggesting no significant differences between nocturnal and diurnal sets. The grouping of sites in the dendrogram was mirrored in the two-dimensional ordination derived by MDS analysis, with the "warm water" West Coast marine group been placed closest to the Southwest Coast marine group (Fig. 3.5).

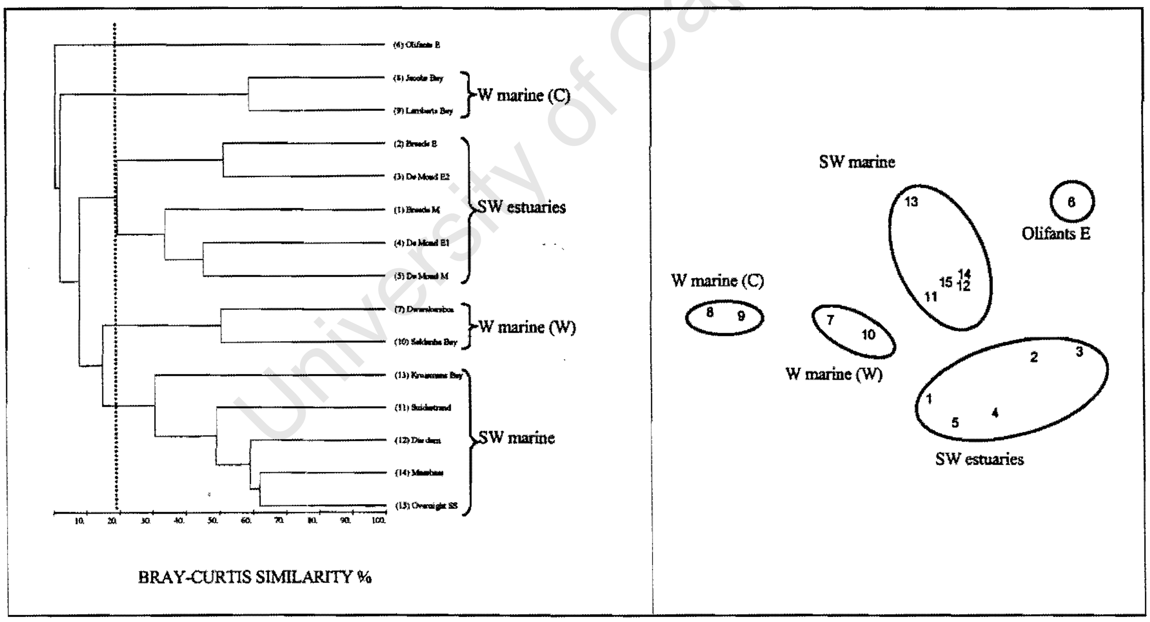


Fig. 3.5: Dendrogram and MDS ordination showing similarities between sites based on the composition and catch rates of fish species in experimental 178 mm gill net sets. Groups of sites identified at the 20 % level of similarity in the dendrogram are circled in the ordination plot. MDS plot stress = 0.04. (C): "cold water" sites, (W): warm water.

A one way ANOSIM test indicated significant differences in catch rates and composition between the *a priori* designated Southwest marine, estuarine and West Coast marine areas (Global R = 0.975, $p < 0.05$). The West Coast estuarine group was excluded from testing as sampling with the 178 mm net was only conducted at one site. Multivariate pairwise tests showed significant differences ($P < 0.01$) between all three areas.

The average *intra*-group similarity for the three areas, calculated by the SIMPER program, was low, 28.2 % for the Southwest estuarine group, 27.2 % for the West Coast marine group and 45 % for the Southwest marine group. Once again, estuarine opportunists, *P. commersonnii* (51.6 %), *L. amia* (24.4 %) and *A. japonicus* (8.8 %) were responsible for more than 80 % of the average similarity within the Southwest estuary group (Wallace *et al.* 1984, Griffiths 1997a). The legal target species, *C. capensis* (47.7 %), and a common by-catch species, seven-gilled cow shark *Notorynchus cepidianus* (36.2 %) contributed 83.9 % to the average similarity within the West Coast marine group. Similarity within Southwest Coast marine group was largely due to catches of *T. megalopterus* (31.6 %), *D. capensis* (16.1 %), *M. aquila* (15.5 %) and *S. durbanensis* (7.8 %).

Average dissimilarity between the Southwest estuarine group and the Southwest (90.7 %) and West Coast (97.6 %) marine groups is again due to the presence of estuarine opportunists and the absence of marine species, particularly chondrichthyes such as *C. capensis, N. cepedianus, M. mustelus* and *T. megalopterus* in estuaries. Of the nine species collectively responsible for 78 % of the dissimilarity between Southwest and West Coast marine groups (Table 3.7), five were caught only along the Southwest Coast, although none of these is limited in distribution to the east of Cape Point (Smith & Heemstra 1986). The two species that were caught solely in the West Coast sets, *C. capensis* and *N. cepedianus,* do occur along both coasts (Smith & Heemstra 1986).

Table 3.7: Breakdown of average dissimilarity between Southwest Coast (SS) and West Coast (WS) marine gill net catches into contributions of the top species, in order of decreasing contribution. $\check{S}i$ is the average contribution of the *i*'th species to the dissimilarity between the areas, and Cum $\check{S}i$ % the cumulative percent contribution to the total dissimilarity.

Species	Ave. SS *cpue*	Ave WS *cpue*	$\check{S}_i$	Cum $\check{S}i$ %
44 –51 mm nets				
Sarpa salpa	3.89	0.25	6.36	9.84
Rhabdosargus globiceps	1.10	0.29	3.84	15.78
Pomatomus saltatrix	1.70	0.19	3.62	21.38
Trachurus trachurus	0.16	0.72	3.31	26.50
Liza richardsonii	7.47	16.62	3.09	31.28
Haploblepharus pictus	/	0.13	2.81	35.62
Argyrosomus inodorus	0.19	0.01	2.65	39.72
Haploblepharus edwardsii	0.16	/	2.46	43.52
Pomadasys olivaceum	0.18	/	2.43	47.29
Chelidonichthys capensis	/	0.70	2.35	50.92
Dichistius capensis	0.10	/	2.34	54.54
Raja straeleni	/	0.05	2.21	57.96
Liza tricuspidens	0.26	/	2.20	61.36
145 mm nets				
Callorhinchus capensis	/	0.54	11.4	14.20
Dichistius capensis	0.95	0.10	7.41	23.40
Mustelus mustelus	0.01	0.46	7.40	32.59
L. lithognathus	0.06	/	6.32	40.43
Myliobatis aquila	0.03	0.28	5.36	47.09
Rhinobatos annulatus	0.08	0.04	4.89	53.16
Poroderma africanum	0.05	/	4.67	58.97
Raja straleni	/	0.05	4.41	64.45
Diplodus cervinus	0.04	/	4.18	69.64
Sparadon durbanensis	0.03	/	3.20	73.61
Argyrosomus inodorus	0.04	/	3.09	77.45
178 mm nets				
Triakis megalopterus	0.14	/	12.69	13.73
Dichistius capensis	0.28	/	10.22	24.78
Callorhinchus capensis	/	0.43	10.14	35.74
Myliobatis aquila	0.13	0.93	10.05	46.61
Mustelus mustelus	0.05	0.28	7.70	54.93
Sparadon durbanensis	0.12	/	7.66	63.21
Notorynchus cepedianus	/	0.03	6.05	69.76
Lithognathus lithognathus	0.05	/	4.33	74.44
Argyrosomus inodorus	0.03	/	3.50	78.23

3.4 Size frequency distributions of experimental catches

The size frequency distributions of the legal target species *L. richardsonii* caught during experimental gill netting around the coast are shown in Figure 3.6. Significant differences were found between the average size fish caught in the different regions (ANOVA, $p < 0.05$). The average size *L. richardsonii* caught in estuaries and the sea on the West Coast, where netting is intensive, was significantly smaller than the average size fish caught in the sea along the Southwest Coast, where only limited beach-seining takes place (Tukey HSD test,). *Liza* *richardsonii* caught in estuaries along the Southwest Coast, where no legal netting takes place, were larger than the fish caught in all other regions (Fig. 3.6). A greater range in the size of fish caught in Southwest Coast estuaries was observed, probably due to the capture of a combination of small fish that had recently migrated into the estuary and larger fish, that had been resident for some time.

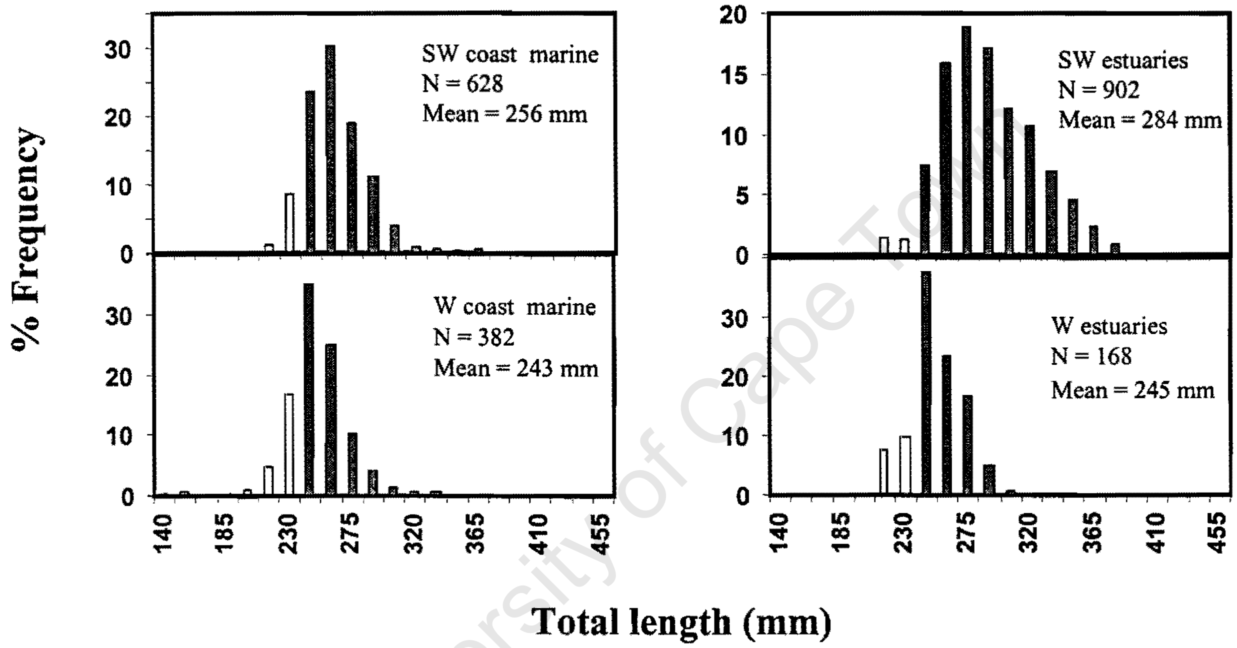


Fig: 3.6: Size frequency distributions of harders *Liza richardsonii* caught in 48 mm experimental gill nets in different regions. Unshaded bars represent immature fish (De Viliers 1987).

Length frequency distributions for the more commonly caught linefish by-catch in experimental gill net sets in the sea along both the West and Southwest coasts are shown in Figure 3.7. For all species that occurred in sets on both coasts, the average size of fish caught on the West Coast was significantly smaller (t-test, $p < 0.05$) than the average size caught on the Southwest Coast (Fig. 3.7).

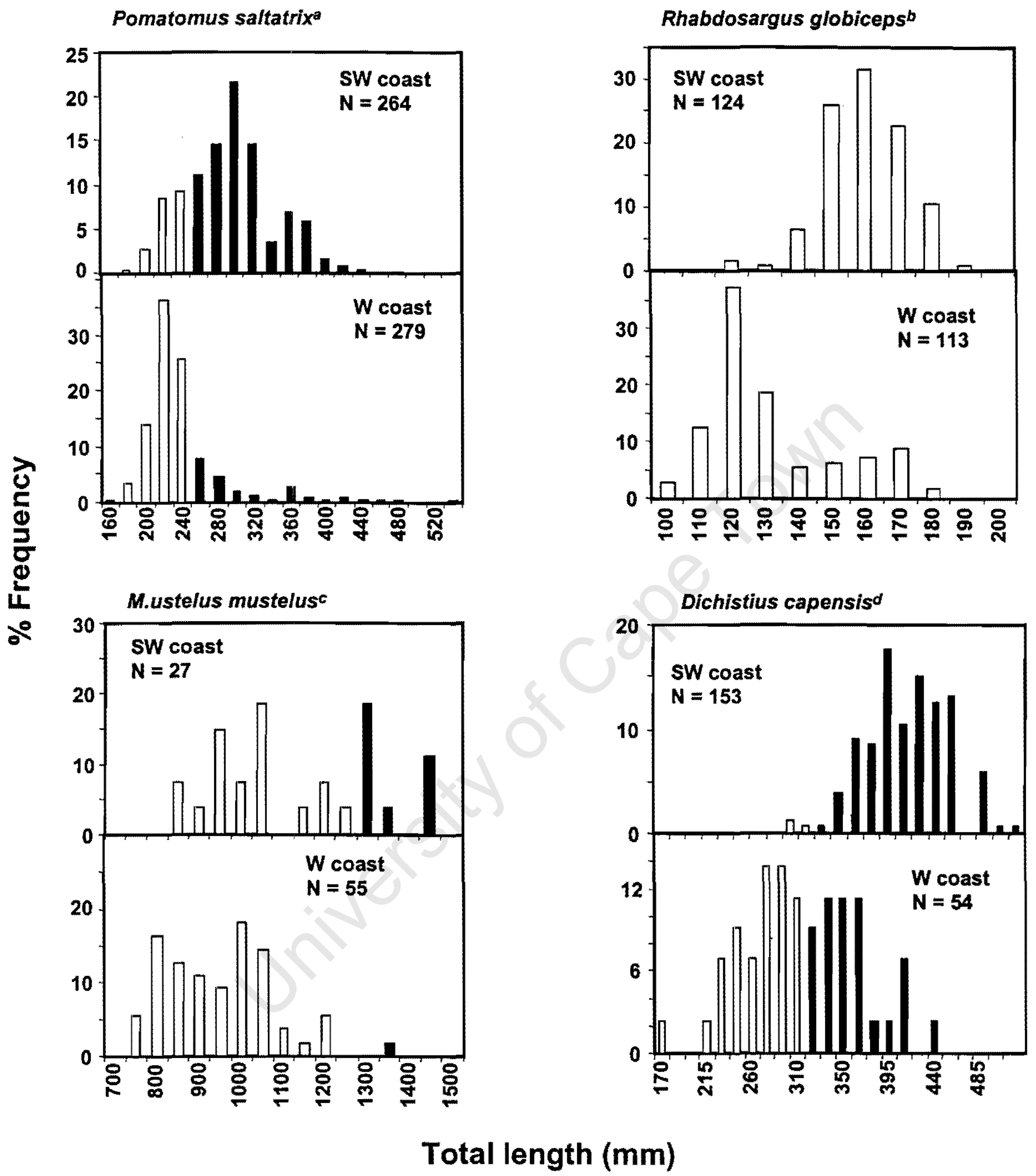


Fig. 3.7: Comparative size frequency distributions of gill net by-catch along the West and Southwest coasts. Unshaded bars represent fish < TL 50 % maturity. a. van der Elst (1976), b.Talbot (1955), c. Smale & Compango (1997), d. Bennett & Griffiths (1986)

Length frequency distributions of species that were caught in estuaries and the sea along the Southwest Coast only are shown in Figure 3.8. With the exception of *P. saltatrix, D. capensis, S. durbanensis* and *P. commersonnii* caught on the Southwest Coast, the majority of the gill net by-catch comprised immature fish. This is partly a result of the size selectivity of the small mesh harder nets, but also reflects the importance of the inshore surf zone and estuaries as nursery areas for many species.

3.5 Comparative catch rates of shore anglers and experimental gill nets

Gill nets, unlike beach-seines and trawls, can be set over shallow rocky substrata and catch fish that can usually only be exploited by line or spear fishing. Catch rates of line-fish species in experimental gill net sets in the sea and estuaries were substantially greater than those made by recreational shore anglers along the Southwest Coast (Table 3.9). Gill nets are far more efficient at catching many vulnerable and overexploited fish species than line or spear-fishers are, but can still be worked easily by one or two people. Based on the relative catch rates of gill nets and line-fishers, each net permit issued for the Southwest coast will have an overall impact on line-fish species roughly equivalent to that of twenty-one anglers.

Table 3.9: Comparison of experimental gill net and shore angler catches for linefish species. *Species caught exclusively in estuaries marked with an asterisk. Shore and estuarine angler catch rates from Lamberth (1997), National Linefish Survey.

Family	Species	Common name	W. coast gill net *cpue*	SW. coast gill net *cpue*	SW. coast angler *cpue*
			Fish. net-hour $^{-1}$		Fish.angler-hour $^{-1}$
OSTEICHTHYES					
Carangidae	*Lichia amia**	Garrick	/	0.23	0.064
Coracinidae	*Dichistius capensis*	Galjoen	0.08	0.58	0.040
Haemulidae	*Pomadasys commersonnii**	Spotted grunter	/	0.47	0.210
	Pomadasys olivaceum	Piggy	/	0.23	0.004
Mugilidae	*Liza tricuspidens**	Striped mullet	/	2.59	0.002
	*Mugil cephalus**	Flathead mullet	0.74	0.28	0.034
Pomatomidae	*Pomatomus saltatrix*	Elf	0.15	1.39	0.140
Sciaenidae	*Argyrosomus inodorus*	Silver kob	<0.01	0.13	0.012
	*Argyrosomus japonicus**	Dusky kob	/	0.12	0.010
	Umbrina spp.	Belman	/	0.04	0.004
Sparidae	*Diplodus sargus*	Dassie	0.06	0.01	0.010
	Diplodus cervinus	Wildeperd	/	0.03	0.003
	Lithognathus lithognathus	White steenbras	/	0.07	0.010
	Rhabdosargus globiceps	White stump	0.23	0.76	<0.001
	*Rhabdosargus holubi**	Cape stump	/	1.48	0.007
	Sarpa salpa	Strepie	0.16	3.26	0.009
	Sparadon durbanensis	Musselcracker	/	0.11	0.002
CHONDRICHTHYES					
Scyliorhinidae	*Poroderma africanum*	Pyjama shark	0.01	0.06	<0.001
Triakidae	*Mustelus mustelus*	Houndshark	0.60	0.05	0.005
	Triakis megalopterus	Spotted gullyshark	/	0.11	0.004
OVERALL *CPUE*			2.03	12.00	0.57

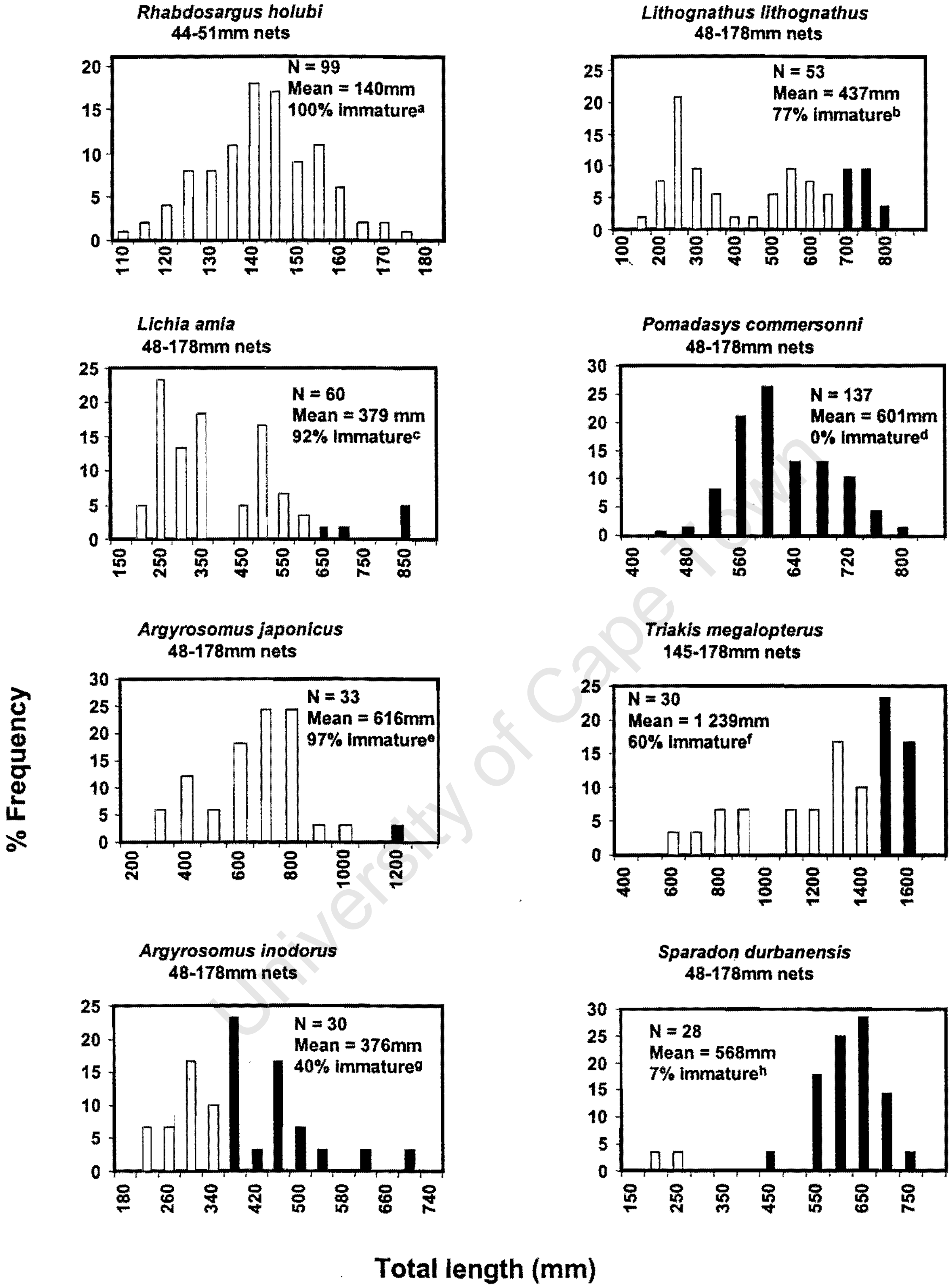


Fig. 3.8: Length frequency distributions of by-catch species caught in estuaries and the sea along the Southwest Coast only. Unshaded bars represent fish < TL 50 % maturity. a. Day *et al.* (1981), b. Bennett (1993[a]), c. van der Elst (1988), d. Wallace (1975), e. Griffiths (1996), f. Goosen (1997), g. Griffiths (1997b), h. Clarke (1988)

Discussion

Numerous applications for gill net permits along the Southwest Coast have been received in recent years (Lamberth 1998). The South African government agency charged with marine resource management, Marine and Coastal Management (MCM) also recently invited applications for gill net permits from subsistence fishers around the entire coast (S. J. Lamberth pers. comm.) There are several advantages in using fishery independent experimental netting, rather than issuing "experimental" permits to aspirant fishers, in order to assess the potential impacts of an expanding gill-net fishery in the Western Cape. The monitoring and control of a commercial scale experimental gill net fishery in the area would be extremely difficult. Furthermore, the issue of experimental permits could create a precedent and high future expectations amongst applicants that gill netting will be allowed along the Southwest Coast (Kyle 1999). On the other hand, commercial fishers develop extensive local knowledge and expertise and are likely to be far more efficient at maximizing the harvest of target species than researchers. This may result in experimental catch data that are not representative of commercial catches (Bronte & Johnson 1984, Quinn 1988).

Commercial West Coast gill net catch composition was similar to that obtained during experimental netting in the same area. Only seven by-catch species that were recorded in low numbers in commercial landings were not present in experimental catches (Chapter 1). Overall catch rates (all species) for commercial operations were much greater (3.6 – 5.4 times) than those recorded for experimental netting (Chapter 1). Commercial fishers are usually only active during favorable weather conditions, or during times of known fish abundance. Experimental netting on the other hand was conducted bi-monthly at each site, even during obviously unfavorable conditions which resulted in catches that were highly variable. Experimental *cpue* recorded under fair conditions was, however, similar to, or in some cases even exceeded that made by commercial fishers active at the same time. Maximum experimental *cpue* should therefore be regarded as the real catch potential of gill nets under fair conditions. The differences between commercial and experimental catch rates do not affect the validity of comparisons made between experimental catches in the different areas. It should simply be noted that if a commercial gill-net fishery is allowed to develop along the Southwest Coast, the number of species caught and particularly catch rates are likely to be greater than the average recorded during experimental netting.

For all net types used, more species were caught in estuaries and the sea on the Southwest Coast than on the currently open West Coast. Although total and target *cpue* for most mesh sizes were not significantly different between areas, the catch rates of by-catch species were significantly greater along the Southwest Coast. With the exception of juvenile snoek *Thyrsites atun,* the other species that were caught exclusively on the West Coast are currently of little or no importance to other sectors (Penney *et al.* 1989, van der Elst & Adkin 1991). At least nine of the species, including *Umbrina spp., D. cervinus, S. durbanensis, L. lithognathus, R. holubi, L. amia, A. japonicus, P. commersonnii* and *T. megalopterus*, that were caught exclusively on the Southwest Coast are highly sought-after by recreational anglers and spearfishers (Wallace *et al.* 1984, van der Elst 1988, 1989, van der Elst & Adkin 1991, Brouwer *et al.* 1997, Mann *et al.* 1997a). Furthermore, catch rates of species important to the commercial or recreational line fisheries, such as *A. inodorus, D. sargus, D. capensis, P. saltatrix, R. globiceps* and *S. salpa,* were substantially greater along the Southwest Coast than on the West Coast.

A new management protocol for South African linefish, based on quantitative stock assessments and the use of biological reference points for each species is currently being implemented (Griffiths *et al.* 1999). The new protocol requires that urgent management action is taken to reduce fishing effort on stocks that are considered to be over-exploited (spawner biomass-per-recruit level, estimated at 25-39 % of pristine) or collapsed (< 25 % $SB/R_{F=0}$) (Griffiths *et al.* 1999). In the absence of quantitative stock assessment data, several alternative stock status indicators, such as declining *cpue,* or species proportion in catch composition, changes in sex-ratio, or public concern over declining catches may be used (Griffiths *et al.* 1999).

The stocks of three species, *L. lithognathus, A. japonicus* and *A. inodorus*, that were caught in experimental gill net sets predominantly or exclusively along the Southwest Coast, are regarded as collapsed (Bennett 1993a, Griffiths 1997a, 1997c). A management recommendation has been made that beach-seine fishers in False Bay should be prohibited from landing and selling *L. lithognathus* and recreational and commercial linefishers be restricted to a bag limit of one fish per permit holder per day (Lamberth 2000). Griffiths (1997c) specifically states that the development of beach-seine and gill net fisheries along the East Coast would be highly undesirable, given that a reduction of inshore fishing mortality is required for rebuilding the *A. japonicus* stocks. The stocks of a further two species that are vulnerable to capture in gill nets, *P. saltatrix* and the female portion of the *D. capensis* stock, are overexploited (Govender 1997, Bennett 1988). The gill net fishery for *D. capensis* on the West Coast was banned more than 15 years ago due to concerns over sustainability (Bennett 1988). Large scale illegal targeting of *D. capensis* still occurs along the West Coast (Chapter 1) and the development of any gill net fishery along the Southwest Coast will likely result in increased illegal targeting of this species. Long-term declines in *cpue* have been recorded for *P. olivaceum* in Natal (Mann *et al.* 1997b), *S. durbanensis* in the Southeast Cape (Brouwer 1997) and *R. globiceps* throughout its range (Griffiths 1999). An increase in fishing mortality for any of these species, which would occur if gill netting were permitted on the Southwest Coast, is contrary to current management objectives. Concern should not only be expressed over catches of species that are important to other sectors, but rather the ecological impacts of the fishery as a whole. Ecosystem effects of fishing include changes in fish community structure and trophic interactions that in turn may affect predator-prey interactions and algal and invertebrate communities (Jennings & Lock 1996). In light of the greater number of species vulnerable to capture and higher catch rates recorded along the Southwest Coast, an expansion of the gill net fishery would be a serious threat to ecological functioning and biodiversity in this region.

Estuaries are widely recognized as fulfilling an important "nursery" function for many fish species (Wallace *et al.* 1984, Bennett 1994). In South Africa, anthropogenic activities in catchment areas and estuaries have seriously degraded many of these systems, with the result that only 24 % of estuaries in the Cape are rated as being in a "good" condition (Heydorn 1989). Widespread estuarine degradation means that many species that utilize estuaries can be regarded as vulnerable (van der Elst & Adkin 1991). There has been some debate over the use of the term "estuarine-dependent" and "estuarine opportunist" is considered more appropriate to describe marine species whose juveniles utilize estuaries, but are also found in neighboring marine waters (Lenaton & Potter 1987, Potter *et al.* 1990). Wallace *et al.* (1984) divided South Africa's estuarine-associated fish fauna into six categories according to the degree of estuarine dependence. Of the 22 species that were caught in experimental gill net sets in Southwest Coast estuaries, eight (36 %) are entirely dependent (Category 2) and another two (9 %) are largely dependent (Category 3) on estuaries as juveniles. Furthermore, three of the Category 2 species, namely, *R. holubi*, *L. amia*, and *P. commersonnii* that were caught in Southwest Coast gill net sets are highly sought after recreational angling species (Wallace *et al.* 1984, van der Elst & Adkin 1991). The stocks of two other Category 2 species, *L. lithognathus* and *A. japonicus*, which are also important in angler and commercial catches, are considered collapsed (Bennett 1993a, Griffiths 1997c). As was found during this study, Ratte (1982) made substantial catches of juvenile linefish during a gill net survey of the Breede River and concluded that commercial exploitation may be detrimental to populations of angling fish. The development of a gill net fishery in Southwestern Cape estuaries, particularly a fishery using 44-51 mm mesh nets, which catch many juveniles, would seriously compromise the value of estuaries in the region as nursery areas for these species.

The nursery function of estuaries brings into question the practice on the West Coast where the only two permanently open estuaries in the Namaqua Marine Biogeographical Province (Olifants and Berg Rivers) are subject to intensive commercial gill net fishing pressure. Indeed, due to the higher proportion of estuarine-dependent species in these rivers, Bennett (1994) and Lamberth and Whitfield (1997) argue that West Coast estuaries may be more important to coastal fish than estuaries in other regions. Important recreational linefish such as *R. globiceps, P. saltatrix, A. inodorus, L. amia, R. holubi* and *L. lithognathus* have previously been recorded in surveys of these estuaries and anecdotal evidence suggests that substantial catches were made by fishers in the past (Day *et al.* 1981, Bennett 1994, Lamberth & Whitfield 1997). The fact that most of these species were not captured in West Coast estuarine sets during this study, but were captured in Southwest Coast estuaries, suggests reduced abundance in the former, possibly due to the high commercial gill net effort. The continued existence of commercial gill-net fisheries in West Coast estuaries is in conflict with the recommendation that estuaries throughout South Africa should not be zoned for commercial use (SAMLMA discussion document, March 1997, cited in Mann 1997).

In contrast, Kyle (1999) reports on the apparently successful transformation of an illegal gill-net fishery to a controlled, artisanal fishery in the Kosi Lakes, a large estuarine system in Northern Kwazulu Natal, and suggests that the approach could be replicated elsewhere. The author does, however, warn that circumstances are dissimilar elsewhere and the approach may not be successful. Several important differences exist between the Kosi Lakes situation and potential gill net fisheries in the Southwestern Cape. The Kosi Lakes are a large system of approximately 35 km^2, compared to the much smaller Southwestern Cape estuaries (Heydorn 1989). Gill netting is also only permitted in one of the lakes and fishers are prohibited from setting their nets in connecting channels or the estuary itself, which would interfere with fish spawning or recruitment migrations (Kyle 1999). Estuaries in the Southwest Cape, with the exception of the Bot River estuary near Hermanus, do not contain such large bodies of water and gill netting in these systems would seriously interfere with fish movement into or out of these systems.

Designated target species account for 85 % by numbers and 81 % by mass respectively of the total annual catch in the Kosi Lakes fishery and there is little overlap in catch composition, and hence potential for conflict, between gill netters and other fishing sectors (Kyle 1999). Most (90%) of the Kosi Bay catch comprised fish that were larger than the size at 50 % maturity and above the minimum size limits. Hence there is little problem in maintaining consistency with current legislation (Kyle 1999). Target species, *L. richardsonii* and *L. dumerilii,* numerically accounted for a similar proportion (81 %) of the total experimental gill net catch in Southwest Coast estuaries, but only approximately 33 % by mass. There is considerable overlap in Southwest Coast experimental gill net and shore angler catch composition and the potential for conflict between the two sectors is great. The majority of the Southwest Coast experimental gill net by-catch was made up of immature fish, well below the minimum legal size. These are often injured during entanglement and cannot be released alive. This creates a potential management problem, as any exemption granted to gill net fishers would cause resentment amongst other sectors that are expected to abide by the regulations.

The Kosi Lakes fishery was developed in consultation with, and is co-managed by, well-defined local communities and the nature reserve management authorities. The relationship between the fishers and the reserve authorities is good, and control and monitoring of the fishery is effective (Kyle 1999). A similar initiative to develop a legal subsistence gill net fishery in the nearby St Lucia Lakes has not been nearly as successful, largely due to a lack of cooperation from the fishing communities and poor control and monitoring of the fishery (Mann 1997). There are few well-defined fishing communities in the Southwest Cape and the relationship between the management authority (MCM) and fishers in the area cannot be regarded as amicable. Furthermore, MCM does not appear to have the resources to effectively patrol and enforce regulations at current levels of exploitation (Brouwer *et al.* 1997), let alone after any future increase in participation.

The primary aim of this study was to investigate and compare gill net catches between the currently open West Coast and the closed Southwest Coast. Multivariate analysis showed significant differences in the catch rates and composition between areas, which are clearly displayed in the dendrograms and MDS ordination plots. Examining some of the possible reasons as to why the catches between these two areas differ so dramatically however, can give some insight into the past and possible future impacts of gill net fishing in the region. Intuitively, the biogeographical trend of decreasing fish species richness from east to west (van der Elst 1981, Whitfield 1983, Smith & Heemstra 1986, van der Elst & Adkin 1991, Bennett 1994, Turpie 1999), is the most obvious reason for the differences between West and Southwest Coast catches. This southwestward decline in diversity is linked to the attenuation of tropical and subtropical species due to changing oceanographic conditions, particularly decreasing water temperature (Whitfield 1983, Turpie 2000).

Experimental gill net sites along the Southwest Coast are exposed to the warm Agulhas current and the average temperature recorded (16.8 ^{0}C) at these sites was slightly greater than that recorded for West Coast sites (16.1 ^{0}C) that lie within the cold Benguela upwelling region (Shannon 1989). The difference in average temperature recorded at sites on each coast is, however, not as marked as would be expected given the broad scale oceanographic differences. It must be noted that experimental gill netting was conducted close inshore (usually within 500 m of the shore) and localized oceanographic processes can have marked effects on water temperature over smaller spatial scales. Turpie (2000) suggested that the lower fish species richness on the West Coast may also be inversely related to productivity, as was found for rocky-shore invertebrates (Hockey & Branch 1994).

Habitat diversity also influences fish species richness, both in estuaries (Whitfield 1983) and the marine environment (Turpie 1999). Although no quantitative assessment of habitat diversity was undertaken during this study, differences in habitat diversity between West and Southwest Coast sites may explain some of the discrepancy in the number of species caught between these two areas. The presence of rocky banks and substratum at some of the Southwest Coast estuarine sites sampled, compared to the predominantly mud banks and substratum found at the West Coast estuarine sites, may be part of the explanation as to why more species were caught in the former. All four of the regular marine sampling sites along the Southwest Coast were dominated by rocky substrata and were in close proximity to extensive inshore reefs, resulting in high physical and biological habitat diversity. Two of the West Coast sampling sites (Saldanha and Lambert's Bay) however, had predominantly sandy substrata although rocky reef was present in the nearby vicinity. Very few species were caught at the Lambert's Bay site, but more species were caught at the usually warm Saldanha Bay site than the other West Coast sites, suggesting that temperature was more important than habitat diversity in determining the catch composition.

The variation in the physical environment and the resultant biogeographical trends discussed above undoubtedly played a role in determining catch differences between areas. Certainly for estuarine catches, differences between Southwest and West Coasts result from the fact that many of the species that were caught along the Southwest Coast simply do not occur on the West Coast. On the other hand, species that are limited in distribution to the east of Cape Point contributed little (< 10 %) to the dissimilarity between West and Southwest Coast marine catches. For all net types, most of the species that were identified by SIMPER analysis as being primarily responsible for the dissimilarity between West and Southwest Coast marine gill catches do occur along both coasts. A possible explanation as to why the experimental catch rates of species such as *D. capensis, P. saltatrix, A. inodorus, D. sargus, R. globiceps, L. lithognathus* and *S. salpa* were substantially greater along the Southwest Coast, is that over 100 years of intensive commercial gill netting has reduced the abundance of these species on the West Coast.

A reduction in numerical abundance and biomass of species selectively targeted by a fishery is the most likely detectable effect of fishing pressure (Jennings & Lock 1996). The evidence is, however, far from conclusive, as one would first expect a reduction in the abundance of the target species. Catch rates of the target species *L. richardsonii* and *Callorhinchus capensis,* along with some other by-catch species such as *T. trachurus*, *Chelidonichthys capensis* and *M. mustelus,* were greater along the West Coast. It can be argued that the environment on the West Coast is simply more suitable for these species and they are naturally more abundant in this region, but the same argument is true for species that were more abundant in Southwest Coast catches. *Liza richardsonii* and *Callorhinchus capensis* are the only target species designated by law, and fishers do and have in the past specifically targeted the more valuable line-fish species mentioned above. Historical records document substantial net catches of *D. capensis, L. lithognathus, R. globiceps, P. saltatrix* and *A. inodorus* on the West Coast in the past (Bennett 1988, 1993a, Biden 1954). This suggests that suitable habitat for these species does exist on the West Coast and their current low catch rates may indeed be due to past net-fishing pressure. The life-history characteristics (relatively slower growth, large size at maturity, longevity) and small size at which these species are vulnerable to capture in gill nets probably makes them less resilient to exploitation than the target species (Bennett & Griffiths 1986, Bennett 1993b, Griffiths 1996, Buxton 1996). Gilchrist (1914) provides data on *L. richardsonii* catches made in St Helena Bay over a 33 year period which show a dramatic decrease in average annual catch from over 100 tons for the years 1880-1900 to less than 20 tons for the years 1901-1913. Fishing thus does appear to have reduced the abundance of the target species, as far back as 100 years ago.

It is difficult, if not impossible, to separate the influence of biogeographical and natural distribution patterns from fishery effects on the catches made in different areas during this study. Indeed the preliminary findings of an Australian study indicate no significant differences in experimental by-catch composition from estuaries within the same biogeographical region that are open and closed to commercial gill netting (Ley *et al.* 1999). It is, however, noteworthy, that due to the selection effect of the large mesh size (150 mm) used in the Australian fishery, much of the estuarine icthyofauna is not vulnerable to capture and the fishery may indeed be having little impact on the overall fish biodiversity (Ley *et al.* 1999). It can only be concluded that a combination of biogeographical and fishery effects are responsible for differences in experimental gill net catches between the West and Southwest Cape coasts of South Africa.

Other documented effects of fishing pressure are changes in the size and age structure of exploited populations, which is particularly noticeable if the fishing gear or methods are size selective (Law 1991, Boehlert 1996, Jennings & Lock 1996). Gill nets are highly selective as a function of mesh size and fish shape and size (Dalzell 1996). The smaller mean size of fish caught and few individuals at liberty above the size selected for by the gill nets used in the fishery suggests that fishing mortality for these species is high relative to recruitment on the West Coast. The clear differences in population size structure of both target and by-catch species caught on the heavily exploited West Coast and the Southwest Coast (an area with low net fishing effort) lend considerable support to the argument that gill-net fishing pressure has impacted on West Coast fish populations. The exact same nets were used and sampling was conducted during the same two-week field trips on both coasts, so net selectivity and size-specific temporal variation in distribution are not the causes of these population size structure differences. This evidence must be interpreted with caution, as there may be natural size-specific spatial variations in the species distribution or biases induced by migration patterns (Jennings & Lock 1996), e.g. juveniles frequenting the West Coast and migrating to the Southwest Coast as adults. Fish of similar maximum size were, however, recorded on both coasts, suggesting that there are no biological or environmental forces restricting growth on the West Coast. Whatever the reason, the implication of this is that an expansion of the gill net fishery along the Southwest Coast will result in an increased net catch of large mature linefish and the "fishing down" of the average size fish on the Southwest Coast.

Selective fishing may also act as an agent of directional, artificial (as opposed to natural) selection, usually by removing larger, faster-growing fish resulting in changes in the genetic structure of exploited populations (Law 1991, Boehlert 1996, Jennings & Lock 1996). Evidence of phenotypic or genotypic compensatory responses by exploited fish populations, such as increased fecundity or decreased age at maturity, also exist (Law 1991, Boehlert 1996). These changes may appear beneficial in reducing the risk of recruitment overfishing, but have the negative consequence of creating a less productive stock because of the slow growth of individual fish. Furthermore, the species ability to respond in compensatory ways to fishing pressure may be compromised, as selective fishing can reduce the genetic diversity of the population (Boehlert 1996). Although highly speculative, it is possible that such changes have occurred in exploited *L. richardsonii* populations on the West Coast, given the size-selective nature of the net-fishery, the long time the fishery has been in existence and the relatively short generation time of three years (De Villiers 1987). Selective breeding experiments with fish show that a genetic response to selection in the order of 10 % per generation of the selection differential applied is likely (Law 1991). If this has occurred, Southwest and West Coast *L. richardsonii* populations could be separate stocks, with different growth and biological characteristics. This may explain some of the differences observed in the population size structure between the areas. On the other hand, West Coast – Southwest Coast size structure differences may simply be a result of different catch – at – age distributions. During this study, biological data on *L. richardsonii* were collected and hopefully some of these questions can be answered in the near future. The concern exists, however, that the development of a gill net fishery along the Southwest Coast could result in counter – productive changes to the genetic structure (particularly decreases in genetic diversity and growth rates) of vulnerable fish populations.

Experimental netting indicates that with an expansion of the gill net-fishery in the Southwest Cape, the catch composition is likely to change from one dominated by the target species with a small by-catch component (< 5 %), to a situation where high value line-fish comprise a substantial proportion of the total catch. If a gill net-fishery with similar effort levels (approximately 28 000 gill net days. year^{-1}, Chapter 1) to the one that currently exists on the West Coast were to develop along the Southwest Coast, the line-fish by-catch, based on experimental catch rates, would increase by approximately 600 %. The resultant Southwest Coast annual line-fish catch by gill nets would be in the region of 1 080 tons, cf. 130 tons on the West Coast. This figure is roughly equivalent to the annual shore angler catch (1 020 tons) estimated by Brouwer *et al.* (1997) despite much higher levels of participation and effort in the recreational line fishery. An increase of this magnitude in effort directed at line-fish species and the resultant increase in fishing mortality is obviously not desirable at a time when management is trying to reduce total catch and effort, with the aim of rebuilding overexploited line-fish stocks. The development of a gill-net fishery along the Southwest Coast, a much more densely populated region where an estimated 658 862 shore-angler days.year^{-1} occur (cf. 205 242 angler days. year^{-1} on the West Coast, Brouwer *et al.* 1997), will drastically increase user conflict between these two sectors.

The mullet catch, however, would only increase by about 50 % with a resultant Southwest Coast catch of around 1 500 tons vs. 3 000 tons on the West Coast. These rough calculations are based on experimental catch rates obtained on the relatively unexploited Southwest Coast and the sustainability of these catches at higher effort levels is not known. To new entrants on the Southwest Coast, the economic value of line-fish by-catch to the fishers would far exceed the value of the intended target species; at least initially, until catch rates inevitably decline. It is not realistic to think that this by-catch could be controlled by enforcement of maximum mesh sizes, since substantial numbers of juvenile line-fish are vulnerable to capture in small mesh 44-51 mm nets anyway. Furthermore, once exposed to gill net "technology", fishers would soon realize the economic potential of using larger mesh sizes and illegal net fishing would rapidly develop. Given the failure of attempts by the MCM inspectorate in controlling illegal netting on the West Coast (Chapter 1) it is unlikely that this could be controlled elsewhere.

Conclusion

Closed or restricted netting areas are widely used as a management tool to regulate gill net fisheries. Closed areas help to reduce real or perceived competition and conflict between user groups and/or limit the impact of gill netting in ecologically "sensitive" areas, or on vulnerable species aggregations (Moore 1980, Quinn 1988, Anon. 1998, Milton *et al.* 1998). In South Africa, conflict between commercial gill and beach-seine net fishers on the West Coast was partly resolved by the declaration of exclusive beach-seine areas, where the use of gill nets are prohibited (De Villiers 1987, Sowman *et al.* 1997). Specifically designated netting areas are used to minimize conflict between artisanal gill netters, recreational anglers and traditional trap fishers in the St Lucia and Kosi Bay nature reserves (Mann 1995, 1996, Kyle 1999). Experimental netting conducted during this study has provided strong support for the maintenance of current spatial restriction of gill netting in the Western Cape. Maintenance of the *status quo* is important for minimizing the impact of gill netting on vulnerable by-catch species and in the interests of preventing user conflict, particularly between potential gill-netters and recreational shore anglers.

CONCLUSIONS

One of the most important conclusions that can be made from this study is that despite targeting the same species, *L. richardsonii*, in all areas, the net fisheries are highly diverse in nature. The people involved, their motivations for fishing, activity levels, gear used, as well as the type and quantity of fish caught all vary greatly, both within and between areas. This makes drawing generalized conclusions about the fishery very difficult. It also stresses that for management purposes the fishery should always be assessed on a very small spatial scale. One generalization that can be made is that net fishers (especially on the West Coast) are highly suspicious and distrustful of outsiders, particularly if they suspect management affiliation (Chapter 2). This is understandable, as all management action, from the fishers perspective, appears to have negative consequences (restrictions on the fishers ability to catch fish). The result is that most net fishers (there are exceptions) are more than economical with the truth, be it *via* official (e.g. catch returns – Chapter 1) or unofficial (e.g. surveys – Chapter2) channels. Management should be aware of this and focus fishery data collection at on-the-ground monitoring of catch and effort. A visible presence will also do much to improve compliance with regulations and cooperation between management and the resource users.

The total catch and effort estimates determined for the study area during 1998/1999 are approximately 28 000 gill net trips, landing 2 750 – 3 250 tons of *L. richardsonii*, 650 tons of *Callorhinchus capensis* and 130 tons of by-catch comprising at least 27 species. A minimum estimate of at least 1 800 illegal mesh size gill net days also catch in the region of 100 tons of hound shark and 50 tons of linefish per year. Beach-seine permit holders make approximately 3 300 hauls per year, catching 1 850-1 950 tons of *L. richardsonii* and an undetermined amount of by-catch. The total mass of fish caught by nets in the study area is therefore approximately 6 000 tons per year (Chapter 1). These estimates must, however, be treated with caution as they rely on effort values obtained from interviews and as such are subject to various biases (Chapter 1). Much of the catch and effort is concentrated in a few areas (St Helena Bay, Saldanha-Langebaan, False Bay and the Berg and Olifants Rivers) and mostly confined to the summer months. In some areas, the fishery is oversubscribed (up to 15 nets per km of shoreline) and many permit holders are inactive or only fish a few times per year. There is compelling circumstantial evidence that the *L. richardsonii* stock is overexploited in regions with high effort levels (Chapter 1).

Although 27 by-catch species were landed, these contributed only 5.13 % numerically to the gill net catches that were monitored (Chapter 1). A large proportion of the by-catch were species that are currently of little or no importance to other sectors, and gill net catches can be regarded as insignificant when compared to the catches made by the larger industrial fisheries. Catches of linefish species in gill nets, however, despite contributing less than 1.5 % numerically to the total catch and being regarded as negligible by the net fishers, exceed those made by shore anglers along the West Coast. The majority of the by-catch, particularly in 44-64 mm gill nets, is undersize, immature fish, which have little financial value to the fishers themselves, but are valued as a source of food by impoverished helpers. Although difficult to quantify, larger linefish and sharks (especially *M. mustelus*) illegally targeted by some gill and beach-seines netters do also represent a substantial financial return. If management strategies aimed at rebuilding linefish stocks are to be successful, gill and beach-seine net by-catch and more urgently, illegal gill net catches, will have to be controlled through increased enforcement and education of fishers.

Catch and effort was found to be drastically underreported in compulsory catch returns. Overall, as little as 21 % of the actual effort and 8 % of the target species catch is reported (Chapter 1). Not only do many permit holders fail to report trips that are made, but when they do submit returns, they also substantially underreport the amount of fish that was caught. Reporting of by-catch was even less accurate, with observed catch rates an order of magnitude greater than reported. Reasons for the under-reporting of catches include: apathy and ignorance of the importance or need for catch statistics, a fear of permit loss if the capture of prohibited species is reported, a lack of trust as to the confidentiality of catch returns and subsequent fear of tax implications and a traditional distrust of management (Lamberth *et al.* 1994, 1997). Regular and rapid communication between management and permit holders is essential if the self-reporting system is to work at all. It should be stressed as one of the permit conditions, that failure to correctly submit any catch return is an offence for which a permit will be revoked.

At least two alternate methods of verifying catch returns are available: analysis of factory purchases and an independent observer program to monitor landings. The latter is obviously more desirable as the by-catch can be accurately recorded and this method does not rely on the co-operation of factory owners, who would probably collaborate with the fishers rather than with management. Independent long term monitoring of the net-fishery is the only method that will produce data suitable for use in the scientific assessment of fish stocks. It is however, desirable to continue and improve the catch return system, which is much cheaper and has the potential to provide greater coverage of the fishery than on-the-ground monitoring. This would at the very least allow for analysis of trends in catch and effort.

The following considerations should be taken note of when initiating a monitoring program for the inshore net-fishery in the Western Cape:

- Monitors should be well trained in the methods necessary to collect all the data desired by management. In order to verify catch returns, the following data are the minimum that must be collected: date, permit number and/or boat registration number, species and quantity of fish landed. Monitors could be supplied with a date-recording camera to document landings. Additional data, such as hours fished, weather conditions, length frequencies, biological samples etc. can also be collected when time permits.

- Monitors must be fluent in Afrikaans (99 % of fishers encountered during this study were Afrikaans speaking) and communicate in a polite manner with all fishers encountered in order to encourage cooperation rather than conflict.

- Prior to the implementation of a monitoring system, permit holders should be informed that their activities are to be monitored and catch returns checked. It could be legislated as a permit condition that fishers must allow card-carrying observers access to inspect their vessels and catch, but monitors should never hinder the fishing operation or carry out law enforcement.

- In most areas, the gill-net fishing effort is concentrated over the spring-summer months (Aug.-Mar.); the exceptions being the Olifants River and Saldanha-Langebaan area, where fishing is less seasonal. Monitoring effort should be concentrated in areas where and during periods when high fishing effort occurs in order to maximize the number of observations per unit cost.

- In the main commercial gill-net fishing areas, over 90% of the fishing effort is conducted at night. The catch is landed in the early morning and the nets cleaned in the first few hours of daylight. Any monitoring will have to take place during this period and people contracted to undertake the work must be prepared to operate outside of normal office hours.

- In many areas net fishing is a sporadic and rare event (gill-netting to the north of Dwarskersbos, beach-seining in most areas) and having dedicated net-fish observers will be prohibitively expensive. The use of general marine observers and other state employees (Marine and Nature Conservation staff) to collect data on net-fishing activities in these areas would be beneficial.

- Monitors should be well informed of the current management objectives and should act as a conduit between fishers and management for fisher queries and complaints.

Although most (70 %) of permit holders interviewed had been involved in the net fisheries for more than 10 years, only a small proportion (0-11 %) listed net fishing as their primary occupation (Chapter 2). Approximately two thirds of respondents work or have worked in other fishing sectors and between 6-50 % are retired. Permit holders on average do not represent a particularly affluent group and a substantial proportion (33 %) claim to earn less than the subsistence income level. Approximately 80 % of Saldanha-Langebaan respondents claim to make more than half their income from net-fishing, but in other areas 42-61 % claim to make less than 5 % of their take home pay from net-fishing. Estimated costs and returns to net permit holders show that the average gill net permit holder outside of Saldanha-Langebaan does not cover the opportunity costs of capital and labour. The lack of profits in these areas is further evidence that the fishery is oversubscribed (at or beyond the open access equilibrium point) and suggests that a 60 % reduction in effort is required to obtain maximum economic yield from the fishery (Chapter 2). Between 10-42 % of respondents felt that the fishery was no longer economically viable, and admitted to been inactive for the 12 months preceding the interview.

The net-fisheries do, however, provide part time employment for approximately 2 000 crew and make additional contributions to the regional economy in the form of equipment and fuel purchases, maintenance of fishing gear and the processing and sale of the fish caught (Chapter 2). It may not be desirable to manage the net fisheries for maximum economic yield, but rather to maximize participation. It does, however, appear that this has already been achieved. In light of the negative ecological impacts of the fishery in the form of by-catch mortality, the potential increase in conflict between net fishers and shore anglers and the large amount of latent effort (that may under different economic conditions in the future become active), a timely reduction in effort appears prudent. The sporadic availability of fish in most regions means that net-fishing will always be a part time occupation and function as a source of supplementary rather than sole income for participants. Management should not aim to transform the fishery into a situation where permit holders are reliant solely on net fishing for survival, but rather where only active, economically viable fishers, with a real need to be involved, are participants. To avoid excessive resistance from fishers and undesirable economic consequences, the effort reduction should not be instantaneous, but rather phased in as equipment wears out and permit holders voluntarily leave the fishery, with limits on the transferal of permits to new entrants. Management should, in consultation with net fish associations, develop long-term targets for the number of permits in different areas and clearly explain the need for and benefits to *bona fide* net fishers of an effort reduction.

Given the oversubscribed situation and evidence that the *L. richardsonii* stock is overexploited in the regions where the net fisheries currently operate, it appears that a reduction, rather than an increase in participation is necessary (Chapters 1 & 2). The only other option for allowing increased access in the net fisheries is a geographical expansion of the gill-net fishery, which is currently confined to the West Coast. Experimental netting indicated that if the gill-net fishery were to expand eastwards, the catch composition would change from being dominated by the target species with a small by-catch component (< 5 %), to a situation where high value linefish comprise a substantial proportion of the total catch (Chapter 3). This would have a detrimental impact on already overexploited linefish stocks and lead to an increase in user conflict. If gill netting were also allowed in Southwest Coast estuaries, it would seriously compromise the nursery value of these systems for many fish species (Chapter 3). From a management and conservation viewpoint, a commercial or subsistence gill net fishery along the Southwest Coast would be highly undesirable.

Knowledge and support for the catch restrictions relevant to fish caught in nets amongst fishers interviewed were low (Chapter 2). This is due to a combination of the lack of enforcement of these regulations and a feeling amongst net fishers that the regulations unfairly restrict their activities. In order to improve the situation, several factors need to be taken into account. The list of permit conditions issued with permits needs to be updated. The current conditions are vague and state only that the capture of "angling" fish is prohibited but a total of 10 by-catch fish per day that die in the nets may be retained, providing they meet with the relevant size, season and bag limits. Updated permit conditions should explicitly state the species, minimum legal sizes and bag limits for all fish caught by netfishers. Furthermore, netfishers should be informed as to exactly which by-catch species they may or may not sell.

Enforcement of regulations relevant to net catches needs to be drastically increased. The currently almost non-existent level of enforcement is partly due to the low management priority afforded to the net-fishery and the lack of manpower, with the few available inspectors spending most of their time monitoring the larger pelagic, trawl and rock lobster fisheries. The commercial gill net fishery also mostly operates at night, with the catches unloaded well before office hours start. An increase in the number of inspectors and funding for overtime or shift work is needed. An increase in enforcement would certainly encourage fishers to reduce by-catch levels, either by moving from areas where by-catch is high or by returning more non-target and undersize fish to the water. Some of the permit conditions relevant to linefish by-catch are unrealistic; by-catch species, particularly undersize *P. saltatrix*, often in excess of the allowed $10.day^{-1}$ often die in nets before the fisher has even noticed them (Chapter 1). The reality of the situation is that many commercial net fishers break the regulations daily and some sort of exemption is necessary if any of the regulations are to be meaningful.

The net fisheries operate sporadically over a large stretch of coastline and use a multitude of landing sites, which means that enforcement will always be difficult and expensive. Compliance with regulations is obviously more desirable than enforcement. An attempt should be made to increase support amongst net fishers for restrictions limiting linefish by-catch through open communication between management and net-fish associations. Management should clearly explain the need to reduce fishing mortality on overexploited linefish species. Net-fishers should also be made aware that the restrictions are in their best interests given the threat to their continued fishing rights in light of the huge political pressure of recreational anglers, who nationally outnumber net-fishers by at least 1 000:1. The need of management to minimize conflict and ensure equitable distribution of resources amongst sectors must also be explained. By way of compromise, net permit holders should be allowed to target other species such as *S. sagax*, *T. trachurus* and *Chelidonichthys capensis* that are not currently overexploited. Although sardines are a quota-controlled species, it is unlikely that gill or beach-seine net catches will ever reach levels that affect the TAC for the purse seine fishery.

This study has provided a large amount of information that will have practical applications for the management of the inshore net fisheries in the Western Cape. In retrospect, there are several improvements to the methods used that could produce more accurate data. The use of questionnaire or telephone surveys to estimate total effort is not ideal. The employment of local field assistants or informants to monitor net fishing activity over a small spatial scale for a continuous period would potentially have produced far more realistic effort estimates. Alternatively individual, randomly selected fishers could have been requested to maintain logbooks and document all trips made and fish caught on a daily basis. These fishers could also have been requested to record all expenditure and income, which would allow for a more precise economical analysis of net fishing. A more accurate reflection of the potential impact of commercial netting in currently un-exploited areas could also have been obtained by contracting experienced net fishers to undertake "sampling". These alternatives could, however, have proved expensive and difficult to implement. The reliability and cooperation of observers and fishers would be difficult to ensure. Allowing fishers access to closed areas, even under experimental conditions, could also have legal implications by either creating a precedent or encouraging poaching.

All the evidence relating to the status of the *L. richardsonii* stock that was presented in this study is circumstantial. Clearly there is a need for a quantitative stock assessment before the actual status of the resource is known and defensible management measures can be implemented. Detailed information on the growth, reproduction, distribution, migration, natural and fishing mortality of *L. richardsonii* is needed. Many of the necessary data were collected during the course of this study and a stock assessment of *L. richardsonii* is in the process of being completed.

The *L. richardsonii* stock represents a valuable resource that can be exploited in an economically viable manner by a limited number of beach-seine and gill net fishers. As *L. richardsonii* is not intensively exploited by any other sectors the traditional commercial net fisheries should not be unduly restricted under pressure from other user groups. Urgent management action is, however, required to reduce current effort to more sustainable levels and to limit the ecosystem effects of the fishery. Despite the pressing socio-economic needs of a large proportion of South Africa's population, no increases in net fishing effort or an expansion of the area where the gill-net fishery currently operates should occur.

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APPENDIX 1
NETVIS VRAELYS

Universiteit van Kaapstad

Die **doeleindes van hierdie opname** is om ons verstand van die mense betrokke in die netvis bedryf te verbeter en die waarde van die vissery vas te stel. **Jou antwoorde is heeltemal vertroulik** en sal nie jou status of toekomende status as n permit houer invloed nie.

Plek ________________ Datum ________________ Tyd ________________

Tiepe nette in jou besit (lengte * diepe * mas grote) (Bv. 70m * 3m * 2 duim)
Dryf/Stel: ____
Trek: ____
Gebruik jy enige ongelinseerde nette? JA NEE (sirkel jou keuse) Watse nette? ______________

Naam ________ Ouderdom ______________ Geslag __________________ 1 2 3 4 (Pop. Groep)

Posisie op span? __________ Watter werk doen jy? __________________ Of afgetree? _____

As voltydse visserman, hoeveel van jou tyd (persent) spandeer jy in die verskillende viserye ?
Pelagies ________ lyn __________ kreef __________ net ___________ trawl ________

Behoort jy aan enige vissers unie of club? JA NEE Naam? ______________

Op watter 3 plekke gebruik jy meestal jou nette? ____________ ____________ _________

Hoeveel jare vang jy al vis ? ______________ Met nette? ______________

Hoeveel mense is afhanglik van jou visvang inkomste? (vroue, kinders ens.) __________

Stel methode __________________ As boot, is dit jou boot? JA NEE

Boot tiepe ________ lengte _______ oud ____ Hoeveel sal 'n nuwe boot kos? ____________

Gebruik jy 'n buiteboord motor ? JA NEE Tiepe ______________________

Hoe ver is jou huis van die plek waar jy vis? (km, een rigting) ____________________

Gebruik jy 'n voertuig met jou visvang werk? JA NEE As ja: tiepe, jaar, engine grote __________

Vervangingswaarde van jou voertuig __________

Omtrent hoeveel liter petrol gebruik jy as jy gaan visvang (voertuig en buiteboord)? __________

Hoe dikwels koop jy nuwe : nette _____ toue _____ bouys _____ oilskins _______

Hoeveel geld het jy in die laaste 12maande gespandeer om jou toeristing (voertuig, boot, buiteboord ens.) in 'n werkende toestand te hou? ____________

Omtrent hoeveel mense stel nette sonder permitte in die area? ________

Hoeveel keer het jy in die laste **week** jou nette gestel? _____ **Maand?** _____ **12maande?** _____

Stel jy in die nag? JA NEE Hoe dikwels? (persent) _______

As jy nette stel, vir hoe lank los jy hulle in die water? (gemiddelde syfer) __________ ure

Draai asseblief om

Toets vrae, om uitevind hoe goed die kommunikasie is tussen See Viserye of Natuurbewaaring en die vissermanne. Weet jy of die volgende regulasies toepaslik is vir die vis wat jy vang in jou net?

5 tiepe visse wat jy meestal vang?	Gemiddelde vang/stel of trek (1 net)	Gemiddelde verkoop prys	Is daar 'n grote/maat?	Hoeveel mag jy hou?	Is daar 'n seisoen?	Mag jy die vis verkoop?
b.v. Kob	**3**	**-**	**40 cm**	**5**	**N**	**N**
1.						
2.						
3.						
4.						
5.						

Vang jy enige ander tiepe vis? ________ ________ ________
________ ________ ________

Dink jy die reels oor die net lengte , diepe, masgrote moet verander word? JA NEE
Hoe? ________________________
____
____

En die reels oor watter tiepe en grote vis jy mag vang? JA NEE
Hoe? ________________________
____
____

Verkoop jy al die vis wat jy vang? JA NEE Hoeveel eet jy? ________

Wie koop die vis? ________ Maak jy bokkoms of rolmops of enige iets? ________

Met hoeveel mense gaan jy visvang? ______ Vat jy enige of die selde mense saam? ________

Hoelank vang julle al saam vis? ________ Span geld / deel van die vis? ________

Het hulle ander maniere om geld te maak? JA NEE Wat? ________________

Wat is jou jaarlikste inkomste na belasting? (plus-minus) 1. Onder R1000 2. R1000 – R9999 3. R 10 000 – R19 999 4. R20 000 – R39 999 5. 40 000 – R59 999 6. R60 000 – R79 999 7. R80 000 – R99 999 8. R100 00 – R119 999 9. R120 000 – R139 000 10. Meer as R140 000
Sirkel een asseblief.

Watte deel (persent) van jou geld is van netvisvang? ________

Van die ander visserye? Kreef ____ perlemoen ____ lyn ____ pelagies ____ trawl ____

Het netvis vaangste afgeneem oor die jare? JA NEE Hoekom? ________________

Hoeveel keer was jou vangste in die laaste maand geinspekteer? _____ Jaar? _____ Ooit? _____

Het jy ooit 'n gemerkte vis gevang? JA NEE Wat het jy met hom gemaak? ________

Dink jy nog permitte moet/kan in die rivier of see uitgegee word? JA NEE

Baie dankie vir u saamewerking

APPENDIX 1
NET-FISHING QUESTIONNAIRE

University of Cape Town

The **purposes of this survey** are to improve out understanding of the people involved in the inshore net-fishery and to estimate the economic value of the fishery. Your answers are completely **confidential** and will not influence your current or future status as a permit holder.

Place ________________ Date ________________Time ________________

Types of nets in your possession (length x depth x mesh size) (e.g. 70m * 3m * 2 inch)
Drift/set gill nets:____
Beach seines: ____
Do you use any unlicensed nets? YES NO (circle your choice) What type of nets?____________

Name ________Age_____________ Sex_________________ 1 2 3 4 (Population group)

Position on team (owner/skipper/crew)? _________ Occupation? ____________ or retired? _____

If you are a full-time fisherman, what percentage of your time do you spend in the different fisheries?

Purse-seine _________ Line________ Rock lobster ________Inshore net _________Trawl________

Do you belong to any fisher's union, association or club? YES NO Name of organization ? _________

List the three places you most often set your nets? ___________ ___________ _________

How many years have you been involved in the fishing industry? ________ Inshore net-fishing? ______

How many people are dependent on your fishing income? (Wife, children etc.) ___________

Set method __________________ if boat, do you own it? YES NO

Boat type ________ Length _______ Age _____ Estimated replacement value? ____________

Do you use an outboard motor? YES NO Horsepower: ______________________

How far is your house from the place where you net-fish? (Km, one way) ____________________

Do you use a vehicle for your fishing work? YES NO If yes: make, model and engine size__________

Estimated replacement value of your vehicle: __________

Approximately how many liters of petrol do you use for a fishing trip (vehicle and boat)? _________

How often do you replace your: nets _____ cork and lead ropes _____ buoys ____ oilskins ______

How much have you spent in the last 12 months on maintenance of your fishing equipment (vehicle, boat, outboard etc.)? ____________

How many net-fishing trips did you make in the last **week**? _____ **Month**? _____ **12months**? _____

Do you set nets at night? YES NO How often? (Percent of the time) _______

When you set your nets, how long do you leave them in the water (average estimate) __________hours?

Please turn over

Test questions, to establish the effectiveness of communication between MCM and/or nature conservation and net permit holders Do you know if the following regulations are applicable to the fish that you catch in your nets?

5 species of fish that you most often catch	Average catch per set or haul	Average market price	Is there a size limit?	How many may you keep?	Is there a closed season?	May you sell the fish?
E.g. Kob	**3**	**-**	**40 cm**	**5**	**No**	**No**
1.						
2.						
3.						
4.						
5.						

Do you catch any other species of fish?______________ ______________ __________
______________ ______________ ______________

Do you think that the regulations governing net length, depth or mesh size must be changed? YES NO
If yes, how? ____
____

And the regulations governing the type and size of fish you may catch? YES NO
If yes, how? ____
____

Do you sell all the fish that you catch? YES NO If no, how many (percentage) do you eat or give away ?_

Who buys your fish? _______ Do you process your own fish in any way (bokkoms, rolmops, etc.)? _____

How many crew do you take when fishing? _______ Do you take the same, or different crew? ________

How long has your crew fished together? __________Crew pay/ share of the fish? ______________

Do your crew have other employment? YES NO What? ______________________________

What is your approximate annual take-home pay? (After tax) 1. Under R1000 2. R1000 – R9999
3. R 10 000 – R19 999 4. R20 000 – R39 999 5. 40 000 – R59 999 6. R60 000 – R79 999
7. R80 000 – R99 999 8. R100 00 – R119 999 9. R120 000 – R139 000 10. More than R140 000
Please circle one.

What percent of this income is from net fishing? ________________

And from the other fisheries? Rock lobster _____ abalone _____ line _____ purse-seine _____ trawl ___

Have your net-fishing catches decreased? YES NO Why? ______________________

How many times were your catches inspected in the last month? ______ 12 months? _____ever? _____

Have you ever caught a tagged fish? YES NO What did you do with it? __________________

Do you think that more net permits can or should be allocated for this area? YES NO Why? _____

Thank you for your cooperation

APPENDIX 2

Telefoon opname

Goeie more, my naam is Ken Hutchings, ek bel naamens die Universiteit van Kaapstad. Ek is besig met 'n deurlopende studie van die trek- en dryf net vissery en wil asseblief vir jou ses vrae vrae om 'n beter insig in die vissery tekry.

1. Hoeveel dae het jy met jou nette gevis die afgelope maand ? en die afgelope 12 maande ?

2. Hoeveel vis/kilogram harders het jy in die afgelope 12 maande gevang?
   St Joseph, ander – kabeljou, elf, ens. ?

3. Vis jy hoofsaaklik vir (a) geld/inkomste
   (b) kos
   (c) ontspanning

4. Indien die permit gelde verhoog, gaan jy weer aansoek doen vir 'n netvis permit ?

5. Sou jy belangstel in 'n goedkoper bestaans netvispermit wat die lengte van jou net en verkoop van jou vis sal beperk ?

6. Hoeveel is jy bereid om te betaal vir so 'n permit ?

Telephone survey

Good morning/afternoon, my name is Ken Hutchings; I am calling from the University of Cape Town. I am busy with an ongoing study on the gill and beach-seines net fisheries and would like to ask you a few questions to improve my understanding of the fisheries.

7. How many days did you fish with your nets in the previous month? And the previous 12 months?

8. How many or what mass of harders did you catch in the previous 12 months?
   And, other species – St Joseph, kabeljou, steenbras, galjoen, barbel, sharks, elf, etc.?

9. Do you fish mainly for (a) money i.e. income?
   (b) Food, i.e. subsistence?
   (c) Relaxation and/or recreation?

10. If the cost of a net-permit were to increase, would you still apply for a permit?

11. How much are you prepared to pay for a net permit?

12. Would you be interested in a cheaper "subsistence" net permit, which would limit the length of net you may use and the sale of your fish?