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SCIENCE AND FISHERIES MANAGEMENT IN SOUTHERN AFRICA AND EUROPE©

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Case studies on southern African sardine and anchovy, Cape hake and West Coast rock lobster off southern Africa are described and compared with North Sea herring and cod, and *Nephrops* in European waters. The comparison shows that, in Europe, despite comprehensive institutional arrangements for fisheries management based on a long history of fisheries research, management of stocks has not been particularly successful, and this contrasts with the rather more successful regime in southern Africa. The failure in Europe reflects the difficulty of curtailing international fisheries that have expanded and developed over many years on a complex of shared stocks and mixed fisheries, despite major advances in scientific methodology and strong scientific advice. The European examples also show how scientific uncertainties, and deficiencies in compliance with the Total Allowable Catch system, have contributed to management failure.

Key words: Europe, fisheries science, fisheries management, southern Africa

To a scientist it is inevitable that there must be a finite limit to the global harvest of fish from wild stocks because of the underlying limits to the volume of productive ocean, the transfer efficiency of the marine food chain, and the demographies of fish populations. After increasing at a rate of about 8% annually between 1950 and 1986, global landings stabilized in the range 80–90 million tons, so the upper limit of harvest has likely been reached (FAO 2000). In fact, Watson and Pauly (2001) consider the world's fish production to have been declining for more than a decade. The present challenge is therefore not to increase production, but to achieve it efficiently and sustainably. The omens are not particularly good. The FAO estimates that, although 25% of global fish stocks are only moderately exploited, 47% are fully exploited, 18% are overexploited and 10% are recovering (FAO 2000). In effect, 75% of stocks are not being harvested economically, of which more than one-third either are or have been seriously threatened. In recent times, the general public in the northern hemisphere has become familiar with the example of the northern cod *Gadus morhua* stock around Newfoundland, which collapsed in the 1990s amid recriminations about political and scientific failures (Hutchings and Myers 1994, 1995, Hutchings *et al*. 1997) and has not yet recovered. Even the scientists at the heart of the Canadian cod debate are not unanimous in their views about what really happened, other than that there was major overexploitation, and the extent to which scientists must shoulder the blame (Doubleday *et al*. 1997, Healey 1997).

Other examples of stock overexploitation are detailed in the European case studies dealt with in this paper. The curiosity is that these examples originate in areas where one might suppose that they could not, or should not, happen, viz. areas where there was a very early appreciation of the overfishing problem, followed by a progressive development of international fisheries science, culminating in the establishment of international fisheries management organizations with comprehensive regulatory and enforcement provisions. The aim here is to describe case studies that illustrate and identify some key fisheries management problems of Europe and to compare them with case studies of comparable stocks in southern Africa, in order to look for any differences in the success or failure of fisheries management between the two areas that may illustrate relevant scientific or institutional lessons for the future.

BRIEF OVERVIEWS OF FISHERIES MANAGEMENT IN THE TWO AREAS

Before embarking on the comparative case studies, it is of value to review the fisheries management systems in each of the selected areas. Figure 1 shows the two areas and the locations of many of the places mentioned in text.

Southern Africa

The southern African commercial fish and shellfish

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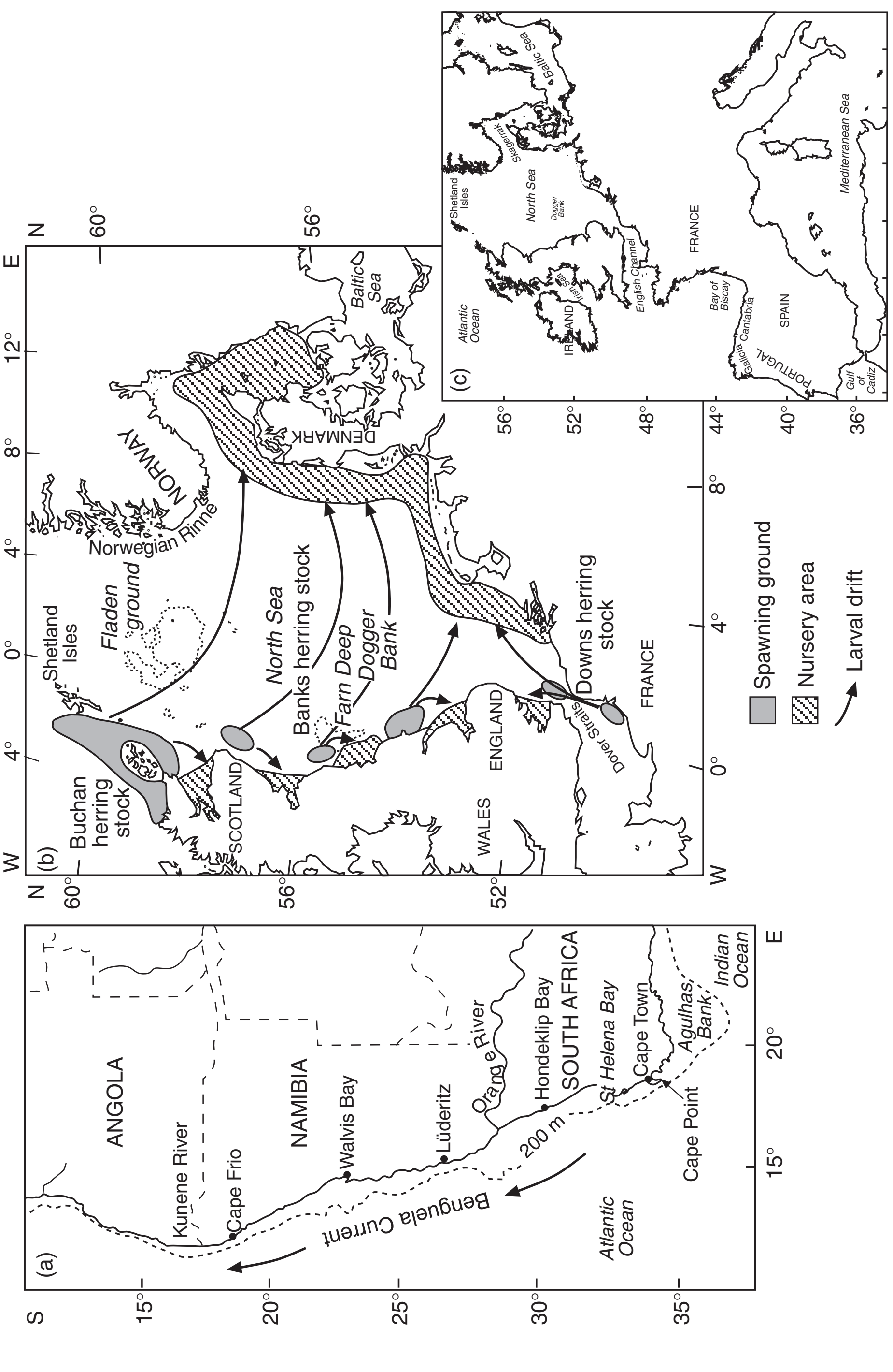

Fig. 1: Locator map of the two study areas, (a) southern Africa and (b) and (c) Europe (part after Nichols 2001)

fauna is dominated by the demersal Cape hake *Merluccius capensis* and *M. paradoxus*, pelagic sardine *Sardinops sagax*, anchovy *Engraulis capensis* and round herring *Etrumeus whiteheadi*, horse mackerel *Trachurus t. capensis*, the spiny lobsters *Jasus lalandii* and *Palinurus gilchristi* and abalone *Haliotis midae* (all except anchovy, round herring and juvenile sardine for direct human consumption). Other species contribute to the total catch and at times contribute extensively to the economics of the fisheries, e.g. monkfish *Lophius vomerinus*, kingklip *Genypterus capensis*, Agulhas sole *Autroglossus pectoralis* and chokka squid *Loligo vulgaris reynaudii*. However, by mass alone, Cape hake and the pelagics dominate (Payne and Crawford 1995). The hake fishery, initially off South Africa and from the 1960s off Namibia, blossomed gradually at first, then spectacularly to a peak of more than 1.1 million tons in the early 1970s, before declining erratically to its current seemingly sustainable level of 300 000–400 000 tons. The pelagic fishery was initiated in the 1940s, was initially dominated by sardine and peaked at some 1.8 million tons in the late 1960s, when fishmeal factory ships reaped a tremendous harvest from particularly Namibian waters (Payne and Crawford 1995). Anchovy started to replace sardine during the 1960s, first off South Africa and then later off Namibia, until in the mid 1980s it yielded more than 600 000 tons annually, mainly off South Africa. Today, pelagic fish are almost absent from Namibian waters, although horse mackerel still yield some hundreds of thousand tons annually (Boyer and Hampton 2001). Anchovy and sardine together now yield some 500 000 tons annually off South Africa.

Descriptions of the fisheries management systems in southern Africa are given in a number of publications. Lees (1969) documents the development of the fisheries throughout the 20th century and the people involved in them. From the early 1970s to 1990 (when Namibia declared its Independence), southern African fisheries were influenced and partly controlled by the International Commission for the Southeast Atlantic Fisheries (ICSEAF). However, after declaration of its national 200 mile EEZ in 1977, South African waters were excluded from such control, and ICSEAF influence over Namibian waters was realistically waning a few years before the Commission ceased to operate. The scientific basis for managing South Africa's offshore fisheries (demersal, pelagic and squid) is outlined by Cochrane *et al*. (1997), and the management of and fishery for the most valuable inshore resource off southern Africa, West Coast rock lobster, was reviewed by Pollock (1986). The latter fishery has been managed recently according to the precautionary principle (Cockcroft and Payne 1999), but heavy fishing mortality and a natural phenomenon of reduced somatic growth have caused it to decline over the past few decades. In terms of the three case studies off southern Africa described in the following section, the most recent descriptions of southern African Cape hake assessment and management are those of Rademeyer and Butterworth (2001) and Butterworth and Rademeyer (in press), for South African pelagics those of Cochrane *et al*. (1998) and De Oliveira *et al*. (1998), and for West Coast rock lobster that of Johnston and Butterworth (2000). Geromont *et al*. (1999) overview the development of some of the operational management procedures currently in use in southern Africa. Namibian pelagic and Cape hake assessment and management procedures post-Independence are documented by Boyer *et al*. (2001) and van der Westhuizen (2001) respectively.

Namibia shares Cape hake, sardine, anchovy and West Coast rock lobster with South Africa, and since Independence, its own scientifically based management has developed at a laudable pace. Prior to Independence, Namibia's stocks were managed separately from South Africa's, offshore ones through ICSEAF and inshore ones by a South African administration guided by the work of South African researchers. An overview of Namibia's fisheries management, focusing on the post-Independence period, is given by Oelofsen (1999) and a comprehensive description of all its living marine resources by Boyer and Hampton (2001). The latter paper also describes the management scheme whereby scientists (for all resources), stakeholders and others (for some resources) make their inputs to a decision-making process in Namibia that, for South Africa, is outlined both before and after full democratization of the country in Anon. (1997a). The latter paper clearly shows how it has been a legislative necessity (in terms of the previous and present Acts – Anon. 1998a) for dialogue to take place between representatives of all interested parties in generating the best advice, to which decision-makers have generally responded favourably.

Two of the keys to the apparent success of southern African fisheries management are very likely its long history, the first scientist/adviser being appointed as long ago as 1896 (Brown 1997), plus the fact that, at least until the 1960s (Payne 1995), there was no foreign involvement in the fisheries. Some regulations still in place date back to the 1930s (e.g. the minimum mesh size when fishing for Agulhas sole – Marchand 1934), so they have clearly stood the test of time. There has also been a willingness of most parties in both South Africa and, since Independence in Namibia, to collaborate in debating the most appropriate forms of sustainable fisheries management for each fishery, although at the time of initial development of South Africa's latest fisheries policy, there was a tendency for scientists to stand aside from the debate (Payne and Cochrane 1995), something seen by most scientists as a mistake and later remedied by their full involvement (Cochrane and Payne 1998).

It must be stressed too that, although the same species of commercial fish are found off South Africa and Namibia, the extent of mingling between the fish populations off the two countries is not that great, so there is justification for separate management in the two countries. However, as will be shown later, there is some overlap of stocks, of pelagic fish when the perennial area of cold upwelled water off Lüderitz (Lutjeharms and Meeuwis 1987) retracts, and occasionally of Cape hake across the common border when stocks to the south expand or when environmental conditions in the area fluctuate.

Overall though, throughout the long history of marine science in southern Africa (Payne and Lutjeharms 1997, Payne *et al*. 2001), fisheries management has been a collaborative affair, with decision-makers generally willing to listen to scientific advice (though less so off Namibia in the ICSEAF era), often to heed it to the letter, and with a will to ensure that southern Africans learn from "mistakes" made elsewhere in the world.

Europe

The North-East Atlantic supports a wide variety of fish stocks that have been harvested commercially since the 1800s. Today, landings of all species from the area total 10–11 million tons, almost 12% of the 84 million tons landed globally by marine capture fisheries. North Atlantic species include a wide range of gadoids (e.g. cod to blue whiting *Micromesistius poutassou*), flatfish (e.g. halibut *Hippoglossus hippoglossus* to sole *Solea solea*), pelagic (e.g. herring *Clupea harengus* to mackerel *Scomber scombrus*), and deep-water (e.g. ling *Molva molva*, orange roughy *Hoplostethus atlanticus*, grenadiers Coryphaenoidae) species, as well as crustaceans (e.g. *Nephrops norvegicus*), molluscs (e.g. scallop *Pecten maximus*), and species caught in the small-meshed industrial fisheries (e.g. sandeel *Ammodytes* spp., Norway pout *Trisopterus esmarki*). These stocks support a wide diversity of high-seas and coastal fishing fleets, supplying sophisticated processing and retailing networks.

At first sight, a comprehensive framework that should facilitate strong fisheries management and sustainable harvesting has evolved in the North Atlantic. Concern about overfishing began there as early as the 1860s (Anon. 1866), giving rise to national fisheries and oceanographic research (Holt 1895, Hjort 1914) that later became internationalized with the formation of the International Council for the Exploration of the Sea (ICES) in 1902. Since then, generations of ICES scientists have undertaken biological sampling and survey programmes, coordinated their studies in fisheries biology and oceanography, and initiated quantitative methods of population analysis (e.g. Russell 1931, Graham 1935, Gulland 1955, 1965, Beverton and Holt 1957, Pope 1972, Cushing 1973, Baranov 1977, Shep-herd 1992). Since the late 1960s, international ICES working groups have met annually to collate data and to carry out standard assessments on more than 100 North Atlantic stocks, leading to the impartial advice now given each year by the ICES Advisory Committee on Fishery Management (ACFM; e.g. Anon. 2001a). The ACFM meets twice annually to review the assessments and to provide recommendations to managers on fishing mortality (*F*), Total Allowable Catch (*TAC*), and in some cases technical measures. The managers are usually senior officials of member countries in the various commissions, plus senior officials and Ministers of Member States of the European Union. The advice so generated is used by international regulatory bodies such as the North East Atlantic Fisheries Commission (NEAFC) and the International Baltic Sea Fishery Commission, as well as the European Union, which in the mid 1970s, after the Law of the Sea Conference, established its own fisheries management regime within the EU EEZ. Regulations made by the fisheries commissions and under the EU Common Fisheries Policy represent a very detailed legal framework that specifies *TAC*s and technical measures under which modern fishing fleets are permitted to operate, and which are supported by national licensing, enforcement and data-recording regimes.

In the 1950s and 1960s, ICES stocks were assessed using catch per unit effort (*cpue*) and yield per recruit methods, but since the mid 1970s the principal assessment approach has been Virtual Population Analysis (VPA; Gulland 1965), implementing an annual operational fishing mortality through a *TAC* derived from short-term forecasts of stock size. VPA uses the historical matrix of landings at age to calculate vectors of fishing mortality and stock at age up to the most recent year, giving rise to historic trends in mean fishing mortality, exploitation pattern, biomass and recruitment. In the form of VPA currently used (extended survivors' analysis, XSA; Shepherd 1992), the analysis is tuned using survey data and catch rates of the commercial fleets. In the accompanying short-term forecast, the stock at age at the end of the most recent year ($TAC_{\text{year-2}}$) is projected through $TAC_{\text{year-1}}$ to the start of TAC_{year}, incorporating estimates of new recruitment derived from surveys or as an average of historical values. The forecast then calculates the expected landings in the *TAC* year for various multiples of *F* in order to produce catch options from which

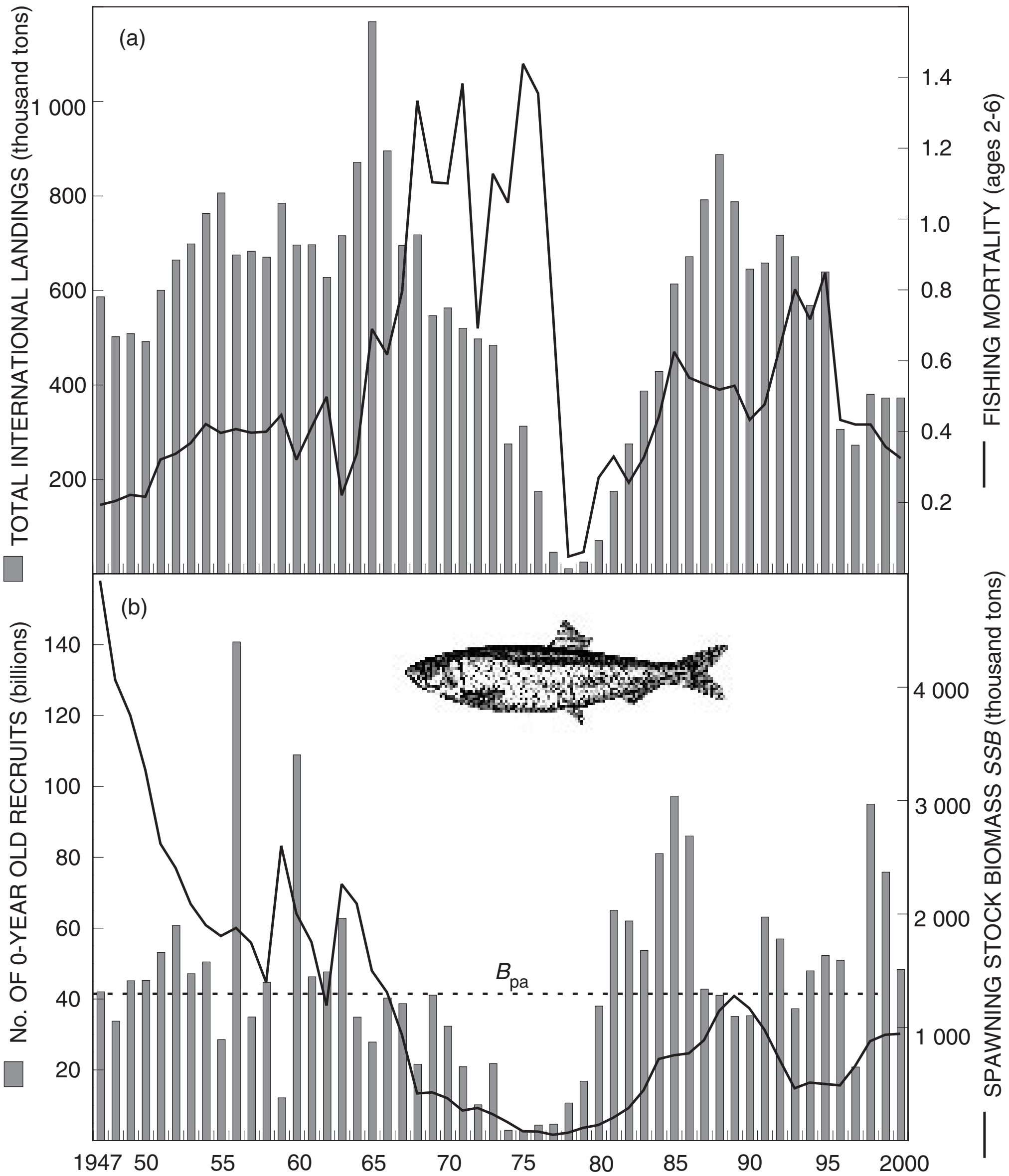

Fig. 2: Plots of North Sea herring post World War II, showing (a) landings and fishing mortality on age-classes 2–6 and (b) recruitment and *SSB* (with the reference B_{pa} level indicated)

the *TAC* can be selected.

Since 1998, ICES scientific advice on fish stocks (and the management decisions made) has been guided by precautionary reference points (Anon. 1997b, 1998b) adopted following analysis of historic trends in spawning stock biomass (*SSB*) and *F*. In this system, stock collapse is avoided by ensuring that $F < F_{lim}$ and $SSB > B_{lim}$, so-called limit reference points.

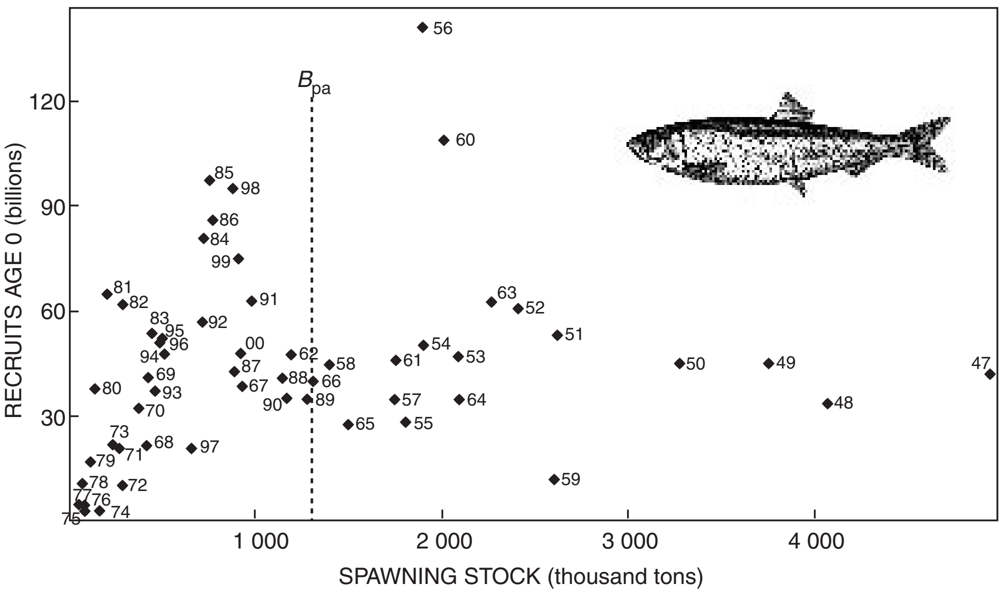

Fig. 3: Stock–recruitment relationship for North Sea herring post World War II, with the current precautionary biomass reference point (B_{pa}) shown

However, because of uncertainty and error in the assessments, this situation can only be achieved with high probability if precautionary approach buffer levels of reference point are adhered to, i.e that $F < F_{pa}$ and $SSB > B_{pa}$, where $F_{pa} < F_{lim}$ and $B_{pa} > B_{lim}$ respectively. Stocks assessed as below B_{pa} and above F_{pa} are outside safe biological limits, and only those catch options that would restore the stock to safe limits are deemed to be precautionary.

In the light of what is written above and comprehensive infrastructure, it is disappointing to have to record that today a majority of North Atlantic fish stocks are outside these safe biological limits (Anon. 2001b), that in EU waters three cod stocks and one hake stock are currently the subject of crisis management to return them to safe limits as soon as possible over the next 5–8 years, and that other stocks may well join them in the near future.

CASE STUDIES

To compare the fisheries management performance, strengths and weaknesses in the two areas under discussion here, some case studies are outlined in the pages that follow. Those selected are representative of the pelagic fishery, namely North Sea herring and the multispecies fishery for anchovy and sardine off southern Africa, of the demersal (groundfish) fishery, namely North Sea cod and Cape hake off southern Africa, and of a crustacean fishery, in this case Norwegian prawn *Nephrops norvegicus* in Europe and West Coast rock lobster off southern Africa.

Herring v. sardine/anchovy

NORTH SEA AND ENGLISH CHANNEL HERRING

In the North Sea, three stocks of herring spawn in autumn on different grounds along the UK coast, off Scotland (the Buchan stock), off the north-east coast of England (the Banks stock), and in the eastern Channel and Dover Strait (the Downs stock). Progeny from these spawning groups drift into nearby UK coastal waters but are also carried to the southern and eastern sides of the North Sea, where they mix before maturing and segregating back to their own natal spawning grounds.

The effects of exploitation and management are illustrated by the history of the stock since 1947, summarized by Burd (1974) and Nichols (2001). Total recorded landings of herring from the North Sea (Fig. 2) averaged 650 000 tons for a sustained period from 1947 to 1967, before suddenly collapsing steeply in the late 1960s and 1970s, leading to complete closure of the fishery from 1977 to 1981. In the same period, *SSB* (the weight of mature herring) declined continuously from a peak of 5 *million* tons in 1947, just after World War II, to a mere 46 *thousand* tons in 1977, a hundred-fold decrease. Recruitment of young herring, generally 20–40 billion 0-group fish, plunged from 40 billion in 1970 to 3 billion in 1976. The relationship in Figure 3, describing the dependence of recruitment on spawning stock derived from later analyses, shows the progressive trend of points into the lower left hand corner of the diagram in the 1970s.

The case of North Sea herring provides one of the few clear-cut examples of a genuine stock collapse, attributable in retrospect to some very obvious causes. First, the fishery was for many years unregulated, so that any increase in fishing mortality was uncontrolled. The annual harvest rate was a moderate 15% in 1947, but it doubled between 1947 and 1962, then doubled again from 1968 to 1976, reaching 70% (a very high instantaneous coefficient of fishing mortality of 1.4). Second, as Burd (1974) demonstrated, herring were captured at all phases of their life history. Juveniles were caught in small-meshed industrial fisheries for oil and meal (particularly on the eastern nursery grounds) and mature adults in trawl- and driftnet fisheries on feeding grounds, *en route* to spawning grounds and in the close vicinity of the spawning grounds themselves, especially in the western Dogger Bank area (Banks stock) and around the Dover Strait (Downs stock). Third, there was a failure to respond to scientific concerns about herring until very late in the day. National interests and socio-economic factors exploited the fact that there was a prolonged period of scientific debate about what was actually happening to the stock (Burd 1974).

Hindsight, using data derived from VPA, gives a much clearer view of the collapse of the stock than was perceived at the time, when the main tools available were data on *cpue*, percentage size and age structure, larval abundance and juvenile tag-recapture rates (Burd 1974). Scientists were aware that the autumn fishery off the south-east coast of England, and the abundance of larvae produced by the Downs spawning, declined during the 1950s. There was uncertainty, however, because an increase in herring growth rate was causing earlier recruitment and affecting the proportion of the fish landings attributable to fish from the different stocks. International juvenile tagging experiments in 1957 and 1958 revealed that, although industrial fishery landings were large, the juvenile fishing rate of 15–20% could not alone explain the decline in the stock. Debate in ICES about these aspects, and about possible environmental influences, was protracted. Consequently, NEAFC, newly formed in 1963 as the responsible management body, could not agree clear action in the face of competing national interests and scientific hypotheses. It was not until 1968, when herring landings from the other North Sea stocks were also already declining seriously, that an ICES working group on herring concluded that North Sea landings had exceeded the estimated maximum sustainable yield of herring in every year since 1951.

Scientific advice then fell into line and called for strong action. NEAFC discussed, but could not deliver, a quota management system for herring, but eventually in 1971 introduced short seasonal fishing bans in May and September, some 15 years after the first ICES discussions about North Sea herring conservation. By the time the then European Economic Community (EEC) assumed responsibility for the management of Community fish stocks in 1975/1976, the herring stock was at its lowest ebb. Based on the newly introduced VPA, the stock-recruit relationship (with many points in the lower left hand corner) led ICES scientists advising the EEC to recommend complete closure. In 1976, industrial landings of herring were banned, except as a 10% bycatch in the sprat *Sprattus sprattus* fishery, and eventually in 1977, after an epic struggle in various Council meetings, the EEC closed the directed fishery until the *SSB*, and in particular the Downs stock, showed signs of recovery, to be demonstrated by larval survey data.

This closure did allow the stock to recover, although it pre-empted the intended EEC use of herring in exchange for cod in third country waters. It also led to a loss of markets, so that the beneficiaries of the stock recovery were not necessarily those that had prosecuted the previous fishery. The fishery was opened in steps in 1981 and 1983, and the EU imposed a *TAC* for the human consumption fishery on the basis of ICES advice aimed at maintaining the *SSB* above 800 000 tons, the level at which recruitment became impaired previously. Following good recruitment in the mid 1980s, the *SSB* increased above a million tons and remained there from 1985 to 1990, the harvest rate increased to >40%, and landings reached 600 000 tons. From 1990 to 1995, the harvest rate increased further to 55% and the *SSB* again fell below the minimum acceptable level of 800 000 tons. Fearing a repeat of the collapse, ICES then recommended a sharp reduction in the *TAC* in mid 1996, and in 1997 the EU and Norway responded by agreeing an immediate 50% reduction, coupled with a strict limit on the by-catch of herring in the sprat fishery. Since 1999 and the adoption of

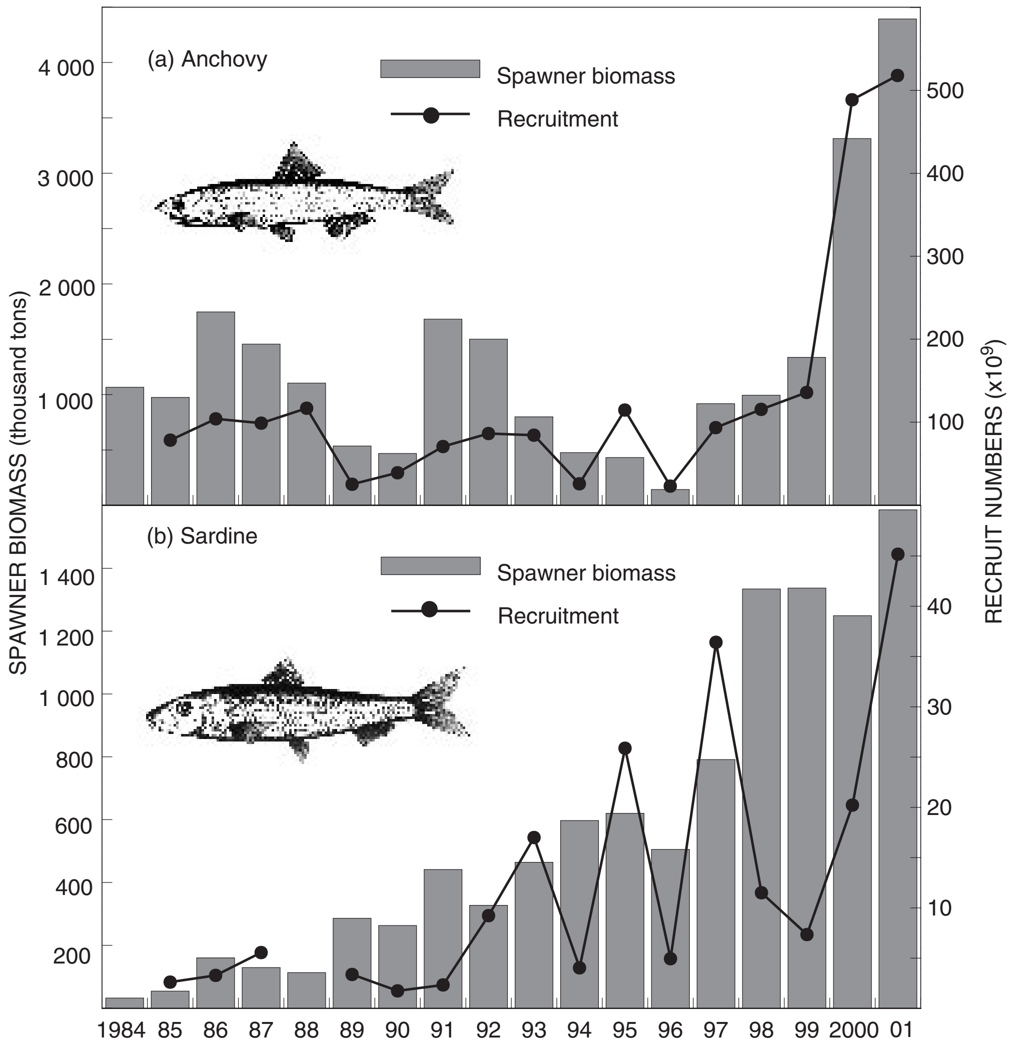

Fig. 4: Acoustic estimates of (a) anchovy and (b) sardine spawner biomass and recruitment 1984–2001 (updated from Hampton 1992)

precautionary reference points, the *TAC* has been set as a harvest control rule to comply with low juvenile and adult values of *F* specified in the EU-Norway management agreement. Although these *TAC*s are still being exceeded (Table 2 of Nichols 2001), the harvest rate is now much lower than prior to the collapse, *SSB* is close to B_{pa} and herring recruitment is reasonable, so it is fair to say that, to some extent at least, the herring stock has been rehabilitated.

SARDINE/ANCHOVY IN SOUTHERN AFRICA

Off southern Africa, the dominant pelagic species are sardine and anchovy, the first dominating the canning industry and the second fishmeal production. Armstrong and Thomas (1995) outline the biology, ecology and distribution of both species, and the fisheries are described in many papers, the most recent authoritative reviews being those of Boyer and Hampton (2001) for the Namibian stocks and Cochrane *et al.* (1997, 1998) for the South African ones. Armstrong and Thomas (1995) also describe certain aspects of the management systems over the years.

It was after World War II that interest in harvesting southern Africa's pelagic stocks burgeoned alongside the international need for more protein. From small beginnings, catches of sardine and horse mackerel escalated off South Africa, but controls were slow to follow. Although scientists had expressed concern about the state of the sardine stocks already by the late 1940s, minimum mesh sizes, curbs on industrial expansion and closed seasons took several years to implement. The fishery expanded geographically from its epicentre at St Helena Bay, and annual sardine catches rapidly peaked at more than 400 000 tons by the early 1960s, after which anchovy first made its appearance and sardine stocks declined. Quotas had been in place for part of the 1950s, but signs of the vastness of the resource simply caused them to be relaxed. As sardine declined and was "replaced" by anchovy off South Africa, so the fleet (accompanied off Namibia by up to two factory ships that allowed purse-seine operations offshore, away from the land-based plants) moved north to Namibian waters, where vast shoals of sardine had been found. Initially off southern Namibia, but later out of Walvis Bay in central Namibia, sardine catches escalated to peak at nearly 1.4 million tons in 1968. The crash was not long in coming, and catches of sardine off Namibia decreased after the mid 1970s; during the 1990s catches were very small, and by 2002 a zero *TAC* was in place (D. C. Boyer, National Marine Information and Research Centre, Swakopmund, Namibia, pers. comm.).

Sardine management off South Africa has since the early 1980s been based on acoustic estimates of *SSB* (Hampton 1992). From a very low stock size and hence *TAC* in the early 1980s (Fig. 4), the stock has recovered gradually under cautious exploitation strategies to a situation where multispecies management of sardine and anchovy is essential to optimal harvesting strategies for both (Cochrane *et al*. 1998). For part of the 1990s, sardine biomass exceeded that of anchovy, but current (2002) catches of the two species are similar. Sardine are now harvested according to a pre-agreed Operational Management Procedure (OMP, a simple set of decision rules based on a pre-agreed scientific formulation and appropriate data; De Oliveira *et al*. 1998, Geromont *et al*. 1999) that aims to optimize catches of the two pelagic species at sustainable levels. Annual sardine catches off South Africa now exceed 200 000 tons, a healthy recovery from the situation in the early 1980s. Sardine are harvested for both canning (direct human consumption) and (particularly recently) for fishmeal.

Anchovy fishing off southern Africa is predominantly on recruits of the year. Consequently, the acoustic assessment technique used off South Africa takes cognizance of spawner stock biomass at the end of one calendar year in providing information on appropriate harvest levels for the start of the next calendar year's *TAC*, as well as autumn (May/June) estimates of recruitment strength, in generating appropriate recruit-fishing levels (Fig. 4; Butterworth *et al*. 1998). Being so short-lived, fluctuations in recruit strength are large for anchovy and survivorship to adulthood at the end of the year is also strongly affected by the high natural mortality and the level of fishing mortality during the recruit-fishing phase of the season. Management takes account of the fluctuations, and the current OMP is designed to maximize catches while limiting inter-annual fluctuations (Geromont *et al*. 1999). In the 1970s, prior to initiation of acoustic assessment techniques off South Africa, anchovy catches were regularly of the order of 200 000 tons, but this increased to an average of 300 000 tons during the early 1980s and peaked at some 600 000 tons in 1987 and 1988, before falling to former levels of 200 000–300 000 tons. Problems with managing the anchovy and sardine resources in tandem surfaced in the mid 1990s as a result of the high levels of sardine bycatch (a consequence of the recovering sardine stock) in the anchovy recruit fishery, and it was this fact that pre-empted the development of the multispecies OMP currently in use (Cochrane *et al*. 1998, De Oliveira *et al*. 1998).

Namibian anchovy catches fluctuated with quotas around some 200 000 tons during the 1970s, but then declined. Apart from a sudden peak in 1987 (considered by some to be an overspill from the huge anchovy resource off South Africa that year, but just as likely related to environmental phenomena), annual catches gradually declined to about 50 000 tons by the early 1990s, and to virtually zero after Namibia's anomalous environmental conditions of the mid 1990s (Boyer and Hampton 2001).

Cod v. Cape hake

NORTH SEA COD

Cod are large, omnivorous demersal fish that spawn widely in ill-defined areas throughout the North Sea, and the structure of the stock is not well known. Some progeny are transported into UK coastal waters, others to areas around the Dogger Bank, but most to the south-eastern and eastern sectors of the North Sea. From an age of 2, cod become more abundant off the north-east coast of England and in the central and northern North Sea. They are fished by large-meshed gillnets in the southern and eastern North Sea, but especially by bottom trawlers north of the

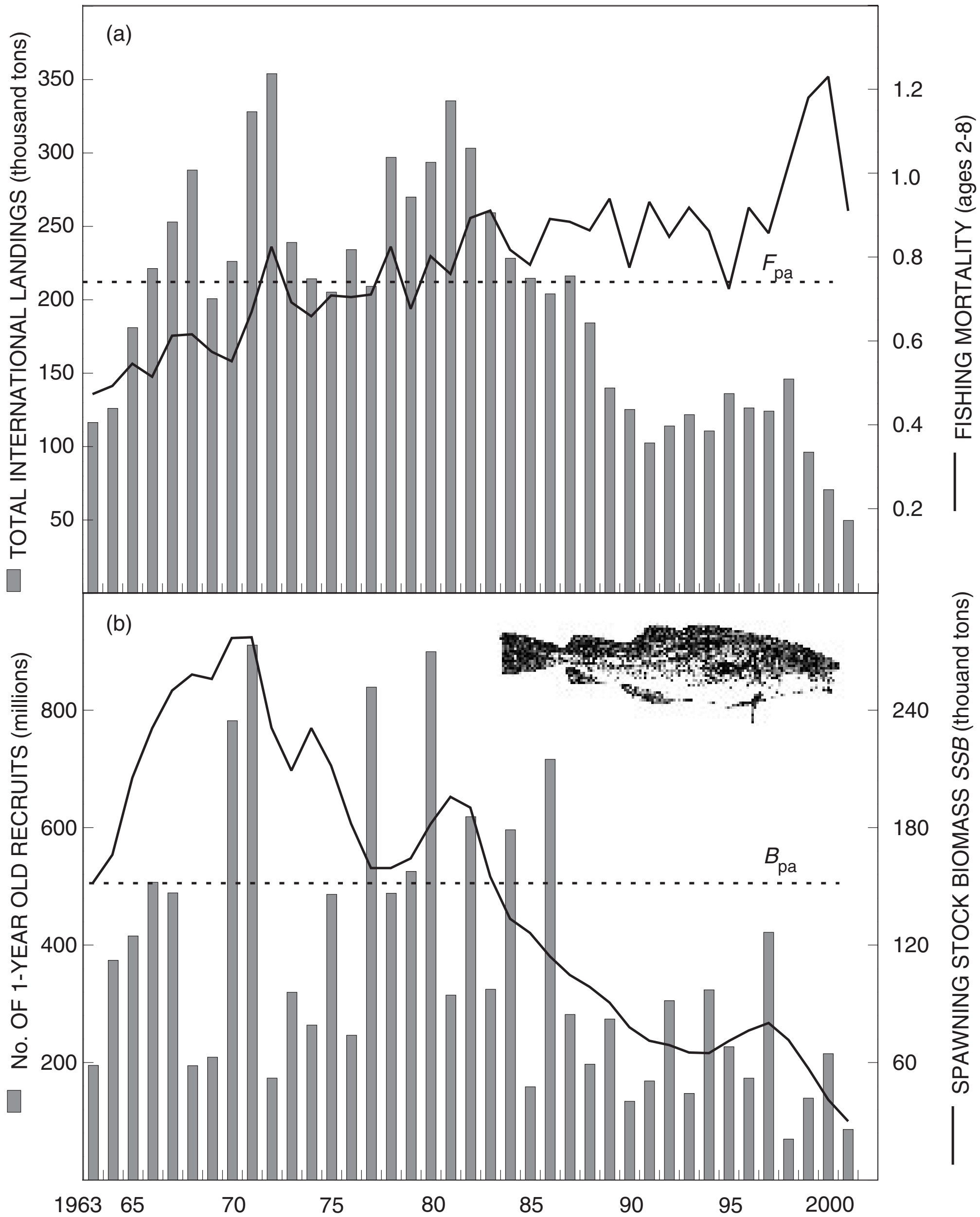

Fig. 5: Plots of North Sea cod since 1963, showing (a) landings and fishing mortality on age-classes 2–8 and (b) recruitment and *SSB* (with the reference B_{pa} level indicated)

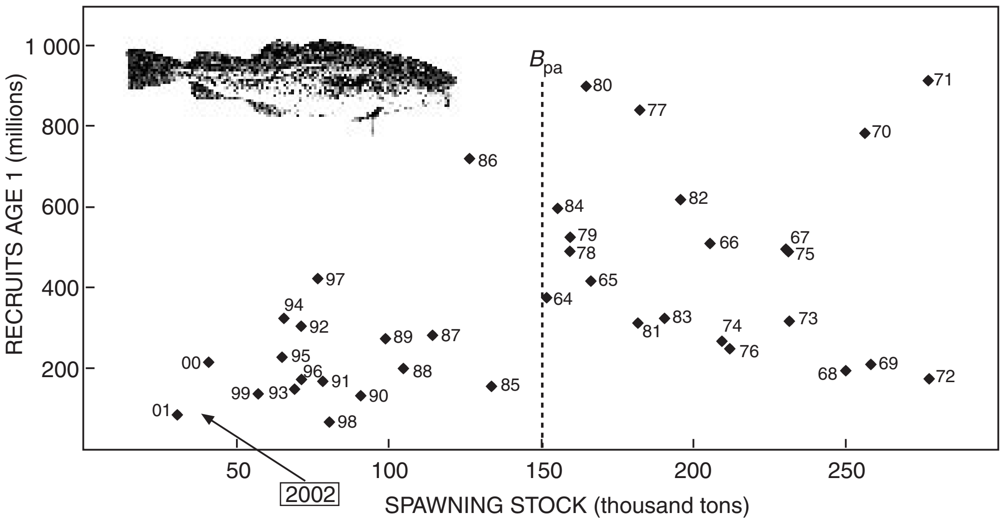

Fig. 6: Stock–recruitment relationship for North Sea cod, 1963–2002, with the current precautionary biomass reference point (B_{pa}) shown

Dogger Bank and from west of Shetland to the Norwegian Rinne. In the trawl fisheries, cod, haddock *Melanogrammus aeglefinus* and whiting *Merlangius merlangus* often co-occur on the fishing grounds. However, because haddock and whiting are smaller than cod, the preferred mesh size for the mixed fishery, which until 2001 was 100 mm diamond-mesh, is too small to allow immature cod to escape. Female cod mature at about age 4, and the mesh size required to allow significant numbers of younger cod to escape is at least 160 mm diamond-mesh, a size that would also allow much of the haddock and almost all the whiting to escape.

Figure 5 shows the trend in the North Sea cod fishery[1] and stock since 1963. *F* increased progressively from 0.5 in 1963 to 0.85 in 1983, and has since fluctuated around this high level, well above the precautionary F_{pa} of 0.65, and identical to the limit fishing mortality reference point (F_{lim}) of 0.86, introduced in 1999. Throughout this period, cod *SSB* declined from a peak of 275 000 tons in 1970 to 30 000 tons in 2001, a historical low well below the precautionary B_{pa} of 150 000 tons, and below even the limit biomass reference point (B_{lim}) of 70 000 tons. Recorded landings were high from 1966 to 1983, in the range 200 000–350 000 tons, but thereafter they fell rapidly to 100 000 tons by 1991. Then, until 1998, they fluctuated in the range 114 000–146 000 tons, before falling to 50 000 tons in 2001 in line with the *TAC*. The period of high landings between 1966 and 1983 coincided with the recruitment to the cod fishery of several very good year-classes, and this may have encouraged the marked increase in fishing rate during that period. After 1987, the lower landings, and the considerably reduced *SSB*, coincided with a fall in recruitment to only half the previous level. Conse-quently, there is a strong stock-recruit relationship (Fig. 6), in which recruitment falls markedly once *SSB* has fallen below 150 000 tons. The latter level of *SSB* was initially adopted by ICES as the Minimum Biologically Acceptable Level (MBAL[2]). As the average North Sea cod does not mature until age 4, 2- and 3-year-olds are caught in significant numbers in the relatively small mesh used by the gadoid mixed fishery, and the age

[1] Scientific assessments are generally provided for cod stocks in the North Sea, the Skagerrak and the eastern English Channel combined, so unless otherwise stated, it is these combined values that are referred to in text, Figures and Table as simply North Sea

[2] When precautionary reference points were first assigned, this MBAL became B_{pa}, although in terms of reference point definitions, it should have been B_{lim}, which is the *SSB* at which recruitment becomes impaired

Table I: North Sea cod advice and statistics, 1987–2002, and the realized *SSB* and *F* (after Anon. 2002a)

Year	ACFM advice	*SSB* ('000 tons)	*F*	*TAC* advised ('000 tons)*	*TAC* agreed ('000 tons)*	Official landings ('000 tons)*	ACFM landings ('000 tons)*
1986		114	0.89				
1987	Set *TAC* to recover *SSB*	105	0.88	100/125	175	167	182
1988	Set *TAC* to reduce *F* 30%	99	0.86	148	160	142	157
1989	Set *TAC* to halt *SSB* fall	91	0.94	124	124	110	116
1990	Set *TAC* to give $0.8F_{1988}$	78	0.77	113	105	99	105
1991	70% of effort 1989	71	0.93	–	100	87	89
1992	70% of effort 1989	69	0.85	–	100	98	97
1993	70% of effort 1989	65	0.92	–	101	94	105
1994	Reduce effort significantly	65	0.86	–	102	87	95
1995	Reduce effort significantly	71	0.72	–	120	112	120
1996	$0.8F_{1994}$	76	0.92	141	130	104	107
1997	$0.8F_{1995}$	80	0.87	135	115	100	102
1998	$F_{1998} < F_{1996}$	70	1.02	153	140	114	122
1999	$F = 0.6$, to rebuild *SSB*	57	1.18	125	132	80	78
2000	$F < 0.55$	41	1.23		81	62	59
2001	Lowest possible catch	30	0.91	0	48.6	42.3	41
2002	Lowest possible catch	38		0	49.3		

* North Sea only, i.e. minus the Skagerrak and the eastern English Channel

structure of both stock and catch is dominated by immature fish. The combination of poor recruitment and diminished age structure therefore means that the stock is in a poor state and at serious risk of collapse (Anon. 2001a).

The increase in *F* and the decrease in *SSB* that followed the gadoid outburst (Cushing 1982) was accompanied by more than a decade of strong advice from ICES aimed at reducing *F* and halting the fall in *SSB*, but this has clearly been unsuccessful. Table I is a summary of the scientific advice and its outcome, based on information in the most recent ACFM report (Anon. 2002a). Column 2 of the Table shows the advice prescription and columns 3 and 4 the resulting *SSB* and *F* estimated by the then most recent ICES cod assessment. Columns 5 and 6 are the *TAC*s equivalent to the scientific advice and actually agreed by managers respectively, and columns 7 and 8 the landings reported and estimated by ICES scientists respectively (Columns 5–8 for the North Sea alone, i.e. without the Skagerrak and the eastern English Channel).

From 1987 to 1990, the advice aimed to recover *SSB* or to reduce *F* by 30 or 20%, but *SSB* continued to decline, and 1990 was the only year in which *F* was reduced. The agreed *TAC* was higher than advised in 1987 and 1988 and, although reported landings were below the *TAC*, the landings estimated by ACFM were higher than that value. In 1989 and 1990, the agreed *TAC* was equal to or less than the advice, but although estimated and reported landings were less than the agreed *TAC*, stock decline continued. From 1991 to 2000, ICES stopped advising a *TAC*, preferring rather to advise on required reductions in effort (by 30% in 1991–1993, "significantly" in 1994 and 1995, by 20% in 1996 and 1997, and by 50% or more in 1999 and 2000). Table I shows that, in that period, there was no decrease in *F*, which fluctuated in the range 0.93–0.72, before increasing to 1.23 by 2000. *SSB* continued to fall until 1994, increased slightly up to 1997, but then began to fall more steeply. From 1991 to 1994, the agreed *TAC* was constant, but official and estimated landings were both less than the *TAC*. From 1995 to 1998, the agreed *TAC* increased, but it was less than the advice, and both reported and estimated landings fell short. Throughout the period 1987–1998, therefore, there is no evidence that the scientific advice resulted in a significant reduction in *F* or that it succeeded in reversing the decline in *SSB*. The agreed advice and the realized landings were initially in excess of the advice, but this did not apply to the second half of this period, when the *TAC*s were more in line with the advice, but still landings did not reach it. These results imply that, for much of the 1990s, the *TAC* management regime was not restrictive. One possible cause is that the ICES assessments then appear to have overestimated *SSB* and underestimated *F* (Van Beek 2001).

In 1999, the severity of North Sea cod advice increased, following the introduction of precautionary reference points by ICES and the establishment of an EU-Norway management agreement for shared stocks in the North Sea. For North Sea cod, the agreement aims to maintain *SSB* above B_{lim} (70 000 tons), to restrict fishing mortality to below F_{pa} (0.65) and, if *SSB* falls below B_{pa} (150 000 tons), to ensure a safe and rapid recovery above that level. The 1999 and 2000 advice prescribed a large cut in *F*, and then in 2001 and 2002 the lowest possible catch. The agreed *TAC* was cut by 40% in 2000, and by a further 40% for 2001 and 2002. The resulting landings again fell short of this *TAC* in 2000 and 2001, and yet the *SSB* continued to fall to its present very low level. Clearly, management action has failed to arrest the decline in the stock.

The advice in 2000 noted that the North Sea cod stock was not only outside safe biological limits but at serious risk of collapse (Anon. 2001a). It proposed that to "ensure a safe and rapid recovery to B_{pa}" (as specified in the EU-Norway agreement), managers should agree a rebuilding plan, comprising a severe reduction in catch, and measures to reduce discarding and to improve the exploitation pattern. Technically, the latter can most readily be achieved by increasing the mesh size, but this is difficult for fishers to accept because it would seriously reduce the catches of haddock and whiting that are taken alongside cod in the mixed trawl fishery. In 2000, the EU and Norway agreed to a 40% reduction in the *TAC*, a transitional increase in otter trawl mesh size from 100 to 110 mm to be implemented by 2002, and a large closed area covering a major part of the spawning season fishery from February to April in 2001. The closed area caused excessive diversion of effort onto other sensitive areas (Rijnsdorp *et al*. 2001) and was discontinued in 2002. Forecasts indicate that the stock may require 6–9 years, at best, to reach B_{pa} (Anon. 2001b, 2002a), but negotiations to develop and agree a meaningful trajectory for rebuilding *SSB*, and a policy on effort control, have still not been completed.

Fishers question whether recovery of cod is in fact possible. Their concern is that, over at least the past decade, sea temperatures in the North Sea have increased in conjunction with a strong positive phase of the North Atlantic Oscillation, and that at the latitude of the North Sea and the Irish Sea, the survival of young cod is negatively affected by temperature (Planque and Frédau 1999, O'Brien *et al*. 2000), so compounding the decline in recruitment caused by overfishing. The fishing industry suggests that the stock decline can be blamed on climatic change, and queries whether it will be possible to restore *SSB* to the level of B_{pa}. The current scientific view is that this issue strengthens, rather than reduces, the need to raise egg production by increasing *SSB*, and yield per recruit analysis suggests that, even if recruitment is at the low average of the past decade, *SSB* could still reach B_{pa} provided fishing mortality is reduced sufficiently.

Summarizing, the North Sea cod fishery expanded to a high level during the period of the gadoid outburst, but it is now on the verge of collapse because of a prolonged decline in *SSB*, a marked reduction in recruitment dating from 1987, and the failure of management measures to achieve either a significant reduction in *F* or an improved exploitation pattern, despite strong scientific advice since 1987. Fishing mortality is still estimated to be above F_{lim}, and because of the mixed fishery issue, mesh size in the North Sea has remained too low to prevent large numbers of cod being caught at Age 2 and 3, so that <10% of one-year-old cod survive to maturity at Age 4 or 5. The situation appears to have been compounded by the assessment having overestimated stock size in some recent years, and by the negative effect of increased seawater temperature on cod recruitment. The introduction of reference points, and the new EU-Norway agreement, have led to stronger scientific advice, and tough negotiations about management, but the stock remains in danger of collapse.

CAPE HAKE OFF SOUTHERN AFRICA

Cape hake have been exploited off southern Africa since the turn of the 20th century; the history of the fishery, which expanded rapidly along with the arrival of foreign (to southern Africa) fleets, is summarized by Payne (1995). Biological studies started in earnest in the 1960s as catches expanded, and much of the earlier work is reviewed by Payne and Punt (1995), though there have been rapid developments in knowledge since that work was written. Also, along with enhanced knowledge have come data and numerical tools to permit more accurate assessment of stock status, including better evaluation of the effect of catch strategies and improving technology on the performance of the commercial fishery and a time-series of fisheries-independent surveys. However, for the sake of completeness, management is reviewed here; the reader is referred to the literature for more detailed information.

Hake dominate the southern African demersal ecosystem to the tune of some 70% of demersal fleet landings (Botha 1970). Catches peaked in the early 1970s as local fleets were supplemented by huge fleets of foreign trawlers, and more than a million tons were taken in a single year as the stock was reduced to one based largely on young and immature hake of both species, but mainly *M. capensis* off Namibia and *M. paradoxus* off South Africa (Payne 1995). ICSEAF tried to manage this heavily oversubscribed fishing effort, bringing in the principles of minimum mesh size and allocated *TAC*s. However, when South Africa took control of its own hake fishery in 1977 and foreign effort was effectively withdrawn, the stock

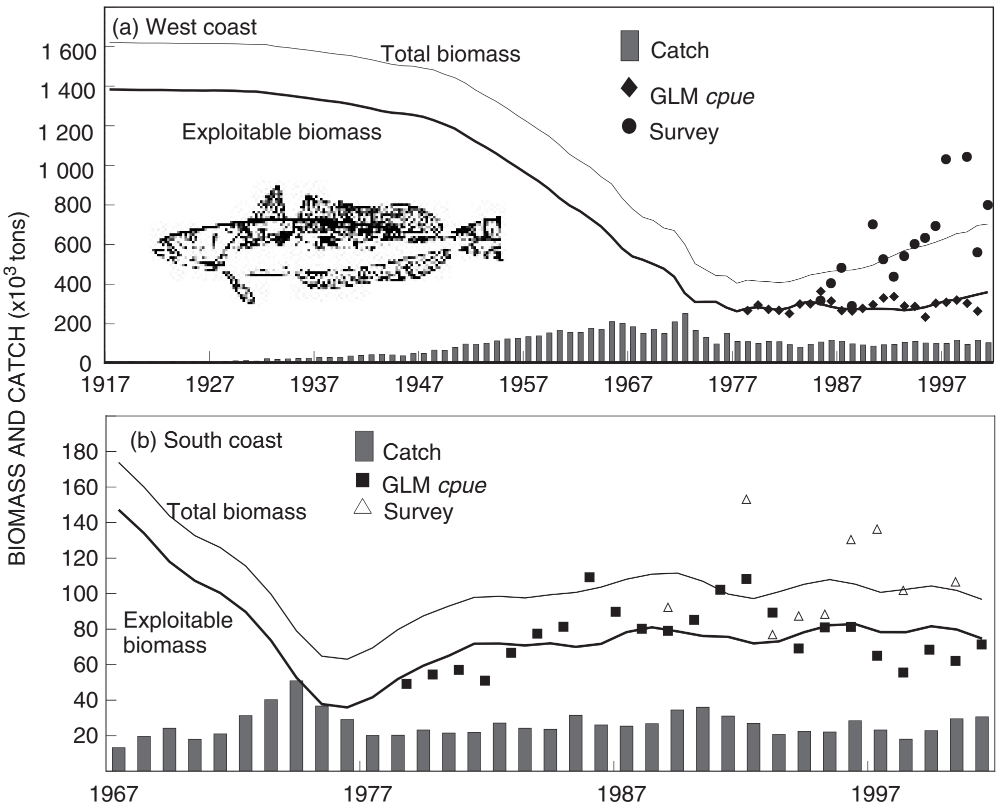

Fig. 7: Total catches and estimates of total and exploitable biomass, as estimated by an age-structured production model, GLM-standardized *cpue* and research survey estimates of abundance, for South African Cape hake (both species) on (a) the West Coast and (b) the South Coast (updated, with permission, from Geromont *et al*. 1999)

was at a low ebb and it did not show signs of real recovery until a scientifically recommended decision was made to cut the *TAC* in 1982. Thereafter, rigorous and improving assessments based initially on the Schaefer form of a dynamic age-aggregated production model approach tuned by means of commercial *cpue* and fisheries-independent survey results, allied to a cautious strategy aimed at rebuilding the stocks (Payne and Punt 1995), gradually realized an improvement in stock size. Today the South African *TAC* is >160 000 tons, probably not far short of its maximum sustainable yield.

A rigorous management procedure is currently in place for South African hake (Geromont *et al*. 1999; Fig. 7). It computes *TAC*s by means of an age-aggregated production model using *cpue* and survey data only, but the approach has been simulation-tested on assessments that were fully age-structured and took available catch-at-age-data into account. The stock trends given in Figure 7 clearly only show that the resources on each coast have "bottomed out". Cynics might therefore say that management has stabilized rather than rebuilt the stock. Given this, the recent (mid 1990s) initiation of a longline fishery for Cape hake (currently some 10% of the *TAC* and restricted in area), though slowly introduced and reasonably well monitored, stressed the need for even better assessments of the status of South Africa's hake stocks. Nevertheless, indications from the surveys point to an improving stock status, at least prior to the onset of longlining, so there is scientific confidence in the increasing advised level of *TAC*. South African hake

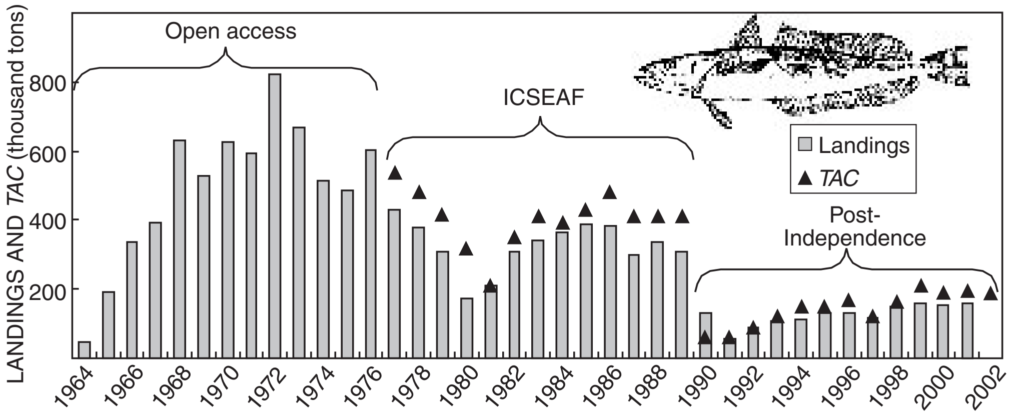

Fig. 8: Landings of Cape hake *Merluccius* spp. off Namibia, 1964–2001, and the *TAC*s proposed, 1977–2002 (updated, with permission, from van der Westhuizen 2001)

constitute one of the few groundfish resources worldwide for which *TAC*s are set according to an age-aggregated production model approach (in contrast to the VPA approach used widely elsewhere; e.g. North Sea cod). The decision to adopt this approach for hake was first made in the 1980s, during ICSEAF days, when the long time-series of catch and effort data for Cape hake that existed virtually from the start of the fishery made the production-model approach particularly attractive scientifically. Subsequently, comparative analyses of production-model and VPA approaches in a management procedure context indicated greater stability of catch limits for the former approach without any compensatory advantages for the latter (Punt 1993).

Namibian hake stocks were subject to ICSEAF control until Independence in 1990, and it is clear that the stock was in poor shape when national control was initiated (Boyer and Hampton 2001, van der Westhuizen 2001). Namibian hake stocks were essentially open access until ICSEAF management was introduced, and even during ICSEAF days, declared hake catches averaged >300 000 tons annually (van der Westhuizen 2001). Namibian national control immediately resulted in hugely reduced *TAC*s of just 60 000 tons for 1990 and 1991 and, once illegal activity of certain foreign fleets had been eliminated, catch rates and catches began to rise (Oelofsen 1999; Fig. 8). The stocks did not always react positively to this massively reduced exploitation, however, and fluctuating levels of recruitment (particularly during the environmentally anomalous years of the mid 1990s, when *TAC*s were again reduced slightly), offset partially by possible overflow from the South African stock of *M. paradoxus*, resulted in smaller catches towards the end of the same decade (Boyer and Hampton 2001). The latter authors believed that these reduced catches were the consequence of fishable biomass having been reduced. However, other assessments (Butterworth and Rademeyer in press) suggest that the drop was more the result of reduced availability, environmental fluctuations having affected catchability, than reduced abundance following a downturn in recruitment. Notwithstanding these setbacks, however, the Namibian hake *TAC* had reached >160 000 tons by 1999 and some optimism in the future of the fishery had returned, although catches were dominated by small fish (D. C. Boyer, pers. comm.). Recently too, management of the resource was put on a more solid scientific footing with the development of an interim management procedure (IMP; Geromont *et al*. 1999, Butterworth and Geromont 2001) based on both commercial *cpue* and fisheries-independent survey results. Slight revision of that management procedure (Rademeyer and Butterworth 2002) was completed and accepted by stakeholders (industry, scientists and decision-makers) in February 2002, and the 2002 *TAC* was set under the revised procedure.

***Nephrops* vs. West Coast rock lobster**

NEPHROPS IN EUROPE

Nephrops norvegicus is a slender decapod crustacean that is a high-priced seafood delicacy. It is caught by

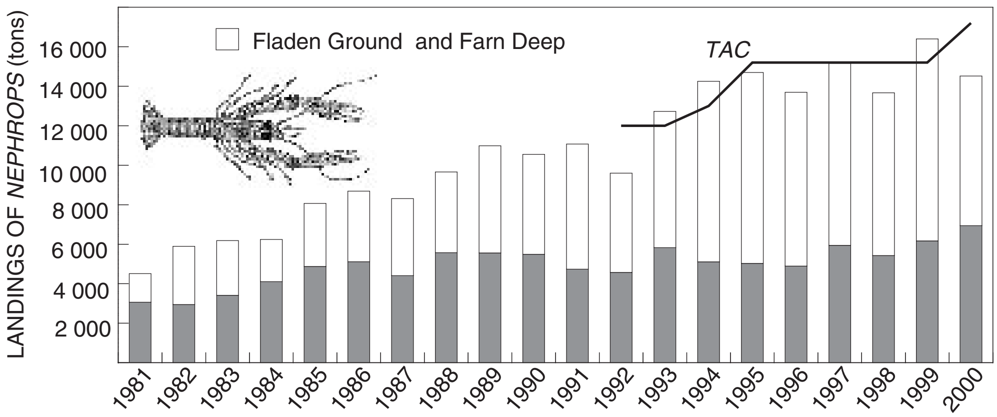

Fig. 9: Landings (histograms) and *TAC* (line) time-series for *Nephrops* in the North Sea (updated from Anon. 2001c)

trawl and in pots ("creels"). It occupies burrow systems in the cohesive muddy sediments that are the preferred habitat, and is caught during diurnal and seasonal patterns of emergence presumably linked to feeding and annual temperature/reproductive cycles respectively. In EU waters, directed trawl fisheries for *Nephrops* are permitted to use mesh sizes smaller than those used for whitefish (e.g. 80–89 mm, instead of 100 mm in the Irish Sea and the North Sea) provided that the catch composition exceeds 35% *Nephrops*. In areas like the Irish Sea and the North Sea, the use of smaller meshes can result in bycatches of whitefish such as whiting, and to a lesser extent cod (Brander and Bennett 1989).

The main *Nephrops* fisheries are in the North Sea, the Irish Sea, west of Scotland, the Celtic Sea, the Bay of Biscay and along the coast of Iberia, and stocks are assessed biennially by the ICES *Nephrops* Working Group. Despite some advances in age determination using carapace implants (Shelton and Chapman 1987) and by measuring lipofuscin (Sheehy 1990), *Nephrops* are not aged routinely. ICES estimates fishing mortality by analysing size distributions (Jones 1981) or "age-sliced" size distributions (Anon. 1991, 2000). Direct counting of burrow entrances is also being developed using sledge-mounted TV (Tuck *et al*. 1997), and *SSB* has also been estimated for some stocks on the basis of annual larval production and population fecundity (Tuck *et al*. 1997, Briggs *et al*. 2002). The catch time-series for *Nephrops* in the North Sea is given in Figure 9.

In many of the northern stocks of *Nephrops*, the fishing mortality on males is generally high (0.6 or more, i.e. at or beyond F_{max} on the yield-per-recruit curve), but only moderate (0.4 or less, below F_{max}) on females. It is assumed that the availability of *Nephrops* to capture depends on their patterns of emergence, and that conservation is enhanced because females do not emerge from their burrows during the egg-carrying phase of their life cycle. In the Irish Sea, however, where the fishery takes place mainly after the release of eggs in summer, mortality on females is similar to that on males. On the newly developing Fladen Ground fishery in the northern North Sea (see Fig. 1b), landings of <10 000 tons are taken from a large stock estimated by the TV method to be more than 100 000 tons, and this is one of the few examples of a large underexploited stock of *Nephrops* anywhere. Based on *F* on females, ICES concludes that the northern stocks of *Nephrops* are not overfished, and has advised *status quo TAC*s that are averages of recent landings. In practice, it is doubtful whether *Nephrops* management is restrictive, because the *TAC*s agreed by the EU are somewhat higher than those recommended, and they are actually set as a single *TAC* aggregated across all the biological stocks in a much larger management area (e.g. all stocks in the North Sea, or all stocks in ICES area VII), which means that the management of each biological stock is not controlled. There are also regular criticisms from the fishing industry itself about the true level of compliance on *Nephrops TAC*s. It is therefore conceivable that the seeming stability of the northern stocks depends more on the behavioural availability of *Nephrops*, and of females in particular, than on the management regime.

The picture is very different in the Bay of Biscay and farther south, where fishing mortality on female *Nephrops* is higher than on the northern stocks, and where landings-per-unit-effort and trawl-survey data show that, in the past decade, stock biomass has declined rapidly. The reasons for this stark difference are not fully understood, but it may be that, because the stocks are located close to the shelf edge, retention and recruitment of juveniles is less certain and the stocks are therefore more easily depleted (the stocks are also comparatively small). At any rate, ICES recommended a 40% reduction in exploitation in the Bay of Biscay and off south and south-west Portugal, and zero fishing off Galicia, Cantabria and western Portugal. The management recommendation for 2003 is a 50% reduction in the Bay of Biscay and zero landings from all Iberian stocks except for an allowance of 50 tons for the Gulf of Cadiz. These stocks are evidence that *Nephrops* stocks can be overfished, and it remains to be seen whether they can be rehabilitated successfully.

WEST COAST ROCK LOBSTER OFF SOUTHERN AFRICA

The West Coast rock lobster has a long history of exploitation off both South Africa and Namibia (Lees 1969). The early life history is likely quite complicated and, before settlement, of long duration (Pollock 1986), but the species is also highly influenced by fluctuations in the environment within which it lives, for instance in responding to less advantageous conditions by its somatic growth rate declining. This decline necessitated a reduction in the minimum legal landing size of *Jasus lalandii* (Pollock *et al*. 2000).

Catches by the South African fishery declined spectacularly during the 20th century, but in stepwise fashion. Early 20th century catches were about 9 000 –11 000 tons whole mass annually, but they dropped to an annual average of about 6 000 tons in the 1960s and 1970s, then to some 3 500–4 000 tons in the 1980s, after which catches and *TAC*s gradually declined to only 1 500 tons in the mid 1990s (Fig. 10). Much has been written about the rock lobster fisheries (see reviews by Pollock 1986, 1995, and Pollock *et al*. 2000), but general scientific consensus is that the first decline was simply the result of the collapse of the resource off northern South Africa caused by a combination of overexploitation and environmental change, and that subsequent decreases were the result of the same factors plus (more recently) an alarming reduction in somatic growth that probably had an environmental stimulus. Notwithstanding, the resource is currently managed according to an OMP formulation, thoroughly discussed with all stakeholders, that makes use of three sources of data, catch rates from the commercial fishery and from a fisheries-independent monitoring survey using traps, and information on somatic growth rate (Johnston and Butterworth 2000). It is clear that the resource is now managed according to many of the principles of the precautionary approach (Cockcroft and Payne 1999), and annual *TAC*s and catches have started to rise again (they are now >2 000 tons). Current scientific effort is devoted towards moving the management procedure towards a population model basis, attempting to make greater use of the long time-series of data now available and reducing (unnecessary) variability in the advised *TAC*s.

The Namibian crash was even more spectacular, catches staying at around 9 000 tons until the mid 1960s when the environmental change allied to overexploitation took its toll (Fig. 10). Various controls were introduced, removing then reinstating the minimum size, and stepwise reducing the *TAC*, but for two decades the *TAC* was never landed, and by 1991 it was just 100 tons (Pollock *et al*. 2000, Boyer and Hampton 2001). Recently, it has increased modestly and annual landings are now of the order of 300 tons.

Clearly, being an inshore and generally very available species, once it has settled after its long larval phase (Pollock 1986, 1995), West Coast rock lobster are highly susceptible to heavy fishing pressure. This fact, allied to environmental change along the southern African coast, resulting in massive somatic growth reductions initially in the north and later in the south, clearly had a negative influence on the size of the animals and the stock. It is therefore gratifying to be able to record that, off South Africa at least, the corner seems to have been turned, and this may well have come about, as for the other southern African species in these case studies, through reasonable scientific advice acted upon by decision-makers.

DISCUSSION

In both Europe and southern Africa, considerable scientific effort and funding has been devoted to providing the best form of advice to managers and decision-makers. In southern Africa in particular, the level of interaction between scientists, scientific managers, commercial fisheries managers and stakeholders and decision-makers has tended to be good (though only post-Independence for Namibia), and the establishment of thoroughly debated OMPs in recent years is testament to the wishes of both sides to succeed (Cochrane *et al*. 1997, 1998, De Oliveira *et al*. 1998, Geromont *et al*. 1999, Boyer and Hampton 2001). It is particularly gratifying as a scientist to read the words of Namibia's Minister of Fisheries and Marine Resources in his introduction to a volume (Payne *et al*. 2001) commemorating the decade of that country's marine scientific advice since Independence. Iyambo (2001)

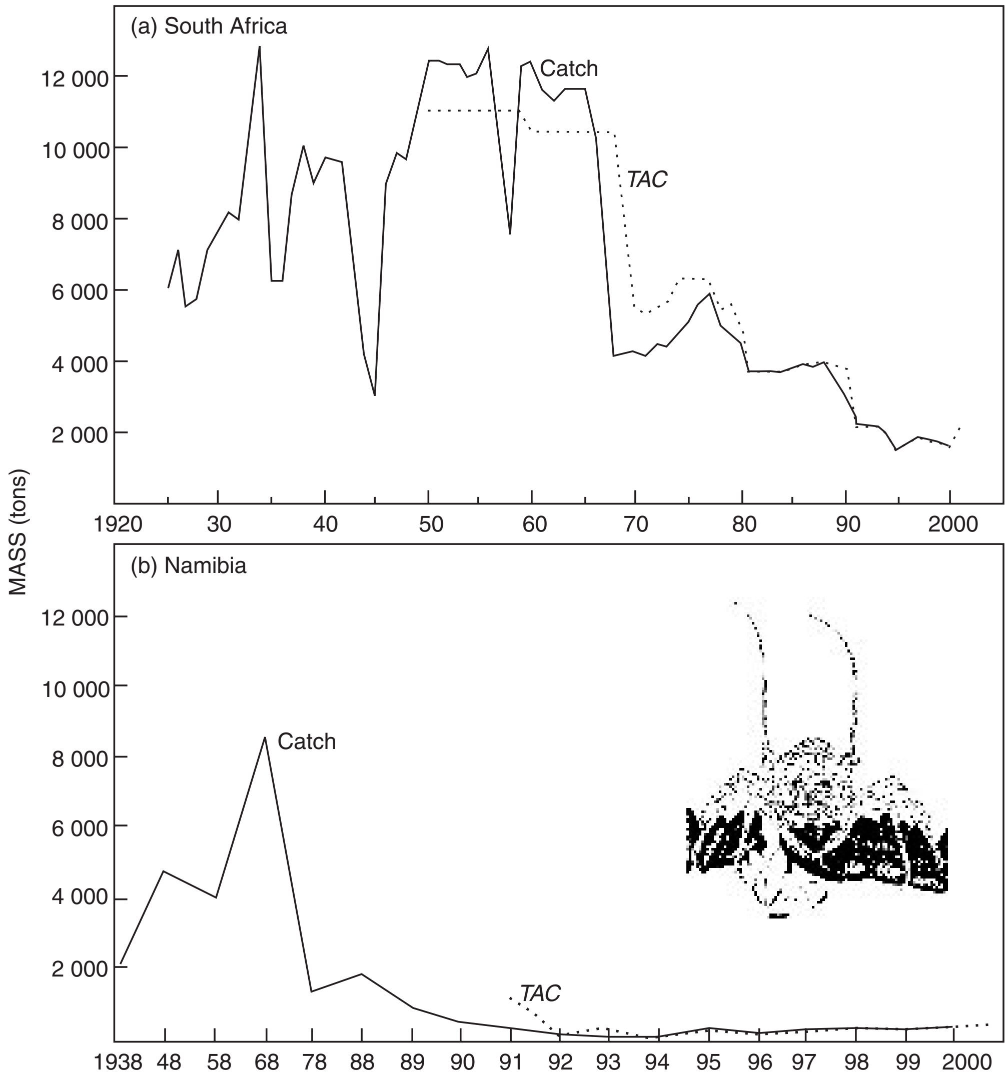

Fig. 10: Catch and *TAC* time-series for West Coast rock lobster off South Africa and Namibia (updated in part, with permission, from Schoeman *et al*. 2002)

uses phrases such as "... some of the excellent research conducted in Namibia during the 1990s ..." which " ... will stand for many years as an icon of what can be achieved by a developing country with the will to take its place among the ranks of those advocating and practicing the principle of sustainable utilization ...". Namibia realized the need for international cooperation where its skills were short, and actively pursued it (and not just from its neighbour, South Africa). Also, like South Africa, Namibia was not shy to levy industry for the funds to support its management initiatives; this foresight seems now to be paying dividends (Oelofsen 1999, Iyambo 2001).

South Africa had a much longer history of scientific endeavour, but it also moved fast after its own democratization in the early 1990s. The White Paper (Anon. 1997a) and its successor the Marine Living Resources Act (Anon. 1998a) show remarkable understanding of stock dynamics and foresight, and the turn-around in the fortunes of the Cape hake, sardine and, to a lesser extent, West Coast rock lobster resources show how will can be translated into success if all parties work together with the same objective. That there were doubters, transformation opponents and those wishing on economic grounds to obstruct or slow change was anticipated and not surprising, but the current status of its marine living resources and the management regime lend optimism to the future of southern African marine resources, as Iyambo (2001) states so eloquently on behalf of Namibia.

Of course, a prerequisite to successful scientific management is the availability of tools and the skills to employ them. South Africa has been very lucky in this regard, having had the foresight to invest heavily in the basic biological and oceanographic research necessary to bring marine science to acceptable international levels and, even in its days of isolation, the will to make the most of local expertise in studies such as the Benguela Ecology Programme (Shannon *et al*. 1988). Further, numerical assessment expertise has been locally available and, virtually from the very start of numerical science, assessment of hake, pelagic species and rock lobster has been rigorous and attuned to the best international standards available. Namibia too has invested heavily in training, and has relied on foreign aid, donor assistance and, recently, cooperative programmes (especially with its neighbours) to generate the momentum for its marine science and fisheries management programmes.

There may well be other differences in fisheries management in the two areas covered here that have allowed the southern African situation to be rather better than in Europe in terms of its success. For instance, the dominance of Cape hake in the demersal ecosystem has meant that mixed-species issues such as for the European gadoids have not been so critical to success. The mixed-species nature of the southern African pelagic fishery has made the situation occasionally difficult to manage, but scientists and decision-makers have striven to ensure the best possible use of all pelagic species through the OMP currently operating. Further, policing (control) can be difficult in southern Africa, as in Europe, but throughout the past 30 years, some degree of self-policing and reasonable relationships between the fisheries control and management arms and the demersal and pelagic fisheries at least have perhaps alleviated some of the problems that the European control system have experienced. Misreporting (of catching area, and occasionally of species in the pelagic fisheries) may well have been prevalent at times, but overall, it is not seen to have been a major problem in southern Africa, and assessments have taken cognizance, where possible, of accurate data on catches. As Oelofsen (1999) points out, Namibia may well have one of the best fisheries control systems anywhere in the world right now. Finally, discarding has taken place in the demersal fishery, but its extent is fairly well known. In the pelagic fishery, discarding has been prevalent because some participants have quotas for anchovy, some for sardine and some for both species, and it is not always easy to maximize one quota species at the expense of the other without discarding. However, in general the situation regarding discarding and misreporting is not considered to be too serious in terms of the assessments made.

For Europe, the North Sea cod and herring case studies show how difficult it is to achieve successful fisheries management despite the early development of fisheries research, and the evolution of seemingly comprehensive institutional arrangements for scientific advice, fisheries management and enforcement. The North Sea herring case illustrates the key points.

- Prior to the 1970s closure, the fishery was unregulated. As a result, the combination of fishing too hard on juveniles and spawners caused a major decrease in *SSB*, leading to stock collapse.
- Collapse was preceded by a prolonged period in which scientific interpretation was not unanimous or clear-cut owing to complexities in stock structure and unresolved competing hypotheses.
- The stocks were shared and harvested simultaneously by a range of different gears and fleets, and the competing national interests found it very difficult to take timely and substantial action to restrict fisheries. Scientific weaknesses or uncertainties were used to justify a negative response to management proposals.
- Even with complete closure, recovery of the herring required 5–8 years, during which time there was serious disruption to the fishery and the market.
- The herring stock is now more moderately exploited, but there is still evidence that fishers do not comply with the *TAC*.

In the case of North Sea cod, *SSB* has been very low throughout the 1990s, and in 2001 it was well below B_{lim}. ICES has repeatedly warned of the danger of stock collapse, and recent advice has recommended the lowest possible catch level and the establishment of a recovery plan to rebuild the stock to B_{pa} as quickly as possible. The low *SSB* followed the rapid rise in *F* during the 1970s and 1980s, and was further affected by the fall in recruitment during 1987. This fall in recruitment is probably both stock-related and influenced by an increase in seawater temperature during the recent positive phase of the North Atlantic Oscillation.

Although *F* on North Sea cod did not rise further during the 1990s, but fluctuated at a high level, it did so in defiance of a succession of ICES recommendations to reduce it in order to rebuild *SSB*. Yet the management system did not achieve its objectives and has been unable to prevent the stock declining towards collapse. It has not been clearly established why this is so. In the late 1980s, *TAC*s were certainly set well above the advice, and were also exceeded, but for much of the 1990s the *TAC* was either similar to or less than the advice, and was frequently not fully taken, at least if reported landings are to be believed. There are scientific concerns about the possibility of under-reporting. A *TAC* system does not reduce capacity, so even when a *TAC* is cut back, fishing effort may still continue at its former level, and the concern is whether the reduced catch is "achieved" by a combination of excessive discarding, high-grading and under-reporting. Comparison between the *SSB* estimated by previous assessments and results in the converged part of recent assessments suggests that *SSB* was being underestimated in the 1990s, especially round about 1995, and that this may have taken place because of under-reporting. It is therefore likely that the *TAC* was not restrictive. The European Community Multi-annual Guidance Programme has set objectives to contain or reduce the capacity of European fishing fleets, but this too does not seem to have reduced *F* on North Sea cod. This might be the case if the number of fishing vessels scrapped is insufficient to compensate for an increase in the efficiency of the remainder. In the EU, the *TAC* system allocates fishery resources between member states on the basis of historic track records. However, if a *TAC* approach cannot deliver the strict management recommended for North Sea cod, serious consideration must be given to direct control of fishing effort through, for example, limitations on days spent at sea, a form of management currently opposed by the fishing industry in Europe.

The seeming stability of *Nephrops* in northern waters is here attributed to the biology and behaviour of the species, determined by its burrowing habit and emergence patterns. Nevertheless, stability should not be taken for granted, because the rapid depletion of the southern stocks shows that overfishing is possible and that its onset can be sudden, especially if, as is postulated, the recruitment mechanisms of the southern stocks are less certain.

Compared with southern Africa, the agreement and implementation of management objectives in Europe is complicated by the large number of competing national and localized fleet and gear interest groups, and by the relative lack of stakeholder involvement in the management process. The nature of the ICES advice is communicated to stakeholders, and they assist in developing a national negotiating position, but it is only in the last year or two that the North Sea Fisheries Commission Partnership has established a regular dialogue with stakeholders to explain the nature and implications of the assessments and the reasons for the advice. This may have contributed to the lack of commitment by fishers to the objectives and methods of fisheries management. The point has been understood by the European Commission, which is advocating that, in the revised Common Fisheries Policy, there should be greater involvement by stakeholders in the management process, and greater emphasis on regional management (Anon. 2002b).

The European context shows that it is easy to underestimate the forces generated by the competitive expansion and inexorable technical innovation that characterize fishing for commercial markets. It is also difficult to surmount the political and economic factors that make it hard for countries to agree to timely restrictive management of shared resources until the stocks are seriously depleted. The examples given here show that, under these circumstances, it is easy to set aside both common sense and best-judgement scientific advice, and to exploit weakness in scientific knowledge based on data that are affected by compliance problems, or methods that are affected by uncertainty.

Despite what is written above, fisheries management science has come a long way over the past century. In both Europe and southern Africa, advances have been spectacular. In Europe, however, success (gauged by sustainable utilization as defined today) has been limited despite the many competent practitioners of the art of fisheries research over the years. Some of the reasons for this failure are likely mentioned above, but one must ask too whether the southern African success in rigour of debate, consensus and extensive buy-in of virtually all interested parties in fisheries management decisions is mirrored in Europe. Nationally perhaps there is some foundation for saying so, but Europe-wide, the answer is probably negative. More stimulus should be given to encouraging ongoing, rigorous debate between stakeholders, decision-makers and scientists across Europe that will result in generations of society having the same or better options regarding the use of marine living resources than the current generation. Headlines in Europe like the recent "Fish out the politicians" (Mackenzie 2002) probable find support in some scientific circles, and there may well be solid scientific foundation for what that article says about management of and adherence to Europe's Common Fisheries Policy.

Geographical distance from the fleets of Europe, the shorter (by at least half) period of heavy exploitation, and the just about timely establishment of the principles of the Law of the Sea paint the southern African picture a lot rosier. Nevertheless, some of the mistakes of the northern hemisphere were still not heeded in time to prevent market forces taking precedence over scientific advice, so bringing some resources to low levels at a time when environmental stimuli and natural fluctuations were anyway negatively influential. Of course, it must be conceded too that, particularly in South Africa, the main pelagic and demersal fisheries have traditionally been in the hands of a few large and prosperous companies. Not only does such a situation favour lobbying, but it also facilitates communication and debate in the establishment of OMPs. The same large companies historically had other business ventures and investments that allowed them leeway to ride the periods of reduced fish yields while exploring better ways to manage stocks for improved long-term yield. European fisheries generally display the antithesis of this situation, with thousands of skipper-owners and small companies belonging to often competing fisher organizations and, obviously, competing national objectives.

Given the above and in the face of transformation necessities following democratization of both South Africa and Namibia, fisheries management and its advisory science in southern Africa has, in the authors' opinion, been at least a qualified success. Fisheries administrators in Europe and other parts of the world could do worse than to take note of the southern African *modus operandi* and, where feasible and appropriate, use it on their resources before it is too late. However, the present authors do not believe that placing all control in the hands of scientists, as seemingly advocated by Mackenzie (2002), is going to be the panacea for a problem that has been worsening for generations. Finally, although Hardin (1968) coined the phrase "Tragedy of the Commons" to refer to what he perceived was happening to many fish resources, he was not referring specifically to the North Sea, with its complexity of inter-related political and economic drivers. The consequences are, however, remarkably similar.

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