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LONG-TERM TRENDS IN CATCH AND EFFORT OF COMMERCIAL LINEFISH OFF SOUTH AFRICA'S CAPE PROVINCE: SNAPSHOTS OF THE 20th CENTURY

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The Cape commercial linefishery, established during the first half of the 19th century, currently consists of about 2 500 vessels (±20 000 crew), which land some 15 500 tons of fish each year. In spite of a long history, a lack of a long-term catch and effort data series has severely hindered the management of the fishery. This paper provides commercial catch and effort data for three periods during the 20th century: 1897–1906, 1927–1931 and 1986–1998. Trends in catch per unit effort (*cpue*) were verified with additional data from the inshore trawl-fishery, from fishery-independent surveys and, where possible, stock assessment. According to a Linefish Management Protocol developed for the linefishery, any stock demonstrating a historical reduction in *cpue* or catch contribution of more than 75% is to be regarded as overexploited. Evaluations based on present datasets support this arbitrarily determined reference point for *cpue*, but reveal that catch composition is a poor indicator of stock status and should be used with caution. In spite of technological advances such as the advent of combustion engines, nylon lines, echo-sounders, electronic navigational aids, onboard freezer facilities and larger vessels, declines in catch rate indicative of severe overexploitation (i.e. 75–99%) were observed for many important linefish species during the 20th century. Most of these were higher-trophic-level species from the warm/temperate East Coast, several of which are also endemic. Life-history characteristics of the vulnerable species (i.e those demonstrating declines in *cpue* of >75%) include predictable location in time and space (either coastal migrant or resident), longevity (>15 years) and late maturity (relative to maximum age). Apart frorreduced productivity associated with stock depletion, other setbacks, such as ecosystem alteration, loss of genetic diversity and short-term commercial extinction, are also anticipated. In order to rebuild depleted linefish stocks it is deemed essential to create additional marine reserves, dramatically improve enforcement, develop extensive public awareness programmes and substantially reduce commercial effort.

The Cape commercial linefishery consists of about 2 500 vessels (5.5–15 m long), which operate on the continental shelf (5–130 m depth) between the Orange and Kei rivers (coastline length of 2 500 km) using handline or rod-and-reel. Approximately 40 teleosts are targeted, of which 20 may be regarded as economically important (Lamberth and Joubert in prep.). Origins of the Cape linefishery can be traced back to the fishing activities of indigenous Khoi and European seafarers in the 1500s (Thompson 1913). The Dutch colonized the Cape in 1652, but as a result of various restrictions, the fishery was slow to develop, despite an abundance of fish. All fishing restrictions were removed when the British captured the Cape Colony in 1795, and by the mid-1800s the boat-based linefishery had become a thriving industry (Thompson 1913). The reported commercial linefish catch off the Cape is currently (1990–1997) around 15 500 tons per annum, approximately 95% of the total South African linefish landings.

In spite of a long history, the first comprehensive management framework for the South African linefishery was introduced only in 1985 (Penney *et al.* 1989). Owing to a lack of biological information and fisheries data, particularly long-term catch and effort series and size composition, stock assessments were not possible, and the level of protection afforded to each species (under this framework) depended largely on subjective perceptions of its vulnerability to exploitation, rather than quantitative evaluations. In the absence of long-term data, management decisions were also undoubtedly influenced by the "shifting base-line syndrome", wherein successive generations of fisheries scientists, managers or user groups lost sight of the state of resources prior to their involvement and earlier accounts of abundance were perceived as unverified anecdotes (Pauly 1995, Pitcher and Pauly 1998). Recent research surveys have revealed that many regulations have failed to provide appropriate resource protection, because they did not limit catches (Attwood and Bennett 1995, Brouwer *et al.* 1997, Griffiths 1997a, Sauer *et al.* 1997). Meanwhile, stock assessments indicate that several of the so-called "resilient" species (e.g. kob *Argyrosomus japonicus* and *A. inodorus* and geelbek *Atractoscion aequidens*) are severely overexploited (Griffiths, 1997a, b, Hutton *et al.* in press). Largely as a result of these findings, but also to fulfil the requirements of the new South African Marine

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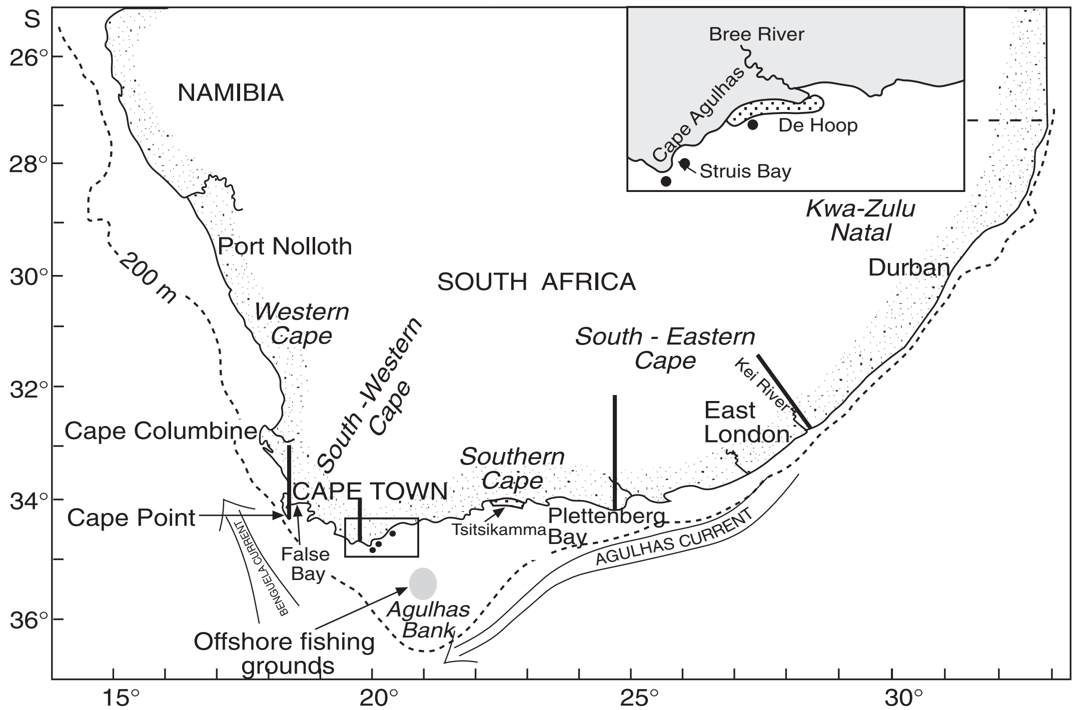

Fig. 1: Map of southern Africa showing the four coastal regions and the key geographic localities and oceanographic features mentioned in the text

Living Resources Act (No. 18 of 1998) a Linefish Management Protocol (LMP) was developed for the linefishery (Griffiths *et al*. 1999); it is proposed that regulations be based on clearly defined objectives and quantifiable reference points.

Owing to the lack of long-term data series suitable for more sophisticated modelling, most linefish stocks will in future be assessed using per-recruit analyses (Griffiths *et al*. 1999). There are basically two ways of interpreting the results of per-recruit analyses: one is the relative lifetime yield and spawner biomass of a cohort; the other is the yield and spawner-biomass of a population in equilibrium. If the population is in equilibrium at the time of analysis, the results will reflect current spawner biomass levels. If not, the results are indicative of future spawner biomass levels, to be achieved by current fishing mortality regimes, once equilibrium is attained. Long-term trends in catch and effort are therefore useful for verifying stock status. They may also be used as "stock status indicators" to generate interim management measures in the absence of stock assessment. According to the LMP, any stock that has demonstrated a historical reduction in *cpue* or catch contribution of >75% should be regarded as overexploited – with suitable interim restrictions promulgated and appropriate research initiated as a priority (Griffiths *et al*. 1999). In the absence of quantitative data, the 75% reference point was derived arbitrarily and remains to be tested.

Ecosystem effects of fishing are poorly understood, and there is currently much international focus on the topic (Jennings and Kaiser 1998, Pauly 1998, Hall 1999). The Marine Living Resources Act is progressive in that it requires stocks to be maintained at levels not only congruent with sustainability, but also consistent with their roles in the ecosystem. Pitcher and Pauly (1998) take the suggestion a step further, presenting sound arguments, based on social, economic and ecological premises, for adopting ecosystem rebuilding, instead of single species sustainability, as the primary management goal – termed "back to the future". Nevertheless, historical catch (*cpue* or catch composition) data are crucial for reconstructing primal (pristine) ecosystems, which are necessary for both assessing the ecosystem effects of fishing and evaluating the benefits of the "back to the future" management goal

(Pauly 1998, Pitcher and Pauly 1998).

The primary objective of this paper is to provide historical trends of catch and effort that could be used to improve current and future management of the Cape linefishery. These include:

(i) evaluating stock status;
(ii) verifying stock status indicators;
(iii) setting the baseline at a realistic pre (early) exploitation condition; and
(iv) reconstructing primal community structure.

It is well established that certain species are more vulnerable to overfishing (at specific effort levels) on account of their life-history strategies (Parrish 1998, Jennings and Kaiser 1998, Musick 1999). A secondary objective of the current study is to use catch trends, together with published biological information, to identify life-history traits that are particularly vulnerable to the Cape linefishery. Such information would assist in the development of fishery regulations for several species that have not been quantitatively assessed using fishery models, and for which historical *cpue* data are not available.

DATA AND METHODS

Study area

The area defined as the "Cape" extends southwards from the Orange River on the West Coast, around Cape Point to the Kei River in the east (Fig. 1). Linefish are predominately shelf species, with most found shallower than 150 m. The continental shelf (<200 m) is typically narrow east of East London, but it widens both west of East London and east of Cape Point, forming the roughly triangular Agulhas Bank (Fig. 1); the Bank has a maximum width of approximately 250 km off Cape Infanta (Bang 1973). Oceanography of the eastern seaboard is strongly influenced by the warm, south-flowing Agulhas Current, which follows the 200-m isobath, is deflected offshore by the Agulhas Bank and ultimately retroflects to flow east (Schumann 1987). Conditions on the West Coast are quite different: key features include the cold Benguela Current, strong coastal upwelling and high productivity (Hutchings *et al.* 1991, Pitcher *et al.* 1992, Shannon and Nelson 1996). The Cape area consequently consists of two biogeographical regions, a cool/temperate Orange River–Cape Point region and a warm/temperate Cape Point–Kei River region (Branch and Branch 1981). Although more productive, the cool/temperate region has less ichthyofaunal diversity (Smith and Heemstra 1986, Turpie *et al.* 2000).

Biological oceanography

Traditional Cape linefish may be broadly divided into three[1] categories: coastal migrants (e.g. seventyfour *Polysteganus undulosus* and geelbek); resident reef-associated fish, including *Chrysoblephus* spp. with high site fidelity, and others such as silver kob *A. inodorus* with large home ranges; and pelagic nomads (e.g. snoek *Thyrsites atun* and yellowtail *Seriola lalandi*), which, although shelf species, cover large areas in short periods and are less predictably located (Ahrens 1964, Griffiths and Hecht 1995, Wilke and Griffiths 1999). The bulk of the demersal catch consists of several sea breams (Sparidae) and two species of croaker (Sciaenidae), whereas the two commercially important pelagic nomads belong to Gempylidae and Carangidae. With one exception, all are indeterminate serial spawners with pelagic eggs and larvae; oceanographic conditions consequently play an important role in shaping their life-history strategies. Coastal migrants utilize the peripheral inshore waters of the Agulhas Current to transport eggs and larvae from spawning grounds in KwaZulu-Natal to nursery areas in the Southern Cape (Beckley 1993, Griffiths and Hecht 1995). In contrast, the eggs and larvae of resident species do not appear to be transported great distances, but are retained close to inshore spawning areas by current reversals and cyclonic circulation, induced by coastal trapped waves and upwelling events respectively (Tilney *et al.* 1996). However, for those resident linefish on the offshore pinnacles (central Agulhas Bank), cyclonic flow around the cool ridge on the central and eastern Agulhas Bank (Boyd and Shillington 1994) provides a mechanism for the transport of ichthyoplankton to inshore nursery areas. Pelagic nomads appear to spawn offshore. Snoek spawn along the western edge of the Agulhas Bank (150–400 m) and rely on the Benguela Current to transport eggs and larvae to nursery grounds north of Cape Columbine (Griffiths in prep.). The spawning grounds of yellowtail are located mainly on the offshore central Agulhas Bank, but nursery areas are yet to be identified (Penney 2000).

Physical oceanography also plays an important role in the distribution patterns of East Coast linefish:

(i) Several warm/temperate species that are caught from the shore in the south-western Cape, e.g. silver kob (Griffiths 1997c) and red steenbras *Petrus rupestris* (Smale 1988), are found progressively farther offshore (and into deeper

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[1] With the development of the tuna industry during the 1980s (Penney *et al.* 1992), a fourth category (oceanic migrants) was added; but these were not traditional target species of the fishery

water) from west to east;

(ii) Species with large home ranges, such as silver kob and white stumpnose *Rhabdosargus globiceps*, disperse farther offshore in winter as the bottom mixed layer (<12°C) retreats down the shelf, but are concentrated closer inshore in summer when coastal upwelling resumes (Griffiths 1997c); this process controls availability of these species to line and trawl fisheries.

(iii) The bottom mixed layer is found consistently closer to the coast between Mossel Bay and Cape St Francis (Griffiths 1997c), so separating stocks of silver kob and increasing availability of shallow-water Cape hake *Merluccius capensis*, a cool/temperate demersal species, to the linefishery.

(iv) A cool, inshore band of cool water (<21°C), prevalent along the East Coast in winter (Baird 1971, Christensen 1980, Armstrong *et al*. 1991), provides a conduit for coastal migrants to visit spawning grounds in southern KwaZulu-Natal (Garratt 1988, Griffiths and Hecht 1995).

(v) Although coastal migrants contribute substantially to linefish catches off KwaZulu-Natal (Penney *et al*. 1999), tropical and subtropical teleosts exploited in that region are rarely caught by commercial linefishers in the cooler waters of the Cape.

Data sources

COMMERCIAL LINE DATA

Although baseline information is not available from the outset of the boat-based commercial linefishery in the Cape, catch and effort data were obtained for the periods 1897–1906, 1927–1931 and 1986–1998, providing three snapshots of the 20th century.

The then Government Marine Biologist of the Cape Colony, Dr J. D. F. Gilchrist, introduced a shore-based observer programme in 1897, with the intention of collecting statistics on catch and effort from all fishing sites. Annual catch by species and the number of vessels active at each of several fishing centres were obtained for the period 1897–1906 from the reports provided by Gilchrist (1897, 1898, 1899, 1900, 1901, 1902, 1903, 1904, 1906, 1907). Although the number of boats operating at each station was consistently recorded, catch was not; *cpue* calculations were therefore limited to those stations for which catch and number of boats were available.

According to Skaife (1948) the Cape Provincial Administration, which took over the collection of statistics in 1905, continued the observer programme until 1930. Unpublished monthly catch records (summarized according to magisterial district) for the period 1927–1931 were recently discovered in the archives of Marine & Coastal Management (MCM, formerly Sea Fisheries) Cape Town, but unfortunately data for the period 1907–1926 are missing. Although vessel numbers were not included in the 1927–1931 dataset, the numbers of boats operating at each fishing station during 1926 and 1934 were respectively obtained from the Fishing Harbour Reports of the Department of Mines and Industries (Mansergh *et al*. 1926, 1927, 1928) and from Report No. 180 of the Board of Trade and Industries (Fahey *et al*. 1934). At sites where the number of vessels in 1926 and 1934 differed, numbers for the interim years were calculated by linear interpolation; at sites where there were no differences, vessel numbers were assumed to have remained constant.

Owners of commercial lineboats have been required to submit daily returns of catch and effort to MCM since 1985. Catch by species and the number of vessels reporting this catch was obtained each year from 1985 to 1998 from the National Marine Linefish System (NMLS).

The three datasets: 1897–1906, 1927–1931 and 1986–1998, were summarized according to four coastal regions (Fig. 1). These were the warm/temperate southern Cape and South-Eastern Cape, the cool/temperate Western Cape, and the South-Western Cape. The latter may be defined as a transition zone, supporting both cool/temperate (e.g. hottentot *Pachymetopon blochii* and snoek) and warm/temperate (e.g. carpenter *Argyrozona argyrozona* and Roman *Chrysoblephus laticeps*) species. Trends in effort were described using boats·km^{-1} of coastline and trends in *cpue* using catch·boat^{-1}·year^{-1}. *Cpue* was further summarized by computing the mean value and standard deviation by species and by region for each of the three periods. Serial overfishing or depletion (*sensu* Bohnsack and Ault 1996) was investigated by comparing species rankings, based on *cpue* in each region and across sampling periods. Species such as mackerel *Scomber japonicus*, Cape hake and panga *Pterogymnus laniarius* were excluded from the catch-trend analysis, because the bulk of the national catch is made by other industries. All traditional Cape linefish (for which data were available) were included in the ranking procedure. In both of the earlier datasets, red and white steenbras *Lithognathus lithognathus* catches were combined (as "steenbras"), and those for dageraad *Chrysoblephus cristiceps* were included in an "others" category; commercial catch trends were therefore not available for these important species.

INSHORE TRAWL DATA

The inshore trawlfishery, established during the

Table I: Catch composition and *cpue* (± *SD*) for the fishery-independent linefish surveys conducted in the Southern Cape in 1931–1993 and 1987–1993. *SD* was calculated for species common to both surveys, but only if more than 100 fish were sampled in either survey

Species	Numbers		*Cpue* (catch·fisher^{-1}·h^{-1})	
	1931–1933	1987–1993	1931–1933	1987–1993
Species recorded in both surveys				
Teleosts				
Carpenter	188	716	0.704 (1.68)	0.176 (1.08)
Red stumpnose	21	406	0.079 (0.25)	0.100 (0.34)
Roman	180	4 198	0.674 (0.91)	1.032 (1.86)
Red steenbras	191	471	0.715 (0.66)	0.116 (0.31)
Seventyfour	825	32	3.089 (4.83)	0.007 (0.05)
Dageraad	189	169	0.708 (17.0)	0.041 (3.02)
Santer	105	1 586	0.393 (1.12)	0.400 (1.12)
Yellowtail	20	105	0.075 (0.16)	0.026 (0.15)
Hottentot	3	13	0.011	0.003
Poenskop	1	10	0.004	0.003
Silver kob	2	1	0.008	<0.001
Musselcracker	1	1	0.004	<0.001
Geelbek	7	13	0.026	0.003
Chondrichthyans				
Soupfin shark	7	35	0.026	0.009
Additional species recorded during the second survey				
Teleosts				
Yellowbelly rockcod		20	0	0.005
Moustache rockcod		5	0	0.001
Bronze bream		9	0	0.002
Steentjie	1	1 222	0.004	0.300
Blue hottentot		371	0	0.091
Fransmadam		2 051	0	0.504
Koester		168	0	0.041
Blacktail		354	0	0.087
Panga		521	0	0.128
Sand soldier		61	0	0.015
White stumpnose		83	0	0.020
Barbel		49	0	0.012
Zebra		21	0	0.005
Elf		5	0	0.001
Mackerel		2	0	0.001
Scorpaenid		9	0	0.002
Chondrichthyans				
Striped catshark		118	0	0.029
Leopard catshark		147	0	0.036
Yellowspotted catshark		4	0	0.001
Copper shark		4	0	0.001
Puffadder shyshark		6	0	0.002
Spiny dogfish		30	0	0.007
Houndshark		45	0	0.011

early 20th century, consists of boats of 15–30 m long, which operate between Cape Agulhas and Port Alfred on substrata of sand/mud and at depths of 50–120 m (Payne and Badenhorst 1989, Japp *et al.* 1994, Booth and Hecht 1998). Although inshore trawlers target Cape hake and sole *Austroglossus pectoralis*, they also land substantial quantities of linefish, predominantly silver kob and carpenter, as a by-catch (Japp *et al.* 1994). Inshore trawl catch and effort data for these two species were therefore used to verify the trends from commercial handline sources. *Cpue* was expressed as catch·boat^{-1}·year^{-1}; data for the Southern Cape and South-Eastern Cape were analysed separately because silver kob in these two regions constitute discrete stocks (Griffiths 1997c). Data for the Southern Cape for the periods 1944–1954, 1963–1965 and 1972–1994, and for the South-Eastern Cape for the periods 1944–1954, 1963–1965 and 1985–1994 were obtained from unpublished (archival) records of MCM. South-Eastern

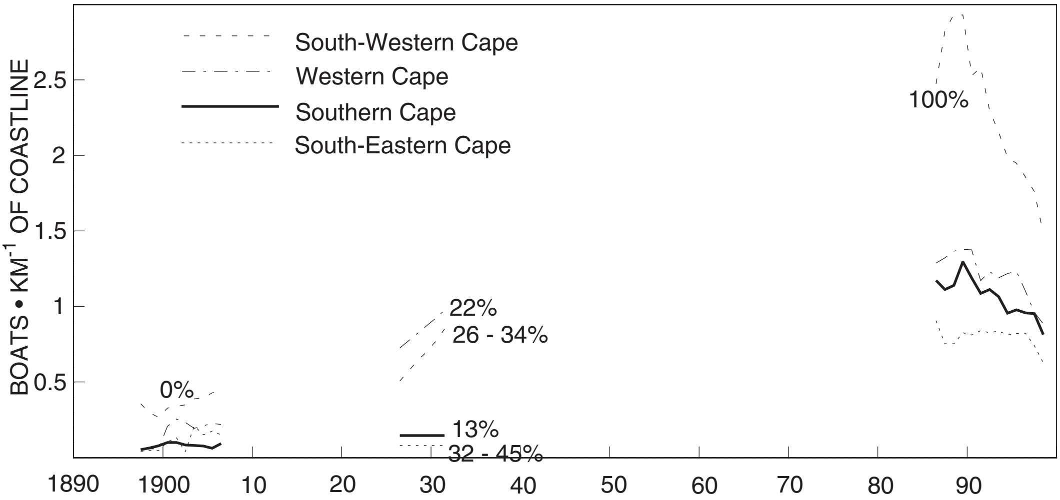

Fig. 2: Regional trends in Cape linefish effort during the 20th century, including proportions (%) of motorized vessels

Cape data for 1967–1975 were obtained from Booth and Hecht (1998).

FISHERY-INDEPENDENT DATA

The Department of Mines and Industries (later the Department of Commerce and Industries) of the then Union of South Africa conducted marine fisheries and marine biological surveys between 1920 and 1948. The primary objective of these surveys was to define the extent of the country's linefish and trawl grounds through experimental fishing. Several new (unfished) linefishing grounds were discovered, including those off De Hoop, Struis Bay (Vlak Bank) and Cape Agulhas (Fig. 1), during 1931 and 1932. Catch and effort data for all research fishing stations on these grounds were included in a series of annual survey reports (Von Bonde 1932, 1933, 1934, 1935). Following the development and exploitation of the grounds, they were systematically fished for the second time during a mark-recapture investigation of fish movement patterns some 50 years later (1987–1993 – Wilke and Griffiths 1999). Numerical catch composition and *cpue* (number·fisher^{-1}·hour^{-1}) were compared between periods (1931–1933 and 1987–1993) in order to provide catch trends for red steenbras and dageraad, and to further verify commercial handline trends for other species.

In all, 44 fishing stations were occupied during the 1931–1933 survey period (267 fisher hours) and 300 stations (4 069 fisher hours) from 1987 to 1993; statistics for the second survey include only those stations in each fishing area (i.e. De Hoop, Vlak Bank and Cape Agulhas) found at depths comparable to those of the first survey. Just 14 species were recorded during the 1931–1933 survey, whereas 37 species were caught during the second (Table I). The reasons for this disparity are unclear, but are believed to be a combination of the following: the use of selective fishing tackle (e.g. larger hook size) during 1931–1933, which selected against small, but common species, e.g. steentjie *Spondyliosoma emarginatum* and fransmadam *Boopsoidea inornata*; a previously higher abundance of shoaling predatory fish that out-competed species such as panga, blacktail *Diplodus sargus capensis*, white stumpnose and catsharks *Poroderma* and *Haploblepharus* spp; and the inclusion of less abundant species, e.g. zebra *Diplodus cervinus hottentotus* and rockcods *Epinephelus* spp, with the much greater fishing effort of the second survey. In order to avoid the confounding effects introduced by those species in the second survey that were previously selected against, only those species common to both surveys were included in comparisons of catch composition.

RESULTS

Trends in linefish effort

Fishing effort at the turn of the 19th century was highest in the South-Western Cape (mean = 0.37 boats·km^{-1}),

Table II: Predominant vessel types at the beginning and the end of the 20th Century

Vessel type	Length (m)	Average number of crew	Propulsion	Operational range (nautical miles)	Echo-sounder	Electronic navigation
			1898–1906			
Open boat	7–8.5	7	Oar and sail	10	No	No
			1986–1998			
Skiboat	5–8	6	Twin outboard engines	20	Yes	Yes
Deckboat	6–13	10	Single diesel screw	20	Yes	Yes
Freezer boat	15–20	20	Diesel engine	1 000	Yes	Yes

followed by the Western Cape (mean = 0.17 boats·km^{-1}), South-Eastern Cape (mean = 0.12 boats·km^{-1}) and Southern Cape (0.12 boats·km^{-1}). Between the first and second periods of study, the number of boats per km of coastline increased more than threefold in the Western Cape and South-Western Cape, but remained relatively constant in the Southern Cape and South-Eastern Cape (Fig. 2). Development of the linefishery at this stage was restricted by inadequate harbour facilities, which limited both number and type of vessels operating

Table III: Mean catch·boat-year^{-1} (± *SD*) for each of 10 important linefish species during the three periods 1897–1906, 1927–1931 and 1986–1998. Data are provided only for regions falling within the main distribution range of each species. % current is the 1986–1998 *cpue* value calculated as a percentage of the highest of the 1897–1906 or 1927–1931 values. Regions were combined for yellowtail and snoek, because they are pelagic nomads that constitute single stocks

Species	Region	Mean catch·boat-year^{-1} (kg)			% current
		1897–1906	1927–1931	1986–1998	
Geelbek	SW Cape	9 784 (4 079)	812 (481)	243 (59)	2.49*
	S Cape	6 508 (4 412)	355 (188)	281 (203)	4.32*
	SE Cape	17 765 (21 714)	3 692 (3 368)	258 (97)	1.46*
Silver kob	SW Cape	2 771 (711)	1 222 (280)	256 (68)	9.24*
	S Cape	3 551 (976)	9 739 (1 739)	763 (174)	7.83*
	SE Cape	14 857 (9 448)	13 516 (5 244)	578 (130)	3.89*
Seventyfour	SW Cape	40 (27)	28 (31)	0.04 (0.06)	0.09*
	S Cape	580 (419)	200 (79)	0.07 (0.08)	0.01*
	SE Cape	5 944 (3 790)	339 (231)	13 (8)	0.22*
Roman	SW Cape	425 (225)	560 (248)	71 (13)	12.65*
	S Cape	132 (65)	229 (55)	40 (14)	17.44*
	SE Cape	860 (723)	558 (209)	40 (6)	4.65*
Red stumpnose	SW Cape	196 (91)	187 (19)	8 (1)	3.90*
	S Cape	70 (54)	757 (242)	7 (3)	0.91*
	SE Cape	96 (89)	382 (245)	20 (3)	5.35*
Carpenter (inshore)	SW Cape	9 350 (3 545)	3 473 (1 296)	300 (94)	3.21*
	S Cape	1 468 (766)	3 481 (1 056)	166 (56)	4.77*
	SE Cape	3 574 (2 797)	3 107 (1 872)	925 (291)	25.88
(offshore)	SW Cape			917 (622)	–
	S Cape			1 782 (1 069)	–
Hottentot	W Cape	1 935 (914)	176 (75)	433 (166)	22.40*
	SW Cape	143 (172)	518 (168)	196 (63)	37.93
White stumpnose	W Cape	52 (45)	247 (82)	79 (60)	31.94
	SW Cape	173 (179)	260 (149)	126 (53)	48.27
	S Cape	344 (159)	416 (90)	0.8 (0.8)	0.20*
Yellowtail	W Cape – S Cape	483 (526)	146 (51)	289 (63)	59.83
Snoek	W Cape + SW Cape	4 669 (3 131)	5 999 (2 694)	3 454 (1 360)	57.58

* Falling below the critical 25% level

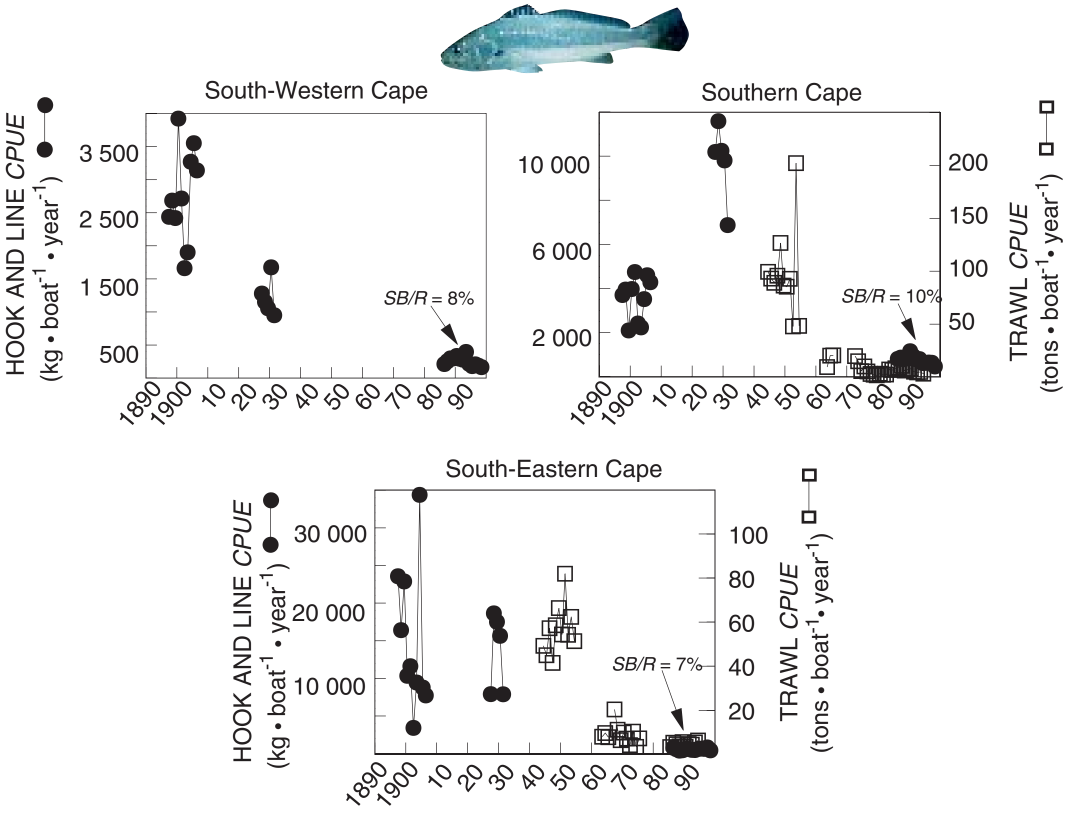

Fig. 3: Average annual *cpue* of three stocks of silver kob caught by lineboats and trawlers in Cape waters. *SB/R* values indicate current spawner biomass-per-recruit ratios calculated as a percentage of pristine (from Griffiths 1997b). Values <25% indicate stock collapse

at the various fishing sites (Mansergh *et al*. 1926, 1927, 1928). At most sites vessels had to be carried from the water, and motorized boats were thus too heavy. The construction of small-boat harbours (1932–1950), however, facilitated a spurt in the growth of the fishery; by 1986 the number of boats (in all but the Western Cape) had increased dramatically (Fig. 2). Over and above the numerical increases, the harbours also facilitated a transition from the "open boat", which dominated during the first third of the 20th century, to motorized vessels. Motorized vessels operating during the 1926–1931 period included steamboats, open boats fitted with early outboard motors, and decked boats with inboard diesel engines (Mansergh *et al*. 1926, 1927, 1928). The trailered skiboat, which increased operational range through both greater speeds at sea and the option of easy land-based transport, was introduced to the Cape from KwaZulu-Natal in the 1970s (L. Hutchings, MCM, pers. comm.). In the early 1980s, freezer boats were developed, further expanding operational range through extended trip time (up to 3 weeks). The dominant vessel types used over the years are compared in Table II. Other technological advances introduced during the second half of the century included nylon lines, echo-sounders and electronic navigational aids.

Trends in commercial *cpue*

Comparisons of *cpue* for the commercial linefishery reveal that the current catch rates of demersal linefish are substantially lower than historical values, many falling well below the critical 25% level (Table III). Owing to tremendous increases in fishing power (associated with technological advances) and possible

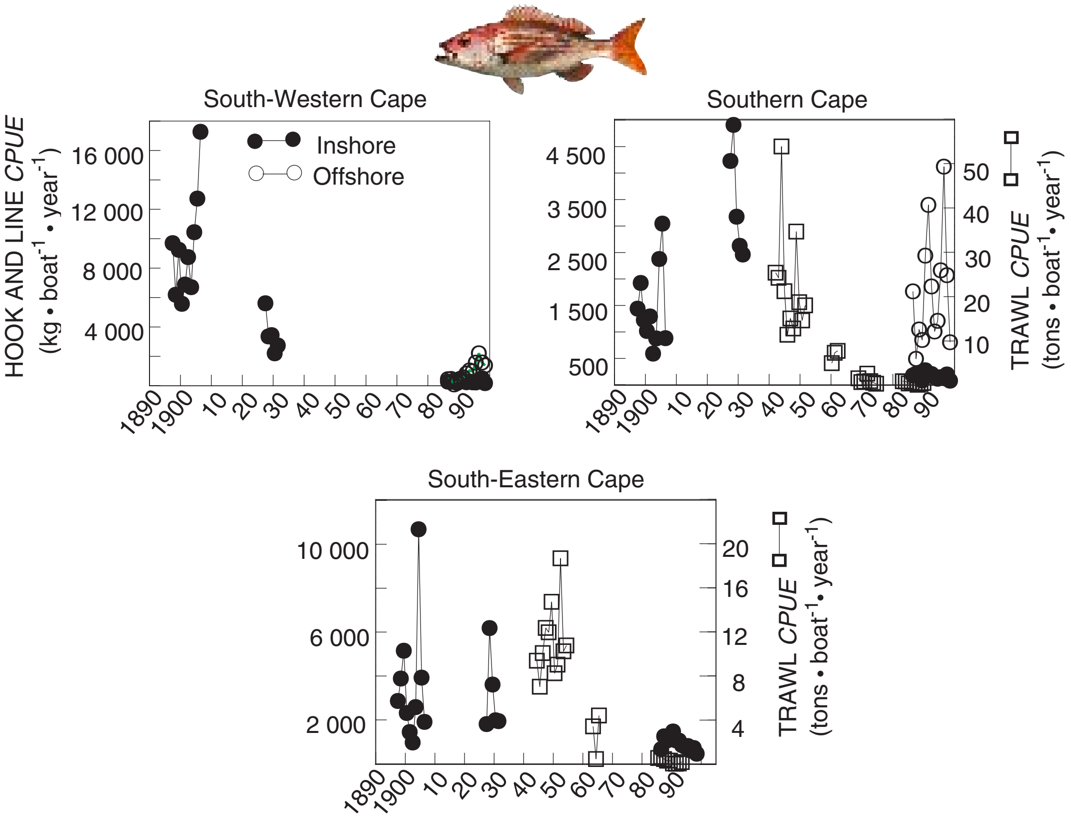

Fig. 4: Average annual *cpue* of carpenter caught by lineboats and trawlers in Cape waters. Closed circles denote line catches made on traditional inshore grounds; open circles represent those from offshore banks

past and recent under-reporting (Table IV), the value of commercial handline trends is questionable. Nevertheless, comparison of catch trends for silver kob and carpenter with those of the trawl industry (Figs 3, 4), and those for seventyfour with that from fishery-independent surveys (Fig. 5), suggest that the commercial line data generally reflect trends in stock abundance. Recent *cpue* for trawled and commercially line-caught silver kob are both <10% of historical values (Tables III, V), whereas that for seventyfour caught commercially and during fishery-independent surveys is <1% (Tables I, III). The value of the commercial line data as an indicator of stock size is further supported by recent stock assessments; species demonstrating dramatic declines in *cpue*, such as silver kob (91–96%), geelbek (96–98%) and seventyfour (99%), are heavily overexploited (*SB/R* <10% of pristine), whereas yellowtail, with a far less dramatic decline (40%), is optimally exploited (spawner biomass = 42% of pristine – Fig. 6).

COASTAL MIGRANTS

Commercial line *cpue* of warm/temperate coastal migrants such as seventyfour (Ahrens 1964, Garratt 1988) and geelbek (Griffiths and Hecht 1995) declined exponentially and simultaneously in each region (Figs 5, 7). That would be expected because they are single stocks. Constituting 40–50% of the KwaZulu-Natal linefish catch in 1923 and 1950, seventyfour had virtually disappeared from that fishery by the early 1960s (Van der Elst and Garratt 1984, Penney *et al.* 1999), so corroborating the Cape trends.

WARM/TEMERATE REEF FISH

Catch rates of warm/temperate, resident, reef fish, e.g.

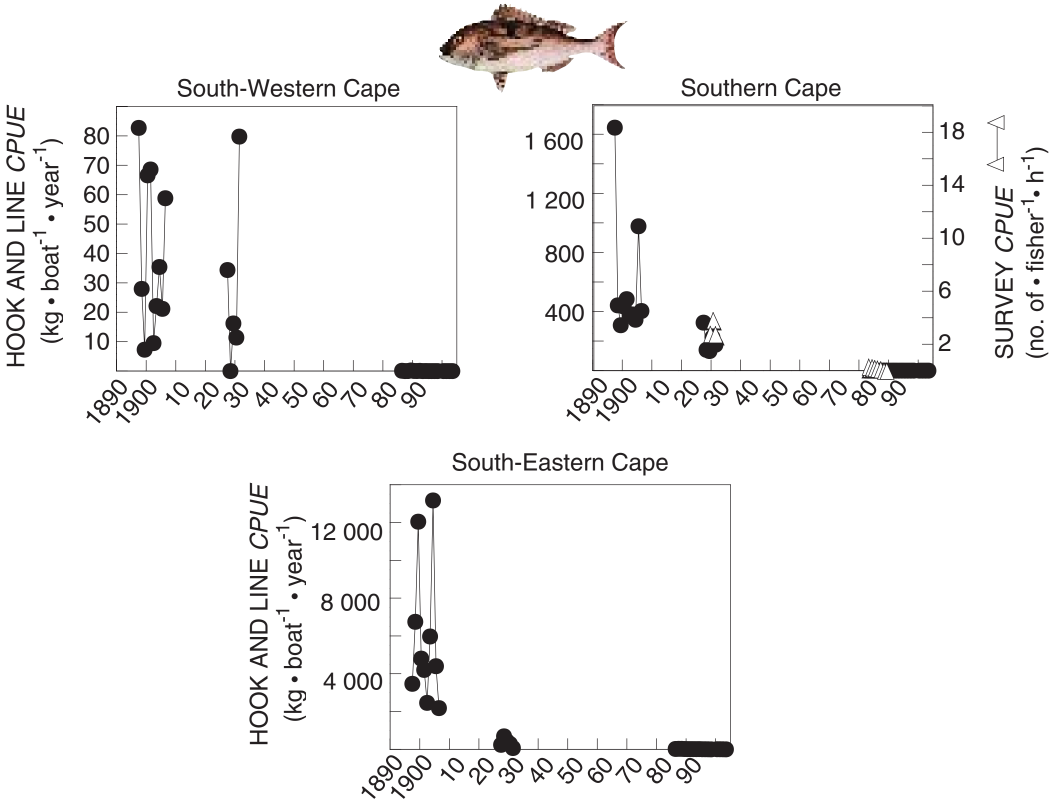

Fig. 5: Average annual *cpue* of seventyfour caught by lineboats in Cape waters, and number of $\text{fish}\cdot\text{fisher}^{-1}\cdot\text{h}^{-1}$ from two fishery-independent surveys (1931–1933 and 1987–1993) in the southern Cape. *SB/R* values indicate current spawner biomass-per-recruit ratios calculated as a percentage of pristine (from Govender and Radebe 2000)

Roman (Fig. 8), carpenter (Fig. 4) and red stumpnose (Fig. 9 – Wilke and Griffiths 1999) and species such as silver kob (Fig. 3), with large home ranges (Griffiths 1997c), declined consistently in the South-Western Cape, but peaked in the Southern Cape during the years 1927–1931. This is attributed to the introduction of motorized vessels, which facilitated the exploitation of new linefishing grounds farther from the coast. Linefish stocks, owing to oceanographic conditions, extend farther offshore on the East Coast (Griffiths 1997c). The Southern Cape pattern was not, however, consistently repeated in the South-Eastern Cape, because the 1927–1931 catch for that region was recorded from Jeffrey's Bay, where motorized vessels had not been introduced by then (Mansergh *et al*. 1927, Fahey *et al*. 1934).

Red steenbras have a complex distribution pattern, and catch trends should be interpreted accordingly. Juveniles (<60 cm fork length) are found on nearshore reefs (<50 m) between Cape Point and the Kei River, whereas adults are more abundant offshore (50–130 m), between Cape Agulhas and southern KwaZulu-Natal (Smale 1988). Juveniles are initially highly resident, but on approaching maturity migrate northwards and offshore to join adult aggregations (Wilke and Griffiths 1999). Fishery-independent data indicate that the *cpue* of red steenbras on inshore reefs in the Southern Cape declined dramatically between 1931–1933 and 1986–1993 (see below). Reports of red steenbras becoming less abundant in the False Bay, Plettenberg Bay and Tsitsikamma areas during the early 1950s (Schoeman 1957) suggest that this trend was widely spread. Large red steenbras (20–40 kg) were commonly caught from the shore of the South-Western Cape at the beginning of the 20th century (Biden 1930, Horne 1955, Burman 1989), thereby implying that there has

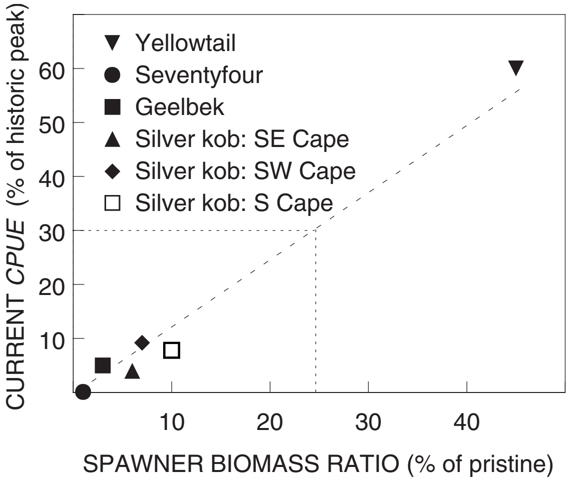

Fig. 6: Relationship between spawner biomass ratio and commercial line *cpue* ratio for six linefish stocks. Dotted line coincides with the threshold reference point (spawner biomass = 25% of pristine). Spawner biomass ratios were obtained from the following sources: Griffiths (1997b), Govender and Radebe (2000), Penney (in press), Hutton *et al*. (in press). Owing to the doubt regarding the stock status of Roman, this species was not included

Table IV: Potential sources of negative bias in the three commercial linefish datasets when used as comparative indices of abundance

1897–1906 (Gilchrist reports)

(i) Rowing boats are more dependent on weather conditions than are motorized vessels (Mansergh *et al*. 1926, 1927, 1928). In conjunction with inadequate harbour facilities this would have resulted in each boat fishing fewer days each year than at present

(ii) Smaller operational ranges, together with the absence of modern technology and longer travel periods (Fahey *et al*. 1934*), resulted in fishing power that was substantially less than that of modern vessels

(iii) At some localities, e.g. Mossel Bay, catch was at times limited by reduced demand (Fahey *et al*. 1934)

(iv) South-Eastern Cape data were strongly influenced by fishing activities at Jeffreys Bay, because catch returns were most often not obtained from Port Elizabeth, Port Alfred or East London

1927–1931 (Unpublished data)

(v) As in i–iv above

(vi) Total catch was recorded by magisterial district; given that catch returns may not have been obtained from some localities, total catch, and therefore *cpue*, could have been underestimated

1986–1998 (NMLS)

(vii) This dataset is based on compulsory catch returns and it is known that some fishers under-report their catches (Sauer *et al.* 1997). However, in most cases under-reporting stems from non-submission, with the result that *cpue* data are not as negatively biased as total catch

(viii) Part-time commercial fishers fish fewer days each year than those fishing full-time, but nevertheless are generally active during periods of high availability

* Time spent travelling, on occasions, accounted for 80% of a fishing trip

been a substantial seaward contraction in adult distributional range.

The offshore pinnacles of the central Agulhas Bank (Fig. 1), 40–140 km from the coast, functioned as a spatial refuge for several linefish species until freezer vessels were introduced in the early 1980s. Equipped with high-precision navigational equipment and long-range capability, these vessels are able to exploit this area efficiently. Red steenbras is the largest sparid caught in South African waters (maximum size = 70 kg – Smith and Heemsra 1986), and by the time the offshore fleet began targeting the Agulhas grounds, it had become a high value, prized fish,

Table V: Mean catch·boat^{-1}·year^{-1} (± *SD*) for silver kob and carpenter landed by inshore trawlers based in the South-Eastern Cape and the Southern Cape. Current (1985–1994) *cpue* is also expressed as a percentage of the historical peak (1944–1954)

Period	Mean catch·boat-year^{-1} (kg)			
	Silver kob		Carpenter	
	SE Cape	S Cape	SE Cape	S Cape
1944–1954	56 581 (11 092)	97 011 (41 312)	11 140 (3 264)	22 746 (12 296)
1963–1969	10 608 (5 076)	16 757 (6 309)	2 778 (2 056)	6 708 (1 490)
1970–1979	7 068 (2 835)	7 833 (6 585)	–	1 110 (774)
1985–1994	4 693 (997)	6 687 (2 341)	310 (229)	542 (270)
% historical peak	8.3	6.9	2.8	2.4

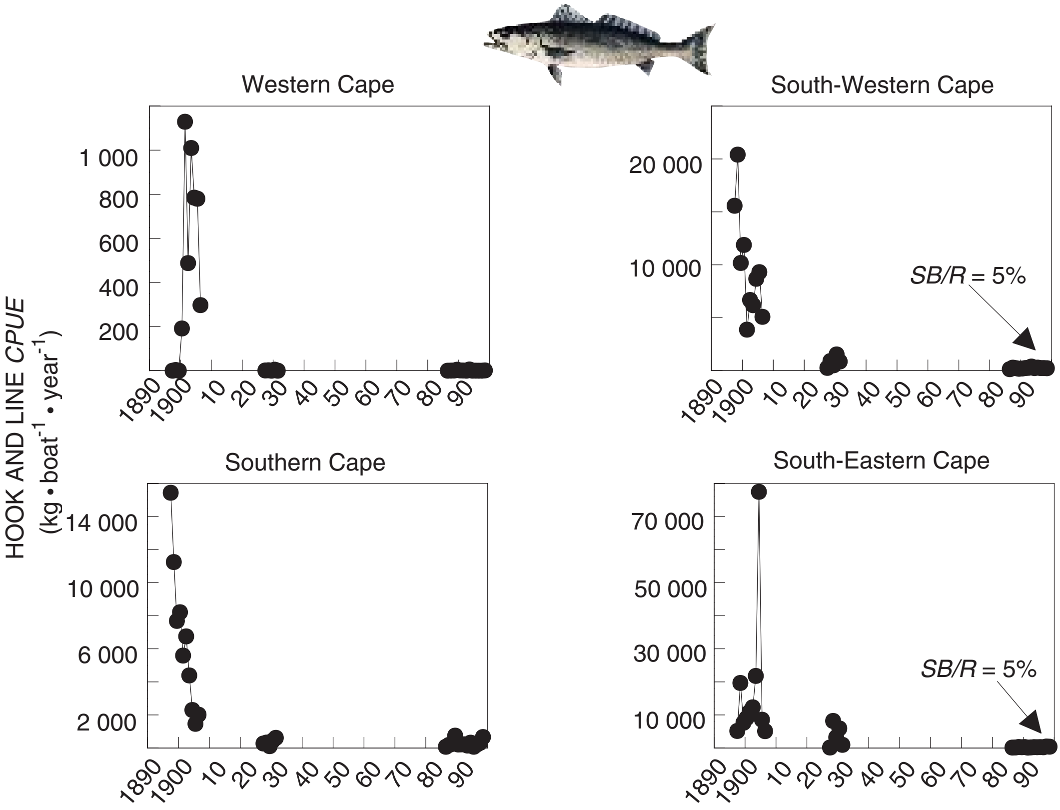

Fig. 7: Average annual *cpue* of geelbek caught by lineboats in Cape waters. *SB/R* values indicate current spawner biomass-per-recruit ratios calculated as a percentage of pristine (from Hutton *et al.* in press). Values <25% indicate stock collapse

with much competition between vessels (S. Knobel and K. Kingma, captains of freezer boats, pers. comm.). Nevertheless, catch rates dropped rapidly from almost 15 kg·fisher^{-1}·day^{-1} in 1986 to around 2 kg·fisher^{-1}·day^{-1} since 1990 (Fig. 10). Red steenbras found on the central Agulhas Bank are all large adults (5–50 kg), and because they spawn there (personal observation of hydrated ovaries), their demise is likely to have a negative impact on recruitment to nearshore fishing grounds off the Southern Cape and South-Western Cape. Catch rates of adult steenbras off northern Transkei and southern KwaZulu-Natal (Van der Elst and Garratt 1984) and in the East London area (Winch 1999) have also declined, but owing to greater accessibility there, this occurred before 1970. Protected by strong currents and historically low fishing effort, adult red steenbras are still abundant off the central and southern Transkei (Kei River to Coffee Bay – Hecht and Buxton 1993). This information suggests that there has been a coastwise as well as a seaward contraction in the range of adult steenbras abundance.

Offshore catch rates of carpenter are currently much higher than those found inshore (Fig. 4). However, the declining nearshore trends indicate that these are unlikely to be sustained. Current research reveals that the offshore catch consists primarily of large adults (MCM, unpublished data). Offshore operations could therefore have a substantial impact on remaining spawner biomass, if they continue unimpeded.

COOL/TEMPERATE REEF FISH

Cpue of Hottentot in the Western Cape plummeted between the turn of the century and the period 1927–1931, but increased slightly from then until the period 1986–1998 (Fig. 11) – the latter can be attributed to the introduction of skiboats allowing access to

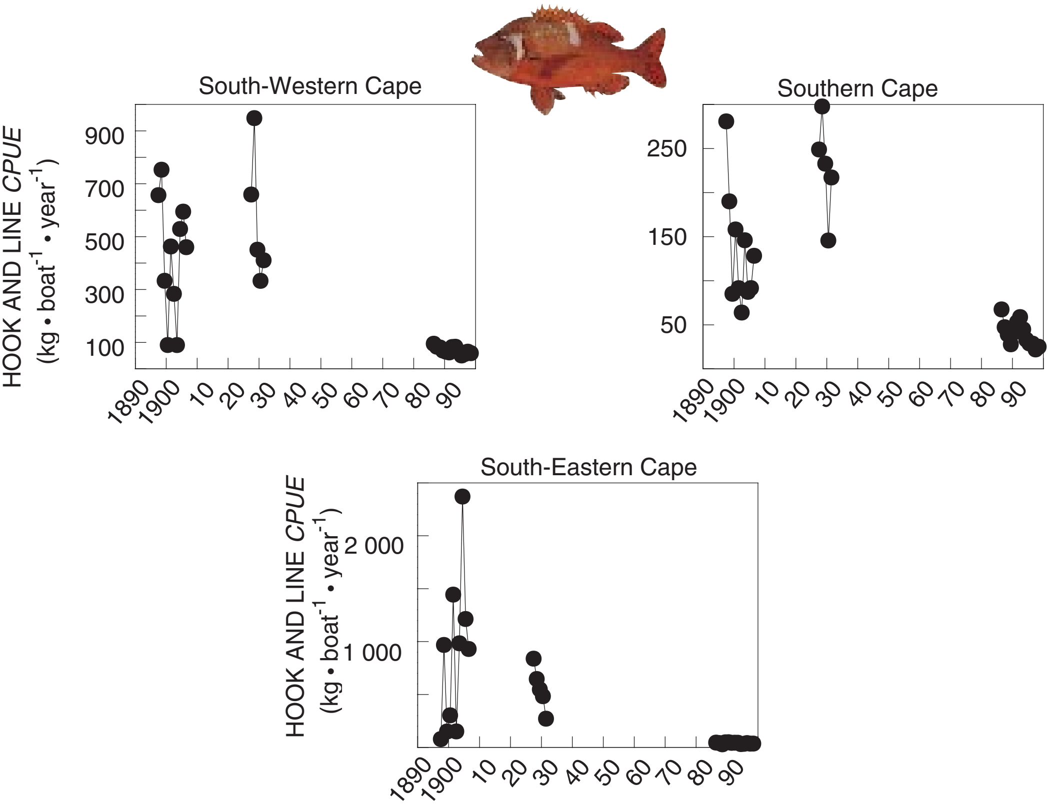

Fig. 8: Average annual *cpue* of Roman caught by lineboats in Cape waters

previously inaccessible areas. Catch rate of hottentot (and white stumpnose – Fig. 12) in the South-Western Cape was, however, highest during the period 1927–1931. This is attributed to a switch in targeting, associated with declining catches of preferred species such as silver kob and geelbek. Currently, South-Western Cape fishers target hottentot when larger species are not available.

Evidence from tagging (Wilke and Griffiths 1999) and spatial catch analyses (Griffiths & Beckley 2000) suggest that white stumpnose in the Western Cape, South-Western Cape and Southern Cape exist as three separate stocks. Although once an important linefish resource in the Southern Cape, the mean annual *cpue* of white stumpnose is now <1% of historical values (Table III). Given that the Southern Cape stock is the only stock exposed to trawling, it would appear that trawling contributed to its decline. Based on *cpue* trends, the Western Cape and South-Western Cape stocks do not appear to have been depleted to the same extent.

PELAGIC NOMADS

Catch rates of pelagic nomads such as yellowtail and snoek (Wilke and Griffiths 1999) have not declined as dramatically as those of coastal migrants and resident species (Table III). The annual snoek catch has been characterized by wide fluctuations throughout the 20th century (Crawford *et al*. 1995), but these have occurred independently of effort, and there is no evidence for a declining trend. There have also been shifts in the proportion of the snoek stock east of Cape Point (Nepgen 1979a), which explains the higher catch rates in the South-Western Cape in 1906 and between 1927 and 1931 (Fig. 13). Increased *cpue* in the southern Cape during the period 1986–1998 is attributable to the exploitation of the offshore pinnacles of the central Agulhas Bank. Most of the yellowtail catch is made in the South-Western Cape and Southern Cape (Fig. 14). Higher catch rates in the latter region during the period 1986–1998 are the result

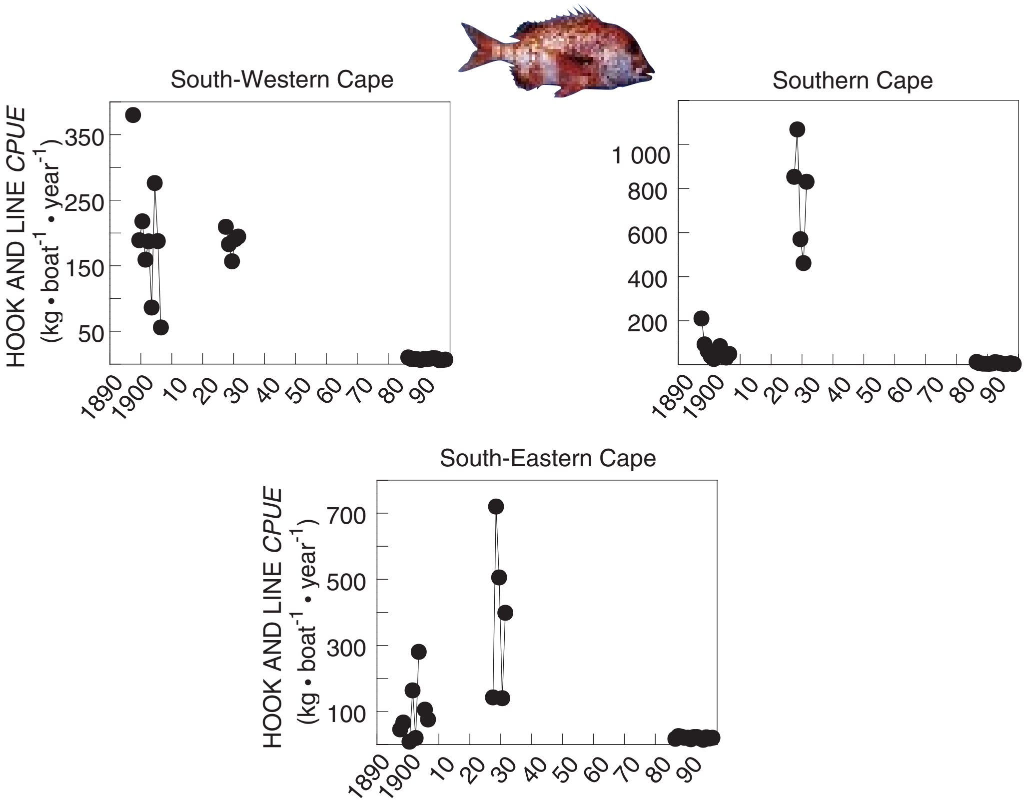

Fig. 9: Average annual *cpue* of red stumpnose caught by lineboats in Cape waters

of the discovery (in 1932) and subsequent exploitation of the 5 mile ("Vlak" Bank) off Struis Bay.

Current effort levels and vessel mobility are such that there is often great competition between vessels (sometimes as many as 50) fishing the same shoal of pelagic nomads. This may negatively bias current estimates of *cpue* for such species because it may lead to effort saturation, and more directly, vessel activity often suppresses the feeding activity of the fish (L. Hutchings, MCM, pers. comm.).

Trends in fishery-independent data

The catch rates of reef fish of a higher trophic level declined dramatically between the two fishery-independent surveys conducted in 1931–33 and 1987–93 off the Southern Cape (Table I). Declines in *cpue* were 75% for carpenter, 84% for red steenbras, 94% for dageraad and 99.8% for seventyfour. Large reductions in the contribution of dageraad to linefish catches in Port Alfred after 1960 (Hecht and Tilney 1989), and inverse correlation between the contribution of dageraad to redfish catches and level of exploitation at several localities in 1980 (Crawford and Crous 1982), suggest declining trends throughout its range. The proportional decline observed for seventyfour was similar to that calculated from commercial data, i.e both >99%. Populations of carpenter and red steenbras in the survey area were almost certainly seeded by partially protected adult stocks on the offshore Agulhas Bank and Transkei; had this not been the case, declines would have been even greater.

In contrast to the shoaling predators, the *cpue* of red stumpnose and Roman increased between surveys, more so in the case of the latter (Table I).

Trends in commercial catch composition

In addition to declining trends in *cpue*, temporally related changes in the ranking of species within each region suggests that serial overfishing has also occurred (Figs 15–18), particularly along the eastern seaboard

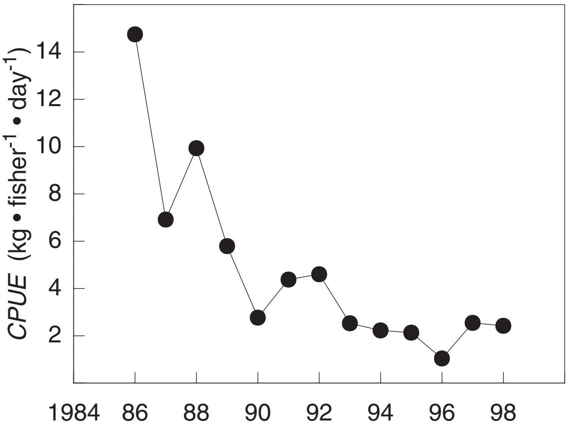

Fig. 10: Average *cpue* of red steenbras caught by lineboats on the offshore fishing grounds of the Agulhas Bank between 1986 and 1998. Effort targeted at pelagic nomads (snoek and yellowtail) was excluded from the analysis

(Cape Point to Kei River). With the decline of inshore shoaling species – first geelbek and seventyfour, and then silver kob – vessels, facilitated by developing technology, moved farther offshore; as a result the importance of yellowtail, carpenter[2] and hake increased throughout the 20th century.

WESTERN CAPE

Owing to the large size and availability of the snoek resource, it played an important role in the development of the linefishery during the early 1800s, especially on the West Coast (Lees 1969). Throughout the 20th century, it remained the premier commercial linefish of the Western Cape (Fig. 15). Other important species of the Western Cape have included hottentot, mackerel, hake and white stumpnose. The contribution of warm/temperate species to the West Coast catches have never been substantial, but catch rates of such species were considerably higher at the turn of the century when stock sizes were larger (Fig. 15), suggesting range contractions concomitant with population declines.

SOUTH-WESTERN CAPE

Based on relative importance, the linefish of the South-Western Cape at the turn of the 20th century can be divided into three categories. Geelbek and carpenter were clearly the most important, followed by a group consisting of silver kob, snoek, yellowtail and mackerel, and finally by a category consisting of five invertebrate-feeding sparids and hake (Fig. 16). With the depletion of geelbek and carpenter, snoek had by 1927 become the most important species, followed by carpenter, mackerel, silver kob, geelbek and yellowtail. Although catch rates have declined by an order of magnitude, the order of the top five species has remained essentially the same, with the exception that mackerel and yellowtail exchanged positions. Given that the relative catch rates within each sampling period also provide an indication of catch composition, the contribution of invertebrate feeding sparids (hottentot,

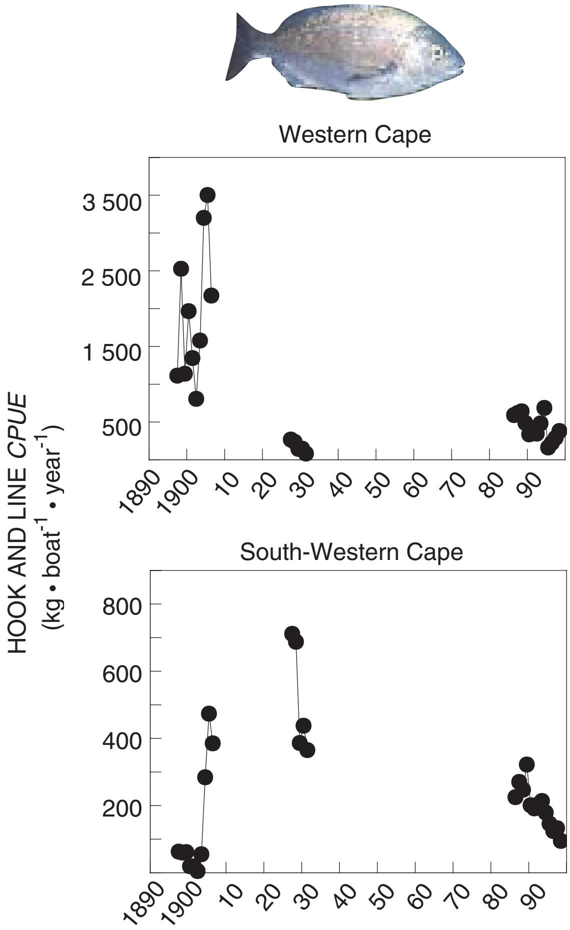

Fig. 11: Average annual *cpue* of hottentot caught by lineboats in Cape waters

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[2] Owing to cooler winter temperatures, carpenter are found closer to the coast in the South-Western Cape, and were consequently an important species in this region from the beginning of the 20th century,

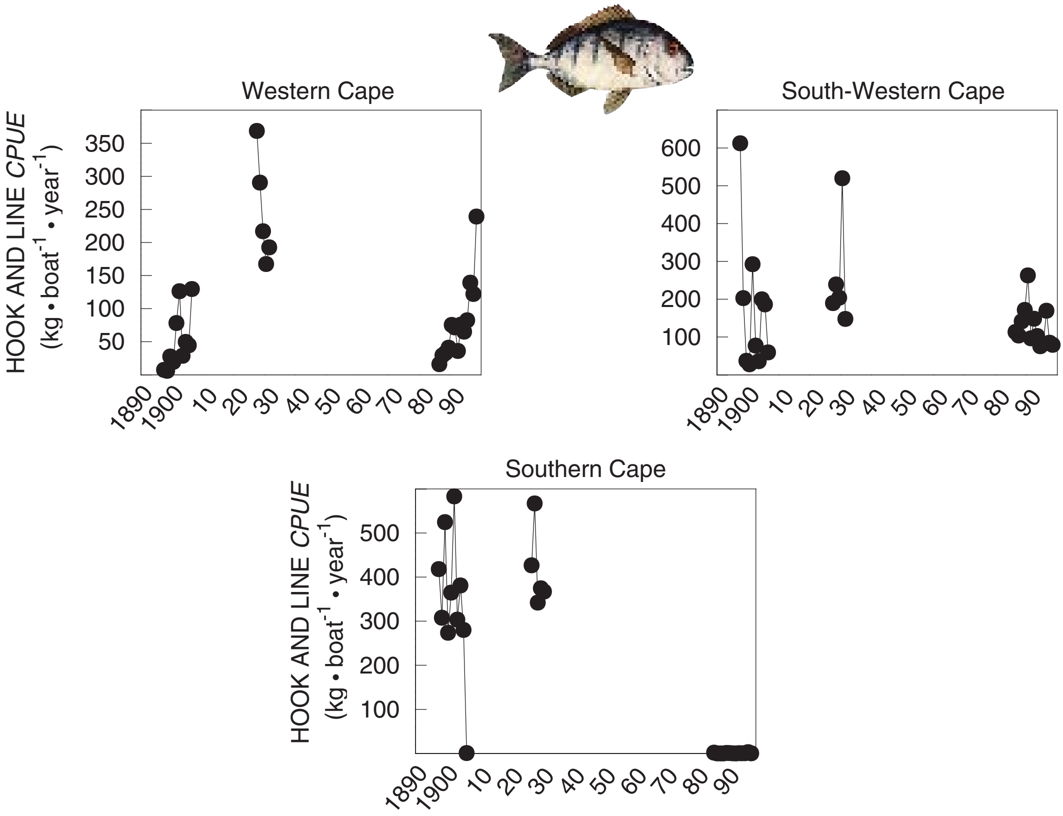

Fig. 12: Average annual *cpue* of white stumpnose caught by lineboats in Cape waters

white stumpnose and Roman) to linefish catches in the South-Western Cape increased with the demise of the target species.

SOUTHERN CAPE

The important linefish species in the Southern Cape at the turn of the century were, in decending order, geelbek, silver kob, carpenter, seventyfour and white stumpnose (Fig. 17). Following the demise of geelbek, the mainstay of the fishery during the period 1927–1931 consisted primarily of silver kob and carpenter, although red stumpnose, hake, white stumpnose, geelbek, Roman and seventyfour also contributed substantially to catches. The 1986–1998 period witnessed some fairly substantial changes to the catch composition in the Southern Cape. In descending order the most important species were hake, carpenter, silver kob, yellowtail, snoek and geelbek. The dramatic escalation in the importance of hake is attributable to the development of lucrative foreign markets and the accessibilty of the resource to the linefishery between Mossel Bay and Plettenberg Bay. The importance of yellowtail is the result of the discovery of the Vlak Bank off Struis Bay (in the early 1930s), where most of the current catch is made. That of snoek is attributable to exploitation of offshore pinnacles by freezer vessels. The previously inaccessible offshore pinnacles were also responsible for the sustained importance of carpenter in the region. It is noteworthy that white stumpnose, red stumpnose and seventyfour can no longer be considered important species in the Southern Cape.

SOUTH-EASTERN CAPE

The most important linefish in the South-Eastern Cape at the turn of the 20th century were, as in the Southern Cape, geelbek and kob; these were followed by seventyfour and carpenter (Fig. 18). By 1927, silver

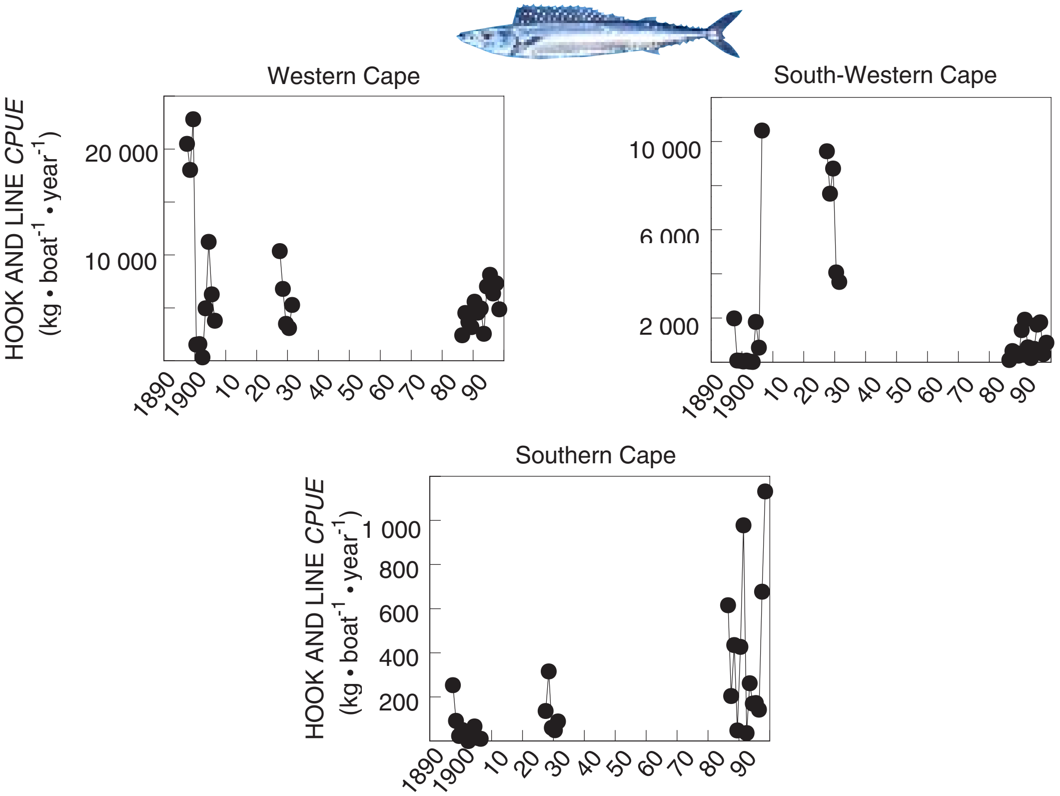

Fig. 13: Average annual *cpue* of snoek caught by lineboats in Cape waters

kob had become the primary species, with catch rates of geelbek and seventyfour having suffered dramatic declines. Precipitated by declining catch rates inshore, and facilitated by technological advances, vessels moved progressively farther offshore. As a result, the relative importance of carpenter, hake and panga was substantially higher during the period 1986–1998. Nevertheless, kob and geelbek also contributed substantially to catches then.

Trends in fishery-independent catch composition

The selective removal of shoaling, predatory reef fish brought about large differences in catch composition between two research surveys conducted off the Southern Cape (Fig. 19). The dominant species (by number) in the 1931–1933 surveys was seventyfour (48%), followed by red steenbras (12%), dageraad (11%), carpenter (11%), Roman (10%) and santer *Cheimerius nufar* (6%). In contrast, Roman (55%) dominated the catch (at least in terms of species common to both surveys) during the second survey, followed by santer (21%), carpenter (10%), red steenbras (6%) and red stumpnose (5%). These results are consistent with those obtained from tropical reef ecosystems, for which dramatic changes, primarily the removal of piscivores, occur at low fishing intensities or when fish communities are fished for the first time (Jennings and Polunin 1996, 1997, Jennings *et al*. 1996, Jennings and Kaiser 1998).

DISCUSSION

Stock status

According to the South African LMP, changes in *cpue* and catch contribution may each be used as interim indicators of stock status. In both cases, declines of 75% or more indicate overexploitation (Griffiths

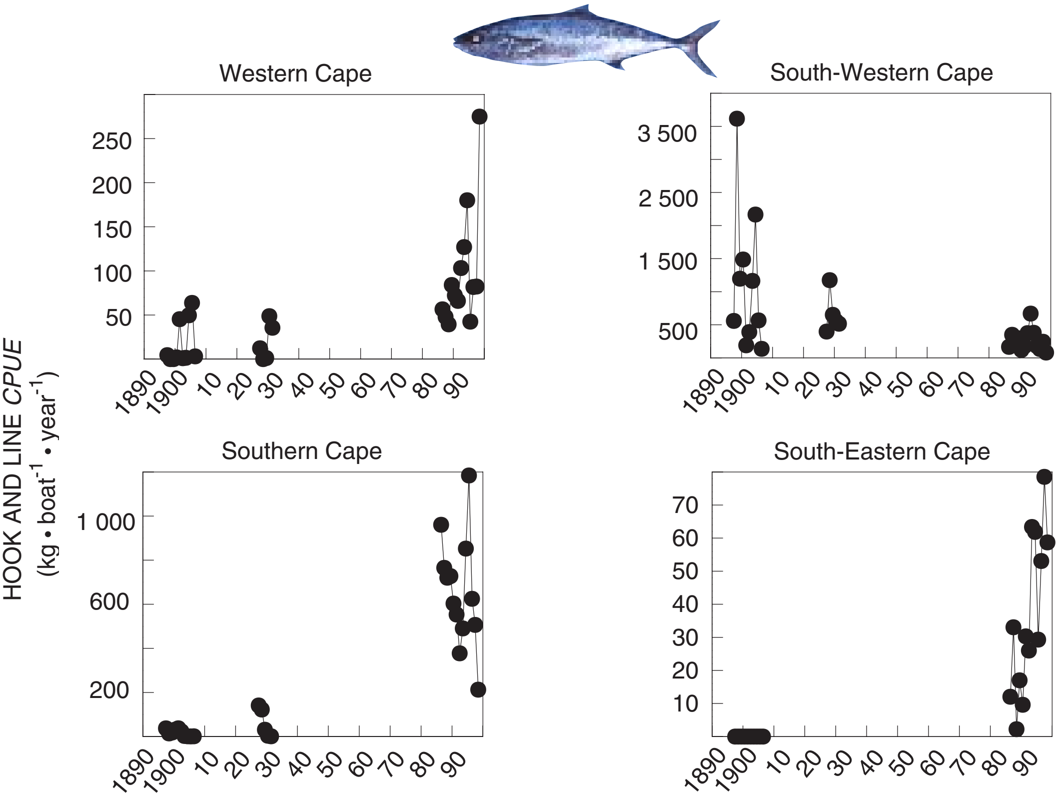

Fig. 14: Average annual *cpue* of yellowtail caught by lineboats in Cape waters

1999). The 75% reference point was, however, determined arbitrarily, and it remains to be tested in the context of the linefishery. Spawner biomass per recruit ratios of <25% of pristine, on the other hand, are indicative of stock depletion in long-lived species (as in the case of most linefish) and yield a high risk of collapse (Clark 1991, Mace and Sissenwine 1993, Thompson 1993, Mace 1994). Spawner biomass per recruit and *cpue* ratios (for those stocks that had been assessed quantitatively) are positively correlated (Fig. 6). Owing to the lack of data in the mid-region (i.e. spawner biomass ratios of 15–35%) the functional form of the relationship between spawner biomass per recruit ratio and *cpue* cannot be delineated accurately. Nevertheless, linear interpolation suggests that declines in catch rate of 75% (in the present commercial dataset) correspond to a spawner biomass per recruit ratio of approximately 20% (Fig. 6). This finding tentatively supports the *cpue* reference point of the LMP. Reductions in *cpue* of >90% coincided with spawner biomass ratios of <10%, and are concluded therefore to be indicative of severe stock depletion.

Even though the catch rate of Roman in the South-Eastern Cape is only 4.65% of the peak historical value, spawner biomass per recruit was estimated to be 60% of pristine there in 1986 (Buxton 1992), so suggesting that the population was underexploited. This disparity may, however, be explained in terms of fishing practice, the life history of Roman and the assessment method used. The bulk of the demersal linefish catch consists of shoaling species that aggregate over primary reefs or portions thereof, often related to or defined by substratum profile. Linefishers generally develop a repertoire of such sites, which they visit on a regular basis. Roman are territorial, protogynous hermaphrodites, living solitarily or in small groups (one male and several females – Buxton 1990). The population is consequently more evenly spread over reefs of various quality than are shoaling species. As a result, there is always a reserve of large individuals on unfished "secondary" reefs that may replace those removed from primary sites. Tag studies show that Roman are highly resident, but that movement of up to 20 km is common (Wilke and Griffiths 1999). Diving ob-

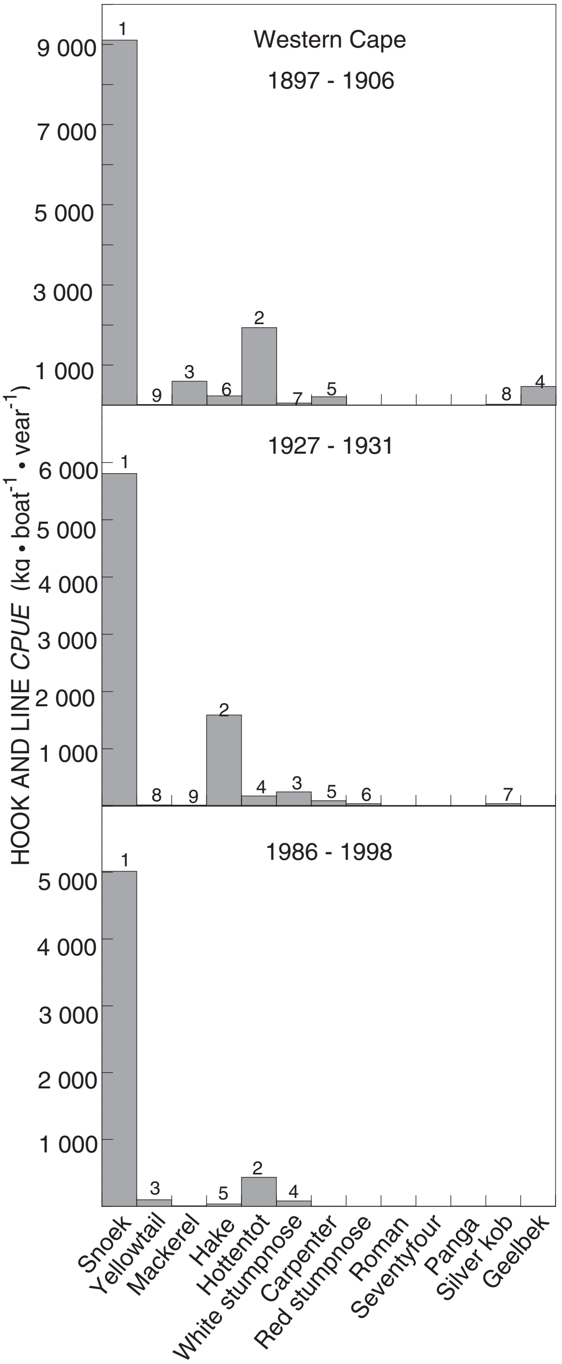

Fig. 15: Relative catch rates of important linefish by lineboats in the Western Cape during three periods of the 20th century: 1897–1906, 1927–1931 and 1986–1998. Numbers above the bars denote species ranking

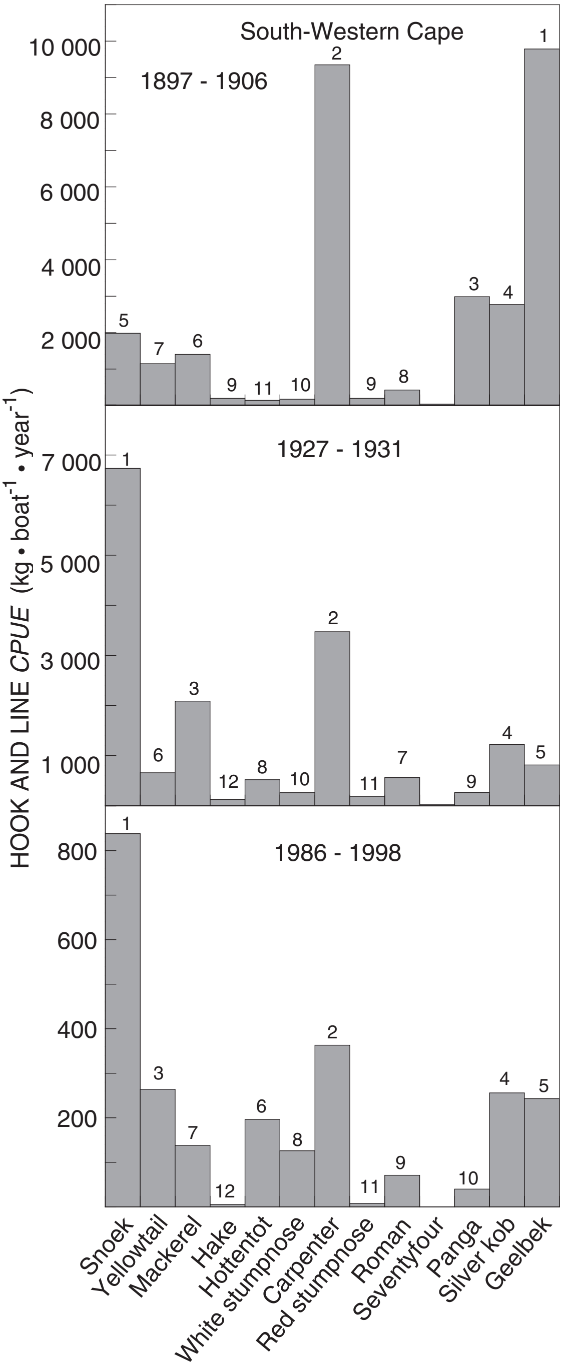

Fig. 16: Relative catch rates of important linefish by lineboats in the South-Western Cape during three periods of the 20th century: 1897–1906, 1927–1931 and 1986–1998. Numbers above the bars denote species ranking

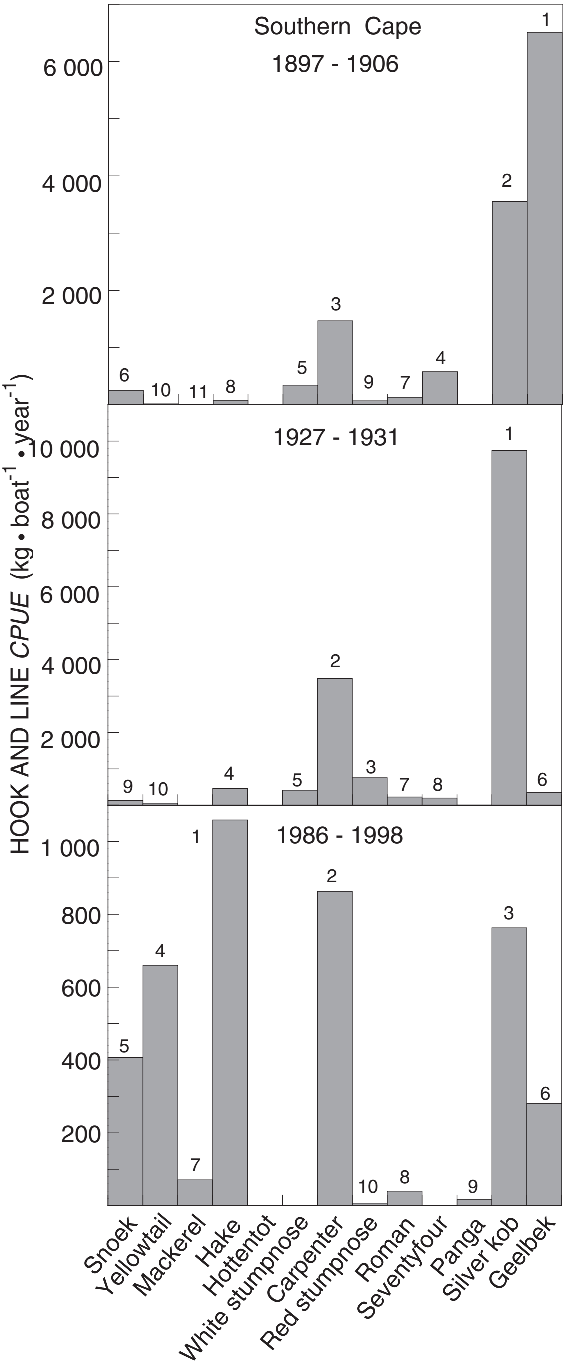

Fig. 17: Relative catch rates of important linefish by lineboats in the Southern Cape during three periods of the 20th century: 1897–1906, 1927–1931 and 1986–1998. Numbers above the bars denote species ranking

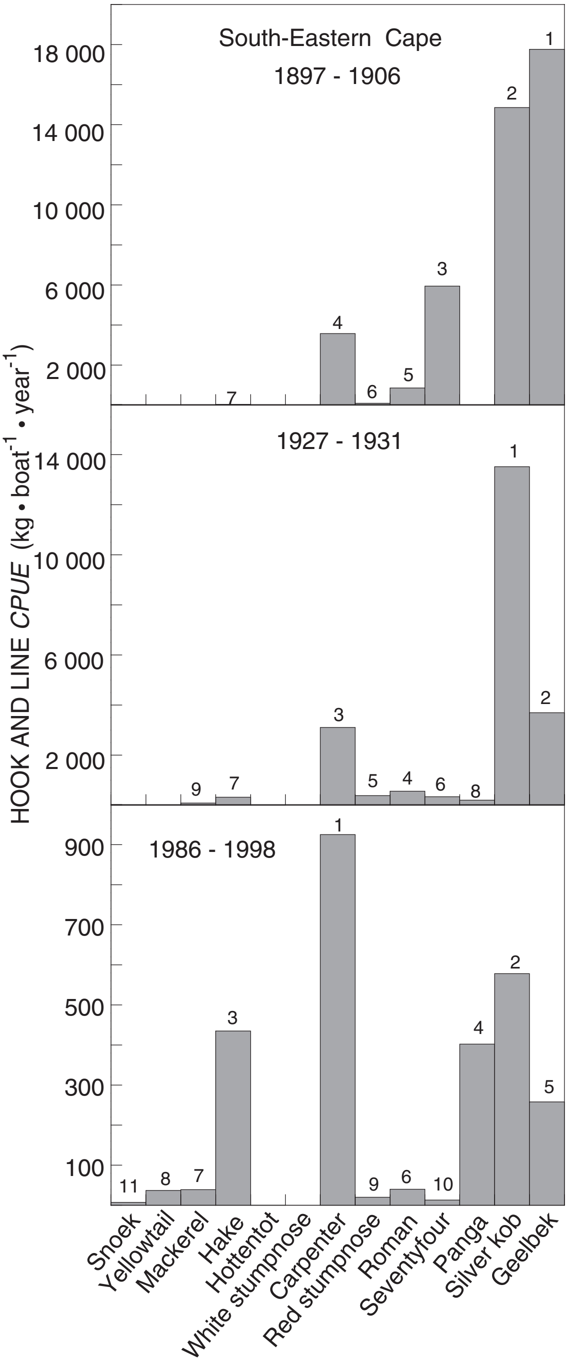

Fig. 18: Relative catch rates of important linefish by lineboats in the South-Eastern Cape during three periods of the 20th century: 1897–1906, 1927–1931 and 1986–1998. Numbers above the bars denote species ranking

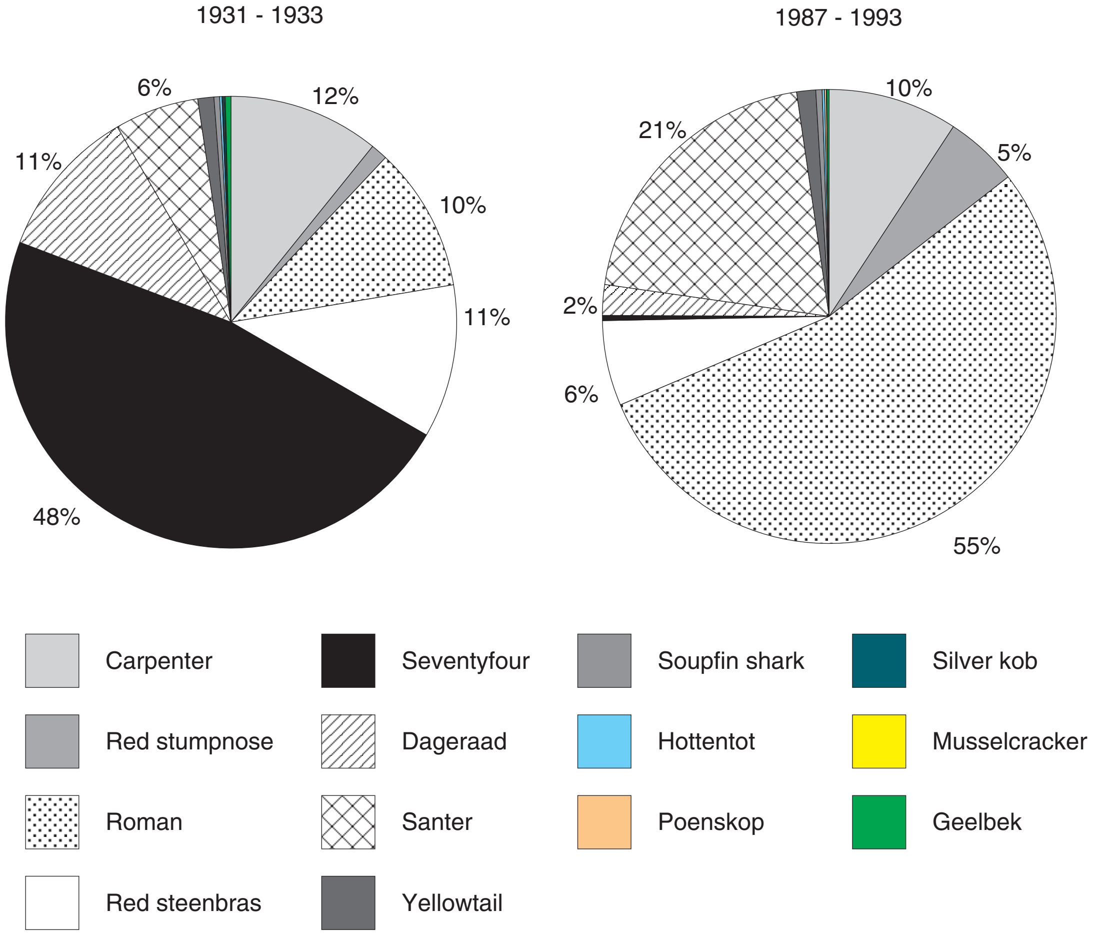

Fig. 19: Relative contribution of species common to two fishery-independent surveys, 1931–1933 and 1987–1993, conducted on identical reef complexes in the Southern Cape

servations by the current author indicate that large fish removed from prime reefs by spearfishing are replaced regularly. The age/size composition of individuals on the primary sites, and hence in the catch, may therefore not mirror that of the total population. In addition, even the size composition of the total population would not reflect exploitation rates (or changes in population size) to the same degree as in resident shoaling species. Under such conditions, the catch curve method used by Buxton (1992) is predicted to underestimate total mortality, leading to overestimates of population size. Roman densities in exploited areas of the South-Eastern Cape were <25% of those in a nearby reserve (Buxton and Smale 1989), supporting this theory. In the absence of a complex survey, incorporating a spatially structured tagging programme, trends in *cpue* probably provide a better indication of Roman stock status than assessment methods that rely on catch curves.

It is interesting that, in contrast to the shoaling predators, the *cpue* of red stumpnose and Roman increased between fishery-independent surveys (Table I). This is unlikely to reflect an increase in abundance. Commercial *cpue* for these two species declined markedly in all regions during the same period. Therefore, the increase is more likely to be the result of increased access to baits, commensurate with the declining abundance of aggressive shoaling predators. Recapture rates obtained for red steenbras (21%) during the second survey were three times those of Roman (5.9%) and twice those of red stumpnose (9.6%), supporting the theory of higher catchability

Table VI: Stock status indicators calculated from commercial and fishery-independent datasets for the Southern Cape. %C is percentage change in contribution to catch, and %*cpue* is percentage change in *cpue* between sampling periods. %C values were between 3.1 and 4.1 times greater than %*cpue* values for a given species and dataset

Species	Datasets compared					
	(1986–1997)* (1898–1906)		(1986–1997)* (1927–1931)		(1986–1997)+ (1931–1933)	
	%C	%*Cpue*	%C	%*Cpue*	%C	%*Cpue*
Snoek	501.9	160.9	1 189.5	313.1		
Yellowtail	12 111.9	3 882.4	4 179.3	1 100.0	116.6	35.0
Mackerel	3 164.3	1 014.3	81 743.9	21 515.2		
Hake	4 525.8	1 450.7	872.8	229.8		
White stumpnose	0.7	0.2	0.7	0.2		
Carpenter	183.4	58.8	94.2	24.8	90.9	25.0
Red stumpnose	31.2	10.0	3.5	0.9	433.3	127.0
Roman	94.5	30.3	66.4	17.5	550.0	153.0
Seventyfour	<0.1	<0.1	0.1	<0.1	0.8	0.2
Panga	3 571.5	114.8	685.5	180.4		
Silver kob	67.0	21.5	29.8	7.8		
Geelbek	13.5	4.3	300.7	79.2		
Red steenbras					50.0	16.0
Dageraad					20.0	6.0
Santer					350.0	102.0

* Commercial
+ Fishery independent

of piscivorous predators (Wilke and Griffiths 1999). One reason why a similar trend was not evident in the commercial data is that, unlike the survey data, the earliest dataset was generated from reefs that had already been fished for some time, i.e. pristine catch rates of Roman and red stumpnose may have been much lower than those recorded for the period 1897–1906. It is also noteworthy that the nylon lines used during the recent survey were much thinner than those used by commercial fishers (0.6 v. 0.9 mm) or the more visible flax lines used during the first survey, and in conjunction with lower predator densities, may have resulted in higher catch rates (relative to available biomass) of red roman and red stumpnose.

Given that changes in catch contribution are influenced not only by the size of the stock, but also by the catch rate and stock size of other species, the value of catch contribution as a stock status indicator is theoretically limited. For example, if all stocks in a given area were to be overexploited at the same rate (relative to pristine levels), no change in catch contribution would be observed. Alternatively, if the catch of one species were to increase dramatically, through increased targeting, long-term environmental effects etc., substantial declines in the catch contribution of other species would be recorded in the absence of any change in stock size. It is therefore not surprising that, during the present study, proportional change in *cpue* and in catch contribution were so dissimilar (Table VI). Expressed as percentages of historical values, current catch contribution was consistently higher than *cpue*: by 1.5–2.2 times off the western Cape, 6.6–12 off the South-Western Cape, 3.1–4.1 off the Southern Cape (Table VI) and 8.7–15.7 off the South-Eastern Cape.

To appreciate the practical implications of this, the example for carpenter in Table VI is noteworthy. When comparing recent commercial data (1986–1997) with those from the turn of the century (1898–1906), catch contribution increased by 183.4%, whereas *cpue* declined by 41.2%. Similarly, when comparing recent data with those from the period 1927–1931, catch contribution declined by 5.8%, whereas *cpue* declined by 75.2%. Given that *cpue* has a more robust foundation as an index of stock size (Hilborn and Walters 1992), and that proportional decline in linefish *cpue* correlated well with that from stock assessment (Fig. 6), it is concluded that the *cpue* should take precedence over catch contributions when stock status indicators are used to evaluate stocks in the absence of conventional stock assessment. Consideration could also be given to reducing the proportional change in catch contribution taken to signify overexploitation, for example from a reduction of 75 to 50% or even less.

In spite of technological advances, such as combustion engines, nylon lines, echo-sounders, electronic navigational aids, onboard freezer facilities and larger vessels, which collectively have increased dramatically the harvesting potential of modern vessels, the catch

Table VII: Life history summaries for 12 traditionally important linefish species. T_{50} = age at 50%-sexual-maturity, T_{max} = maximum age, W_{max} = maximum size. Pelagic fish are predominantly sardine *Sardinops sagax* and anchovy *Engraulis capensis*, but also include round herring *Etrumeus whiteheadi* and horse mackerel *Trachurus trachurus capensis*

Species	T_{50} (years)	T_{max} (cm)	T_{50}/T_{max}(%)	W_{max} (kg)	Diet
Carangidae					
Yellowtail[1]	3.5	10	35	35	Pelagic fish and squid
Gempylidae					
Snoek[2,3,4]	3	10	30	9.5	Pelagic fish and crustaceans
Sparidae					
**Hottentot[5,6]	5	12	42	3	Predominantly algae, echinoderms, small crustaceans and molluscs
*Seventyfour[7,8]	8.8	20	44	14	Pelagic fish and squid
*Carpenter[5,9]	4	20	20	4	Colonial tunicates, pelagic fish and squid
*Roman[4,10,11]	2	17	12	4	Large benthic invertebrates, particularly crustaceans, molluscs and echinoderms
*Red stumpnose[4,9]	?	?	?	?	Large benthic invertebrates, particularly crustaceans, molluscs and echinoderms
**White stumpnose[4,12]	4	21	19	3	Benthic invertebrates, particularly crustaceans and molluscs
*Red steenbras[13,14]	7.2	33	22	70	Reef fish
*Dageraad[11,15]	7.7	21	56	8.7	Large benthic invertebrates, particularly echinoderms, crustaceans and molluscs
Sciaenidae					
**Silver kob[4, 16,17,18]	1.7	25	6.8	36	Pelagic and demersal fish and squid
Geelbek[19]	5	9	55	15	Pelagic fish

[1] A.J. Penney (pers. comm.), [2] Griffiths (in prep.), [3] Nepgen 1979b, [4] Nepgen 1982, [5] Nepgen 1977, [6] Pulfrich and Griffiths (1989), [7] Ahrens (1964), [8] Govender and Radebe (2000), [9] Griffiths and Brouwer (unpublished data), [10] Buxton (1984), [11] Buxton (1993), [12] Griffiths (in press), [13] Smale (1986), [14] Smale (1988), [15] Buxton (1987), [16] Smale and Bruton (1985), [17] Griffiths (1996), [18] Griffiths (1997c), [19] Griffiths and Hecht (1995)

* Endemic to South Africa

** Endemic to Namibia and South Africa

rates of many important linefish species are <10% of values recorded during the first third of the 20th century. This must indicate severe stock depletion.

Baseline information, from before the onset of exploitation, are not available. Rowboat catch rates were in all probability highest in the mid 1800s, and absolute peaks in catch rate could have been anticipated just after the technological explosion of the 1950s. As a result, percentage current values calculated using 1850s or 1960s catch rates (as the denominator) are likely to have been even lower than those presented in Table III. Similarly, the 1931–1933 fishery-independent survey was conducted without such technological advancements as nylon lines, echo-sounding technology or electronic navigational aids, with the result that the catch rates would be expected to be negatively biased in relation to those from the more recent (1987–1993) survey.

Causes of stock decline

Life history characteristics of vulnerable species (i.e those demonstrating declines in *cpue* of >75%) include predictable location in time and space (i.e. coastal migrant or resident), longevity (>15 years), late maturity (relative to maximum age), e.g. geelbek, or both of the latter, e.g. seventyfour (Table VII). Within this "vulnerable" group, as evidenced by patterns in serial overfishing and high rates of recapture, large piscivorous species appear to be most vulnerable to linefishing. Almost all the depleted species were warm/temperate, k-selected, bottom-dwelling species of the South African eastern seaboard, several of which are also endemic (Table VII). Characteristics of resilient species include nomadic movement, presumably resulting in unpredictable distribution and therefore temporary harvest refugia, and shorter (<15 years) lifespans.

Based on these findings, any resident reef fish that lives longer than 15 years, and is susceptible to hook and line, can be expected to be especially vulnerable to overexploitation by the Cape commercial linefishery. Where stock assessments and historical *cpue* trends are not available for such species, consideration might be given to applying the precautionary principle to base regulations on species with similar life-history strategies, and from similar habitats (i.e. equivalent fishing pressure).

Although white stumpnose live in excess of 15 years

(Table VI), catch rates in the Western Cape and the South-Western Cape have not declined to the same degree as those of other demersal fish. However, white stumpnose commonly occur over both reef and sand and, given that linefishers target bottom fish on reef, the portion of the population on sandy substrata is naturally protected, except in the Southern Cape where the sandy habitat is trawled and *cpue* has declined radically.

When commercial permits were issued for the South African linefishery in 1985, virtually all applicants were successful, as either part-time (B permits) or full-time (A permits) operators. Although the intention was to cap effort at this level, most of the damage to the reef fish populations had already been done, i.e. with a smaller and technologically less advanced fleet. It is therefore clear that the depletion of reef fish was brought about by the combination of unregulated effort and k-selected life-history traits. What is perhaps equally important is the mechanism by which heavily depleted stocks have maintained a commercial fishery of more than 2 000 vessels. The answer to this question must be placed squarely in the court of effort subsidization, which has taken the following three forms:

(i) *Part-time commercials* – Fishers in this category have commercial access to the linefishery, but generate most of their income from other sources. They range from a large component of essentially recreational fishers who subsidize their sport through selling their catch (illegally, if they are truly recreational fishers, in terms of the Marine Living Resource Act) to those who subsidize their incomes to varying degrees. The extent of this type of activity is illustrated by the fact that <20% of the boats active between 1994 and 1997 caught more than 80% of the reported catch (NMLS). Only 26% of vessels caught more than 5 tons per year. Combining the price of fish and operational costs, such a catch would not be sufficient to sustain a permit-holder as a sole source of income.

(ii) *Participants with multiple access* – This category of participants has access to traditional linefish as well as to other more lucrative resources, e.g. tuna, rock lobster, squid. As a result, large and highly efficient freezer vessels focus on linefish stocks when their other target species are unavailable (including closed seasons) or during periods of increased linefish availability. Tuna and squid boats are currently responsible for some 15% of the reported traditional linefish catch (NMLS).

(iii) *New entrants* – Combining the low cost of smaller vessels (skiboats) and transferability of commercial permits, it has been relatively easy to buy into the fishery. However, owing to the marginal return rate for small vessels, and perhaps a lack of experience, such new entrants often fail. The cycle is therefore completed when the vessel and permit are sold to the next new entrant. As many as one-third of all linefish commercial permits changed hands each year during the period 1986–1997 (MCM, unpublished data), indicating the high frequency of the above scenario. The uneconomic nature of the fishery is also supported by the continued reduction in the number of active commercial vessels since 1989 (Fig. 2).

In all three of these categories, effort is subsidized by external sources, so precluding the inherent economic regulation of effort that is normal among other commercial fisheries (Seijo *et al*. 1998).

Management implications

Apart from the loss in annual yield associated with the low populations levels of many of the warm/temperate Cape linefish (Griffiths 1997b, Jennings and Lock 1996), the risk of stock collapse and commercial extinction in such long-lived species is extremely high (Musick 1999, Griffiths *et al*. 1999). Empirically, seventyfour had an estimated spawner biomass per recruit ratio in 1960 (Govender and Radebe 2000) that was at the threshold reference point (25% of pristine – Griffiths *et al*. 1999), i.e. larger than the recent estimates for several other species (Fig. 6); seventyfour have now essentially disappeared from the fishery. According to the threshold (limit) reference point and stock status indicators of the LMP, most of the demersal Cape linefish are overexploited or collapsed, particularly the warm/temperate species of the eastern seaboard (Tables III, V, Fig. 6).

Most of the depleted species are important predators of both benthic and pelagic organisms (teleosts and large invertebrates – Table VII) and their removal could have precipitated substantial changes to the species diversity and the trophic pathways of shallow (<100 m) subtidal reef ecosystems off the Cape. Surveys in the Southern Cape revealed that, not only were predators more abundant in a marine reserve (Buxton and Smale 1989), but that there were also differences in the familial composition of cryptic fish on exploited and unexploited reefs (Burger 1990). The exploitation of predators of large invertebrates (including a large sparid fish) has recently been shown to change the community structure and to reduce both primary and secondary production in a temperate-reef ecosystem off New Zealand (Babcock *et al*. 1999).

Sardine *Sardinops sagax* and anchovy *Engraulis capensis* are important food of pelagic and several reef-associated linefish (Table VII). These two prey species spawn on the Agulhas Bank and utilize the Benguela Current to transport eggs and larvae to nutrient-rich nursery areas on the West Coast (Shelton and Hutchings 1990, Armstrong *et al.* 1987, Hampton 1992, Barange *et al.* 1998, 1999). Thereafter, juvenile sardine and anchovy return to the Agulhas Bank to spawn, biologically pumping energy/carbon from the highly productive West Coast upwelling system onto the eastern seaboard. This process presumably allows warm/temperate reef ecosystems to support larger shoals of piscivores than the reefs could sustain alone. It is therefore not incidental that commercially the most important reef-associated fish (i.e. carpenter, silver kob, geelbek and seventyfour) have been those that feed on clupeoids. The extent to which these linefish may have fertilized reefs (nitrogen excretion and faecal pellets) is unclear, but it is possible that their demise has concomitantly reduced the links of reef ecosystems with the pelagic foodweb.

Biodiversity impact is another serious implication. Because fishing is selective with respect to heritable life-history traits such as age/size at maturity and growth, exploited populations are expected to evolve in response to harvesting (Policansky 1993). Such fishing-induced changes in life history traits have been observed for many species worldwide (e.g. Borisov 1978, Rijnsdorp *et al.* 1991, Trippel 1995, Harris and McGovern 1997). Locally, the size at maturity, size-at-sex-change and growth rate of dageraad were all lower in exploited areas than in a nearby marine reserve (Buxton 1993). Similarly, differences between the size at maturity of silver kob in the Southern Cape and South-Eastern Cape have been correlated with levels of fishing mortality (Griffiths 1997c). Although such results may reflect genetic shifts, it is difficult to separate genetic alterations from the phenotypic responses of wild populations to exploitation (Jennings and Kaiser 1998). Nonetheless, losses in genetic diversity (hetero-zygosity) have accompanied relatively small declines in population size, regarded as safe in terms of conventional management objectives (Smith *et al.* 1991). The high fishing pressure and depressed state of many linefish populations (implied by declines in *cpue* as well as stock assessments) suggest that intra-population genetic diversity could well have been reduced. However, genetic studies are necessary to confirm this possibility. The major drawback of narrowing interspecies or intraspecies diversity is that the reduced gene pools limit the ability of ecosystems or species to respond to future environmental changes, including changes in fishing practice (Boehlert 1996, Jennings and Kaiser 1998). In addition, carbon may become channeled into resources that are less desirable commercially, e.g. jellyfish, with concomitant social and economic losses (Pitcher and Pauly 1998).

Stock rebuilding initiatives

Reef ecosystems are particularly sensitive to linefishing. Research in tropical systems reveal that low fishing intensity causes large changes, primarily through the removal of species at higher trophic levels (Jennings *et al.* 1996, Jennings and Kaiser 1998). The results of the present study indicate a similar situation for South African warm/temperate systems. Owing to the sensitivity of resident, k-selected linefish to low levels of exploitation, together with the fact that many are prone to barotrauma, i.e. death upon release, it is unlikely that conventional regulations (e.g. daily bag and minimum size limits) will be effective in rebuilding such stocks (Bohnsack 1993, Buxton 1996).

No-take marine reserves are widely accepted as a management tool that most effectively addresses the negative impacts of fishing on the trophic flow, biodiversity and yield of reef ecosystems (Bohnsack and Ault 1996, Clark 1996, Roberts 1997). Communities of resident, depleted fish within such reserves generally build up rapidly. They have the potential to establish a natural ecosystem balance (Bennett and Attwood 1991, Dugan and Davis 1993, Rowley 1994, Roberts 1995, Bohnsack and Ault 1996, Russ and Alcala 1996a), and they may enhance fisheries in adjacent areas through adult emigration and seeding by eggs and larvae (Carr and Reed 1993, Russ and Alcala 1996b, Sladek Nowlis and Roberts 1999). Based on the dismal track record of conventional fisheries management in preventing overfishing, protecting a portion of a stock's habitat has been strongly recommended as a safeguard against management failure and fishery collapse (Russ 1996, Clark 1996, Lauck *et al.* 1998).

Communities within reserves may also provide baseline information on species assemblages, population parameters and catch rates, against which the impact of fishing in open areas may be assessed. Such comparisons will play an important role in future management of a linefishery (Griffiths *et al.* 1999). An additional advantage of reserves, particularly given the poor compliance among Cape linefishers (Sauer *et al.* 1997), is that enforcement is often easier, requiring less manpower than more conventional regulations (Pitcher and Pauly 1998).

Based on modelling exercises, recommendations for habitat protections are 20–30% to avert collapse and 40–50% to maximize yield from heavily exploited stocks (Plan Development Team 1990, Russ 1996, Holland and Brazee 1996, Sladek Nowlis and Roberts 1999). There are currently six no-take marine reserves off South Africa of between 9 and 64 km long, protecting nearshore, warm/temperate reef fish (Attwood *et al*. 1997). In combination, they encompass 11% of the 1 253 km warm/temperate coastline (Cape Point–Kei River). Given that several of the depleted species (seventyfour, red steenbras, dageraad and geelbek) range as far north as Durban (an additional 440 km) and that in many cases linefish are found beyond the seaward reserve boundary, the habitat proportion actually protected is considerably less than 11%. Because of the depleted status of many warm/temperate linefish, it is imperative that consideration be urgently given to establishing additional no-take reserves, if the objectives of the Marine Living Resources Act and international conventions are to be upheld. New reserves should also include offshore linefish habitats, particularly those of adult red steenbras.

Despite their inherent advantages, marine reserves cannot be regarded as a panacea for all management ills. Even if additional areas were to be closed to fishing, conventional regulations will still be necessary to protect resident k-selected species in heavily fished open areas (Allison *et al*. 1998). Reserves are also most suitable for resident species; they are unlikely to offer much benefit for overexploited coastal migrants (Bohnsack 1993, Clark 1996). Therefore, in South Africa, implementation of the LMP (Griffiths *et al.* 1999) should result in the development of more effective traditional regulations for migratory fish and exploited stocks of resident species.

Overexploitation of marine resources unfortunately appears to be the international norm rather than its exception (Pitcher and Pauly 1998). In most cases, including the South African linefishery, effort has not been controlled effectively, leading to overcapitalization, excessive fishing pressure and ultimately to critically low levels of spawning potential and fisheries collapse (Safina 1995, Garcia *et al*. 1999). Besides impacting directly upon the resource, part-time commercial linefishers also have substantial impact on the market practice of *bona fide* commercial South African linefishers. Given the status of the resource, the financial hardships of such linefishers (Schutte 1993) and the fact that the Marine Living Resources Act does not accommodate part-time commercial activity, access of this nature is difficult to justify. Given that some 90% of outings in the Cape are made by part-time or full-time commercial fishers (calculated from data presented in Sauer *et al*. 1997) and that appropriate commercial bag limits would not be economically viable, it is essential that the number of commercial participants be reduced if stock rebuilding, or even sustainable utilization, is to be achieved. According to stock assessments, the effort reduction required to rebuild stocks of silver kob (Griffiths 1997b), geelbek (Hutton *et al.* in press) and dageraad (Buxton 1992) to target reference points (spawner biomass per recruit = 40% of pristine) is 70, 50 and 80% respectively. Stock rebuilding typically requires initial effort/catch reductions in order to increase future long-term yields and biomass levels, with short-term losses in economic performance offset by long-term gains (Overholz *et al*. 1993). It is estimated that, if depleted species in the United States were allowed to rebuild to their long-term potential, their sustainable use would add about $8 billion to the gross domestic product, and provide some 300 000 extra jobs (Sissenwine and Rosenberg, in Safina 1995).

There must, however, be a final note of caution. Whatever is eventually decided upon, the success of fisheries management, including stock rebuilding, depends heavily on the degree of user compliance, often a function of enforcement level (Hemming and Pierce 1997). A recent national survey revealed that knowledge of, and compliance with, management regulations was generally poor among Cape linefishers (Sauer *et al*. 1997, Brouwer *et al*. 1997). This situation was attributed to inadequate enforcement and a lack of awareness (on the part of the fishers) as to the importance of such control measures in ensuring future catches. However, unless the issue of poor compliance is appropriately addressed, reversal of declining trends and the rebuilding of depleted linefish stocks will never be possible. Although future co-management through the implementation of the LMP may partially address this shortcoming, educational programmes and increased enforcement are regarded as essential (Kuperan and Sutinen 1998).

CONCLUSION

Based on the trends in *cpue* presented in this paper, it is evident that virtually all warm/temperate, bottom-dwelling, subtidal linefish have been overexploited. Apart from loss of productivity (and commensurate socio-economic losses), the risk of commercial extinction is now very high and negative impact on trophic flow and biodiversity are highly probable. In order to rebuild depleted linefish stocks, as required by South Africa's Marine Living Resources Act, the following measures are deemed essential:

- substantial reduction in commercial effort;
- a substantial (three-fold) increase in the proportion of warm/temperate reef protected by no-take marine

reserves.

- promulgation of realistic management regulations for recreational fishers (based on the methods of the LMP).
- increased enforcement capability coupled with intensive public awareness programmes.

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