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AN OVERVIEW OF THE LIVING MARINE RESOURCES OF NAMIBIA

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This paper gives an overview of the main living marine resources of Namibia. It focuses on the scientific research conducted during the past decade as input to the management of these resources. The distribution and habitats of the most important harvested species and the main seabird populations are briefly described and discussed. The life histories of the major exploited species are summarized, with emphasis on spatial and temporal spawning patterns, dispersal of early life stages, migration patterns of recruits and adults, and diet, the latter particularly as it relates to potential competition between species. A number of commercially important species, such as the hake *Merluccius capensis* and *M. paradoxus*, deep-sea red crab *Chaceon maritae*, West Coast rock lobster *Jasus lalandii*, skipjack tuna *Katsuwonus pelamis,* southern albacore *Thunnus alalunga* and to a lesser extent Cape horse mackerel *Trachurus capensis*, southern African sardine *Sardinops sagax* and Cape anchovy *Engraulis capensis*, are distributed across national boundaries, requiring regional cooperation in research and management. The history and current status of the major fisheries is discussed. Over the past 30–40 years total annual catches have declined from a peak of around 2 million tons in the late 1960s to less than a million tons in the 1990s. This decline has been due, mainly, to a collapse in the sardine stock in the late 1960s and 1970s, and a reduction in the catches of hake and horse mackerel under a conservative management strategy in the past decade. Changes in the abundance and distribution of commercially important species, as determined by acoustic and trawl surveys and catch-based analytical methods, are presented. The effect of major environmental anomalies on the distribution and abundance of the resources in recent years is discussed. The most dramatic anomaly in recent years was the wide-scale advection of low-oxygen water into the northern Benguela from the Angola Dome in 1994, and the subsequent Benguela *Niño* of 1995, which appear to have severely impacted the Namibian sardine population and many other resources. The present socio-economic value of the Namibian fishing industry is given together with the broad policy, legislation and formal structures for managing the living marine resources.

Key words: Benguela, exploitation, fisheries, management, marine resources, Namibia

The Benguela ecosystem can be loosely considered to cover the continental shelf between the Angola-Benguela frontal zone off northern Namibia/southern Angola and the Agulhas retroflection area, typically between 36 and 37°S (Parrish *et al.* 1983, Lutjeharms and Meeuwis 1987, Shannon and O'Toole 1998). As such, it covers the west coast of South Africa, the entire Namibian coast, and part of southern Angola, depending on the position of the Angola-Benguela front, which moves seasonally typically between 14 and 17°S (Shannon 1985). Strong perennial upwelling off Lüderitz (26–28°S) effectively separates the northern from the southern Benguela. A tongue of freshly upwelled, turbulent water moving north-west with little vertical stratification acts as a semi-permanent environmental barrier to fish movement (O'Toole 1977, Agenbag 1980, Boyd and Cruickshank 1983, Agenbag and Shannon 1988). Namibia borders much of the northern part of this system, from 17 to 29°S (Boyer *et al.* 2000, Fig. 1).

The Benguela Current is one of the world's major eastern boundary current systems (Wooster and Reid 1963) and is rich in pelagic and demersal fish populations, supported by plankton production driven by intense coastal upwelling (Shannon and Pillar 1986). In comparison to the other eastern boundary upwelling systems, the Benguela is probably the second most productive, in terms of fish, behind the Humboldt (Table I). The Humboldt has provided annual yields of up to 15 million tons of anchovy *Engraulis ringens* and 6 million tons of sardine *Sardinops sagax* (although not in the same year) compared to a combined yield of 0.6 and 1.5 million tons of the equivalent congeners in the northern and southern Benguela system respectively. For more information on the dynamics of the Benguela system the reader is referred to Payne *et al*. (1992) and in particular to three papers in that volume, namely Hutchings (1992), Mann (1992) and Ware (1992).

Many of the living marine resources of the northern Benguela have been heavily exploited, particularly

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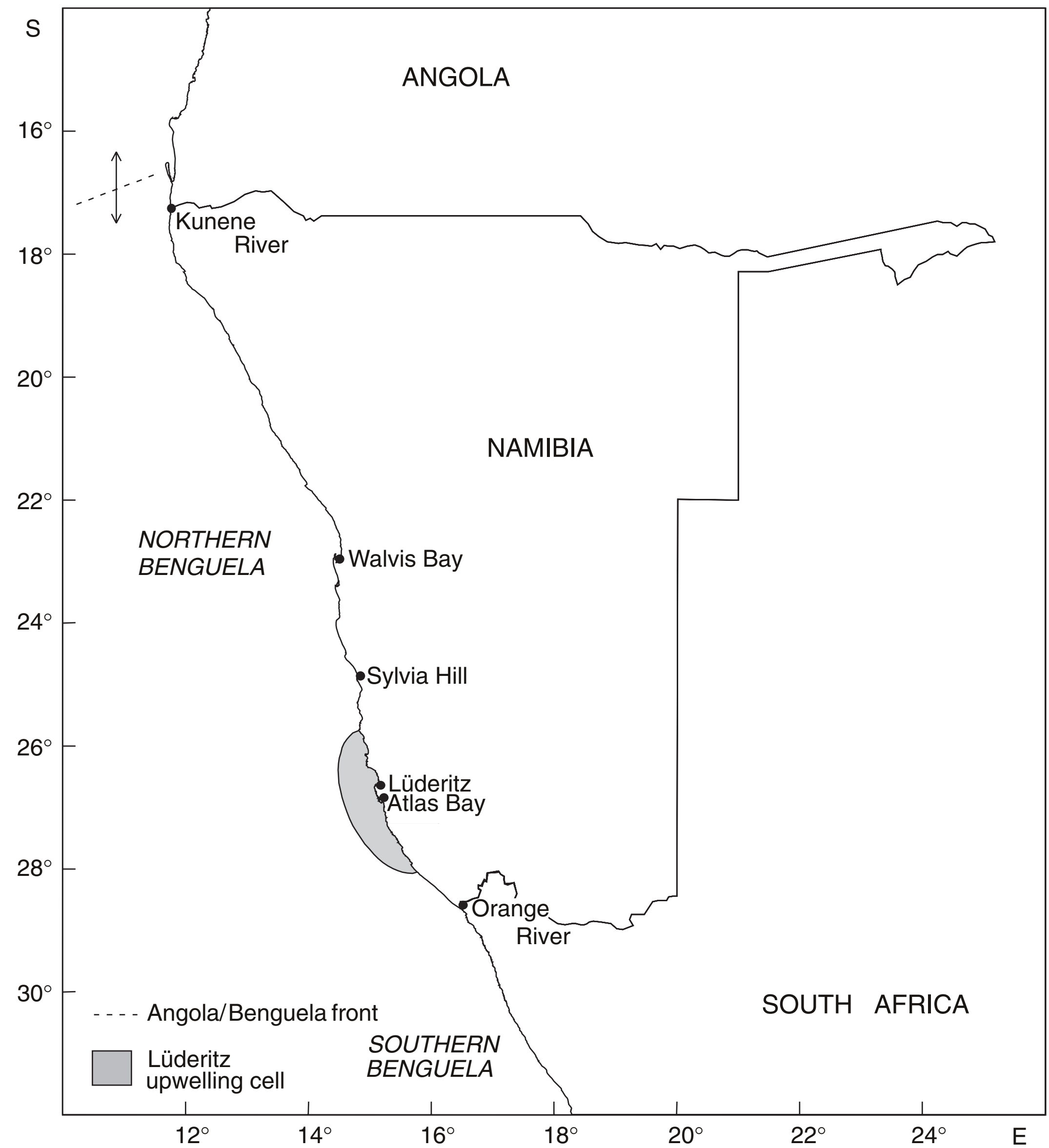

Fig.1: General map of the Benguela, showing places mentioned in the text

since the Second World War. Total fish catches increased rapidly during the 1950s and 1960s, with the development of fisheries on shallow-water *Merluccius capensis* and deep-water Cape hake *M. paradoxus*, southern African sardine *Sardinops sagax*, Cape anchovy *Engraulis capensis* and Cape horse mackerel *Trachurus capensis* (Fig. 2), and a small, but valuable fishery for West Coast rock lobster *Jasus lalandii*.

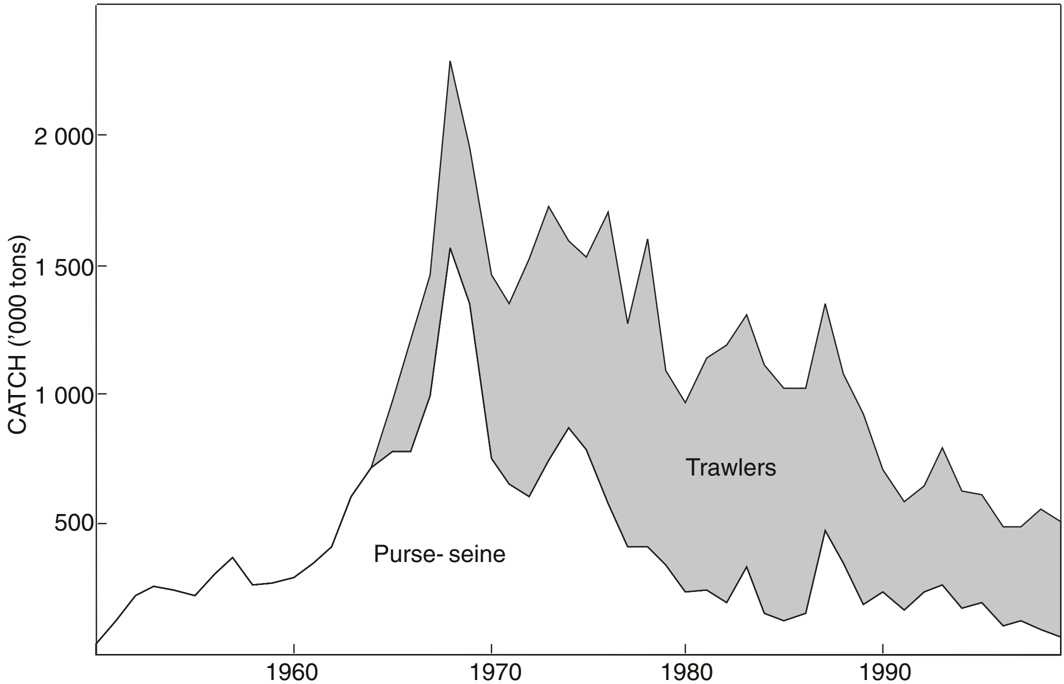

Fig. 2: Total catch of the major commercial fisheries in the Namibian region of the Benguela Current over the past five decades – purse-seining and trawling (data from ICSEAF Bulletins and Ministry of Fisheries and Marine Resources)

The total annual catch peaked at around 2 million tons in 1968, but it subsequently declined to less than 600 000 tons in the 1990s. This was largely because of a major decline in sardine catches and the cessation of foreign trawling for hake and horse mackerel after Namibian Independence in 1990. Since the 1960s there has also been a dramatic decrease in rock lobster catches, which are now some two orders of magnitude below their peak in the 1960s. It is believed that most of these declines are attributable to overfishing, although some of the major fluctuations have probably been influenced to a greater or lesser extent by the large-scale and periodic environmental perturbations in the system during the same period (Shannon and O'Toole 1998).

This overview gives a description of the major living resources of the Namibian part of the Benguela, and of the attempts that have been made, particularly in recent years, to manage them rationally and sustainably. It also highlights the species harvested in Namibia, but that extend beyond Namibia's borders and hence may justify regional management. For a review of the fish resources of the entire Benguela system, the reader is referred to Crawford *et al.* (1987), Payne and Crawford (1989) and Hampton *et al.* (1998).

Table I: Comparison of various productivity parameters of the four major eastern boundary upwelling systems (after Hutchings 1992)

Parameter	Benguela	Humboldt	California	Canary
Phytoplankton productivity (gC m^{-2} day^{-1})	1–5	3–10	0.1–1.4	1–3
Zooplankton biomass (mℓ 1 000 m^{-3})	200–250	250–1 500	100–600	270–1 060
Maximum fish yield (tons × 10^6)	3	14	1	1–2
Total fish biomass (tons × 10^6)	11	20–30	3–5	3–5

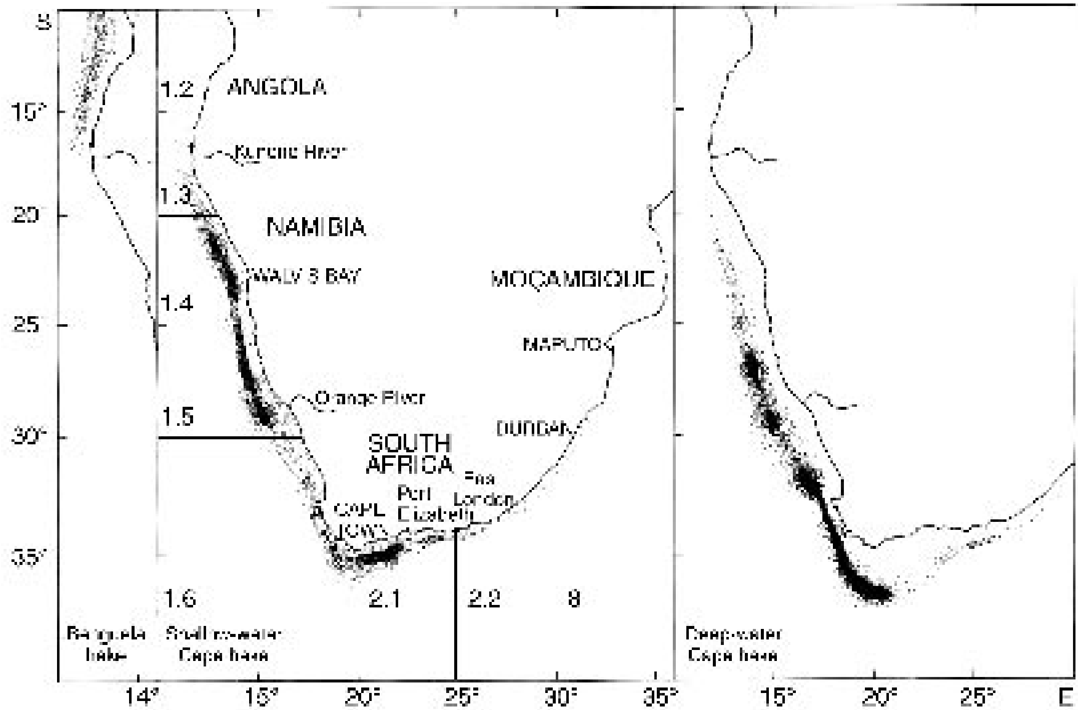

Fig. 3: Distribution of the three hake species, with ICSEAF Divisions indicated (after Payne 1989)

OCCURRENCE AND STOCK IDENTITY

Small pelagic fish

The major fisheries for small pelagic fish off the west coast of southern Africa are those for sardine (also known as pilchard), anchovy and Whitehead's round herring *Etrumeus whiteheadi*. Juvenile Cape horse mackerel also occupy the epipelagic zone and are targeted by the same purse-seine fleet.

Sardine and anchovy live in temperate waters from southern Angola to KwaZulu-Natal in South Africa, with both species co-existing, each occurring as quasi-discrete stocks off northern/central Namibia and off South Africa's Western Cape (Boyd and Cruickshank 1983, Beckley and van der Lingen 1999). According to Grant (1985) the degree of mixing between the southern and the northern populations of these two species is unknown, but considering that the populations spawn in different, widely separated areas and are separated by a large, perennial area of cold, upwelled water off Lüderitz, it is probably not significant for management purposes, except in anomalous years (Boyd and Badenhorst 1980, Cruickshank 1984, Hewitson 1988). Sporadic catches in Angola in the late 1950s, late 1960s (de Campos Rosado 1974), and again in 1995 (Boyer *et al.* 2001a), as well as research surveys, indicate that the stock extends into Angola, and varies seasonally, being most abundant in winter. Round herring are found over a similarly wide latitudinal range, but they appear to be most abundant off South Africa east of Cape Point, particularly over the central and eastern Agulhas Bank (Geldenhuys 1978). Most of the round herring caught in Namibian waters are juveniles, taken as a small bycatch in the purse-seine fishery. The adult stock off Namibia is thought to be small compared to that farther south. Interaction between the southern and northern Benguela stocks is probably of little consequence.

Juvenile Cape horse mackerel (fish <20 cm total length) are most common off northern Namibia or southern Angola, south of the Angola/Benguela front. Juvenile Kunene horse mackerel *T. trecae* are found in subtropical and tropical waters of Angola and occasionally off northern Namibia.

All four stocks tend to occur within the 100 m isobath, and are often found very close inshore, just beyond the surf zone. Catch patterns have clearly indicated a northward shift in the core distribution of sardine since the collapse of the fishery in the 1970s, possibly as a result of the depletion of the southern spawning population and the cessation of associated migrations (King 1977, O'Toole 1977).

Trawled fish

The major species caught by trawl off Namibia are shallow and deep-water Cape hake, which are caught in bottom trawls, and adult Cape horse mackerel, which are taken off Namibia mostly in midwater trawls. A third species of hake, *M. polli*, occurs in Angola, but it is rarely caught in Namibian waters. Species caught as bycatch in the hake fishery in Namibia are monkfish *Lophius* spp., kingklip *Genypterus capensis*, snoek *Thyrsites atun* and West Coast sole *Austroglossus microlepis*. In recent years, a monk-directed fishery has developed, with hake as the most important bycatch (Maartens 1999). On the outer Namibian shelf there is also a valuable deep-water trawl fishery directed at orange roughy *Hoplostethus atlanticus* and, to a lesser extent, alfonsino *Beryx splendens*. Between the late 1970s and mid 1980s large bycatches of chub mackerel *Scomber japonicus* and snoek were taken by midwater trawlers. Those species are now rarely taken by the midwater fleet, although a few hundred tons of chub mackerel are occasionally taken by the purse-seine fleet south of Lüderitz and snoek are caught by handline vessels (see below).

At least two stocks of Cape horse mackerel exist off southern Africa's west coast, one off northern Namibia/southern Angola, and one off South Africa's Western Cape (De Villiers 1977, Draganik 1977). These fish are believed to originate from separate spawning stocks off northern Namibia and South Africa's south coast respectively (Babayan *et al.* 1983) and are likely to be genetically separated by the environmental barrier of the Lüderitz upwelling cell, with only limited interchange between them (Naish *et al.* 1991).

The distribution of the three species of hake in the Benguela is shown in Figure 3. Benguela hake *M. polli* are found predominantly in Angolan waters and are caught on the shelf and slope as a bycatch of the prawn fishery and by bottom trawlers off southern Angola, where their distribution overlaps with that of *M. capensis.* Cape hake are found throughout Namibian and South African waters, although deep-water hake are more common in the south (Burmeister 2001). Deep-water hake occur in deeper water than shallow-water hake, although the two species co-occur at intermediate depths (Payne 1989, Burmeister 2000). Typically, the former are found in water 150–800 m deep, mostly at temperatures of 4–8°C, whereas the latter occur from the coast to a water depth of about 380 m, in temperatures between 4 and 12°C. Larger individuals of both species are found at greater depths than smaller fish, and there is little overlap in the distribution of mature fish.

M. capensis is the more common species off Namibia, especially in the central region, although *M. paradoxus* has become increasingly abundant and more widely distributed in recent years (Burmeister 2000). *M. paradoxus* dominates off the west coast of South Africa and, with the absence of evidence of recruitment in Namibian waters, it is believed that the Namibian *M. paradoxus* stock may be reliant on the South African stock for recruits (Gordoa *et al.* 1995, Burmeister 2000). Figure 3 indicates that the stocks of both species are probably shared between Namibia and South Africa. There is evidence from surveys (e.g. Strømme 1996) and commercial catches that the increased abundance of *M. paradoxus* off Namibia since 1990 may be evidence of a gradual migration or expansion of the stock from South African waters (Burmeister 2000). While seasonal meridional shifts in the distribution of demersal fish communities have been reported by Macpherson and Gordoa (1992), apparently as a result of changes in temperature and oxygen concentrations, this is the only reported evidence of significant longshore movement of any of the three hake species.

The main commercial species of monkfish found in southern African waters are *Lophius vomerinus* (previously known as *L. upsicephalus*) and *L. vaillanti*, of which *L. vomerinus* provides by far the greater proportion of the total catch (Maartens and Booth 2001a). The former is found from northern Namibia to the east coast of South Africa, but the latter occurs only north of Walvis Bay (Leslie and Grant 1990, Maartens and Booth 2001a). Both are demersal species, found mainly at depths of 150–500 m, although off Namibia the highest densities are between 300 and 400 m off central Namibia (Maartens 1999). Two separate recruitment areas for *L. vomerinus* have been located off Namibia: off Walvis Bay and near the Orange River. The relationship between these recruits and *L. vomerinus* to the south is unknown, as is the extent of any longshore migrations of adults. Nonetheless, it seems reasonable to assume that there is some interaction between the populations found in the southernmost part of Namibian waters around the Orange River and on the South African west coast in particular.

Orange roughy are found mainly over the shelf, at depths of 600–1 000 m and bottom temperatures of 3–7°C (Boyer and Hampton 2001, Boyer *et al.* 2001b). They tend to be concentrated over hard substrata in a number of small areas, particularly during the spawning season. Alfonsino tend to be more widely distributed over the outer shelf, at depths of between about 400 and 700 m. The degree to which the distribution of the two species extends into Angolan and South African waters, and the extent of any longshore migrations, is at present unknown.

Crustaceans

The major crustacean fisheries along the western coast of southern Africa are those for the West Coast rock lobster off southern Namibia and South Africa and for deep-sea red crab *Chaceon maritae* off northern Namibia and Angola.

Jasus lalandii are associated with the cool upwelled waters of the Benguela. They occur in commercially exploitable densities from east of Cape Point to approximately 25°S, and at lower densities beyond their core distribution (Crawford *et al.* 1987). Close inshore they are caught by hoopnets deployed from dinghies and by recreational divers, but in deeper water (>10 m) they are harvested commercially by traps.

Red crab occur on the slope of the continental shelf from about 27°S off Namibia, northwards to Angola, Congo and the Ivory Coast (Dias and Seita Machado 1974). Off Namibia they are found at depths of between about 300 and 900 m (Melville-Smith 1983), and currently they are harvested solely by Namibian-flagged Japanese vessels using traps. Off Angola they are found within a similar depth range, particularly in the south, and are caught in traps and occasionally by bottom trawls. It has recently been shown from tagging studies that adult females migrate from Namibia to Angola (Le Roux 1997), suggesting a single stock in the region.

Linefish

The silver kob *Argyrosomus inodorus* is the most important of the nearshore linefish species caught off central Namibia, whereas the dusky kob *A. coronus* occurs off northern Namibia and hence is lightly targeted (Kirchner 1998). Other important angling species in Namibian waters are West Coast steenbras *Lithognathus aureti*, blacktail *Diplodus sargus* and galjoen *Coracinus capensis*.

Snoek is the most important migratory linefish caught commercially on the west coast of South Africa (Griffiths 2000), and, although it is less important in Namibia, it has supported a valuable export business, particularly to Mauritius and Reunion, since the early part of the 20th century. Historical catch records suggest that snoek were once considerably more abundant than at present. They are found along the entire southern African coast from southern Angola to Cape Agulhas, mainly in cool upwelled water, and are a major predator of pelagic fish (Crawford and de Villiers 1985). Snoek were considered to form a single stock extending from Cape Agulhas to northern Namibia, and to migrate seasonally between these two regions (Crawford *et al.* 1990). However, a recent study (Griffiths in press) suggests that there may be two separate subpopulations off Namibia and South Africa, with medium-term exchange (in the order of five years) between them in response to environmental events and food availability.

Of the large pelagic species taken in the region, the most important is southern albacore or longfin tuna *Thunnus alalunga*. This species is caught currently by Namibian and South African pole and line vessels (these are referred to as "bait-boats" by the International Commission for the Conservation of Atlantic Tunas – ICCAT) within territorial waters from south of Cape Point to Lüderitz (F. Botes, NatMIRC, Swakopmund, pers. comm.). The same species is also exploited by Asian high-seas longliners. The stock is believed to be part of a single southern Atlantic stock and to be largely separate from the southern Indian Ocean stock, although there is thought to be some mixing of the two stocks south of the African continent in the austral winter (Crawford *et al.* 1987, Shannon *et al.* 1989). There is also a longline fishery for bigeye tuna *Thunnus obesus* along the edge of the shelf in both countries, mostly by Asian high-seas vessels.

Top predators

The Cape fur seal *Arctocephalus pusillus pusillus* occurs along the southern African coast between Algoa Bay and southern Angola and is harvested in Namibia. Although the harvest is low compared to historical catches (harvesting of seals has occurred for centuries), seals have been included in this overview because they are major top predators in the Benguela (Wickens *et al.* 1992), and their dynamics have been strongly affected by fluctuations in a number of the major fish resources of the region, making them important visible indicators of environmental change.

The same is true of resident seabirds such as the Cape gannet *Morus capensis*, the Cape cormorant *Phalacocorax capensis* and the African penguin *Spheniscus demersus,* which breed mainly on nearshore islands and guano platforms off Namibia and South Africa and feed largely on pelagic fish such as sardine and anchovy (Crawford 1999). The fluctuating abundance of pelagic fish stocks is strongly reflected in changes in abundance, diet and breeding success of the seabirds, to the extent that, in South Africa, consideration is being given to using this information directly in the management of the sardine and anchovy fisheries.

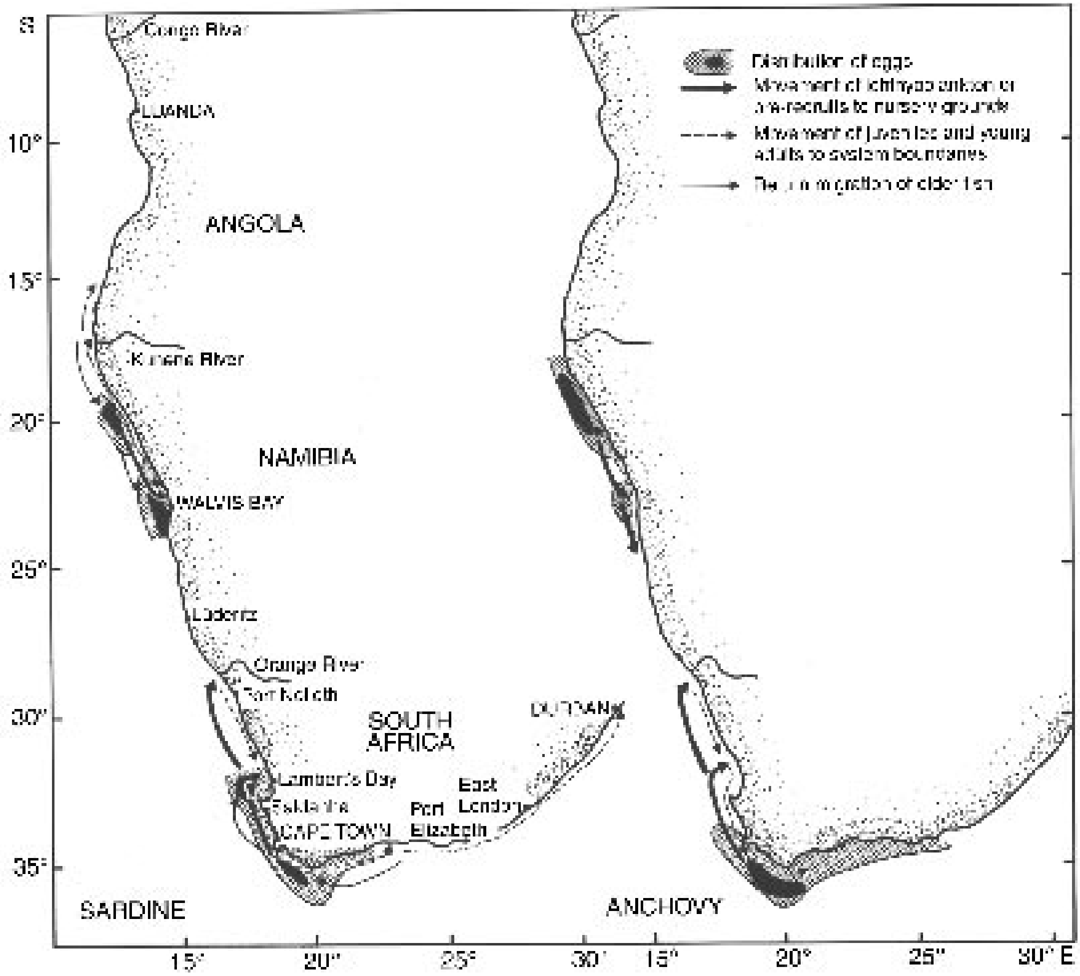

Fig. 4: Sardine spawning and recruitment migration (after Crawford *et al.* 1987)

LIFE HISTORIES OF THE MAJOR RESOURCES

Small pelagic fish

SARDINE AND ANCHOVY

Historically, sardine were recorded spawning largely within 60 km of the coast in two main areas off Namibia, one off Walvis Bay and the other farther north, in the mixing zone south of the confluence of the Benguela and the Angola Current systems (O'Toole 1977). In the northern of these two areas, spawning (mainly by young adults) peaked near the 200 m isobath in late summer/autumn in water temperatures between 19 and 21°C, whereas in the southern of the two areas, spawning (mainly by older fish) took place in summer in cooler water close to upwelling zones (Fig. 4). The distribution and movement of anchovy off Namibia used to be similar to that of sardine, but spawning was only significant north of Walvis Bay (Shannon and Pillar 1986), with dense concentrations of larvae found to beyond 100 km from the coast (O'Toole 1977). The larvae of both species drifted south close to the coast, recruiting as 0-group fish into the fishery in the cool upwelling areas near Walvis Bay. This was followed by a return northward migration of juveniles and young adults to the northern mixing area, where they first spawned. In the case of sardine, older fish subsequently returned south again to spawn near Walvis Bay, whereas younger fish remained in the north. The behaviour of sardine and anchovy off Namibia was analogous to that in other upwelling systems, such as off California, Peru and North-West Africa (Bakun 1996), where both spawning and recruitment occur downstream of the principal upwelling cell (Lüderitz in the case of Namibia).

Since the collapse of the sardine stock in the 1970s, spawning in the south is believed to have diminished in importance (Crawford *et al.* 1987) and the migration of mature fish is also believed to have decreased. Similarly, the anchovy stock has declined to such an extent that it is likely that the life history has also changed considerably from that recorded several decades ago.

There is evidence that, in most years, the northern limit of the anchovy stock in the southern Benguela is the southern edge of the Lüderitz upwelling cell. It has been suggested that, in years when this cell is abnormally weak (as in 1987), pelagic larvae spawned in Cape waters may be carried past the Lüderitz "barrier" and recruit into the southern Namibian fishery, so linking the South African and Namibian stocks of anchovy (Boyd and Badenhorst 1980, Cruickshank 1984). This may have occurred in 1987, when an unexpectedly large number of anchovy recruits appeared off southern Namibia, resulting in a catch several times larger than during the previous and following years (Hewitson 1988). An acoustic survey by Soviet scientists, however, reported large quantities of anchovy (>400 000 tons) in waters outside the 12 mile territorial limits in early 1986 (Assorov *et al.* 1988), suggesting that there was then an anchovy stock in southern Namibia from which the large catch of 1987 may have arisen.

Analyses of stomach contents up to the end of the 1970s suggested that the diets of sardine and anchovy in the Benguela are similar, with phytoplankton the main food source (King and Macleod 1976). However, laboratory and field studies since then have shown that zooplankton is more important in the diet of both species than was previously believed (James 1987). Certainly, juvenile sardine and anchovy, as well as adult anchovy, feed primarily on zooplankton, although adult sardine appear to utilize more phytoplankton in areas of consistently high phytoplankton abundance (James 1988). Little is known about the extent to which sardine and anchovy compete for food in the Benguela ecosystem, but a recent field study on feeding in mixed schools of juveniles, in which a clear size difference was found in the zooplankton taken by the two species (Louw *et al.* 1998), suggests that direct competition may be limited, at least in young stages.

ROUND HERRING

Little is known about the seasonality of round herring spawning in the Benguela, although from ichthyoplankton surveys in the southern Benguela, it appears that spawning occurs throughout the year, reaching a peak between late winter and early summer (Geldenhuys 1978). The species is almost entirely zooplanktivorous (James 1988).

JUVENILE HORSE MACKEREL

Off Namibia, juvenile Cape horse mackerel generally live inshore of the 100 m isobath, the smallest fish being found farthest north (Crawford *et al.* 1987). Slightly larger individuals appear to migrate south towards Walvis Bay, especially in winter. Maturing fish move offshore and northwards to spawn, the adults generally occurring north of 21°S (see below).

Cape horse mackerel up to the age of two years feed near the surface and are zooplanktivorous (Venter 1976). The diet, mainly copepods, is similar to that of sardine and anchovy, and juveniles up to about 10 cm long can co-exist in schools with sardine and anchovy.

Trawled species

ADULT HORSE MACKEREL

Surveys of eggs and larvae off Namibia during the 1970s have shown that spawning is heaviest in the north between October and March in the mixing zone of warm oceanic water and cool coastal water, and that the timing of spawning is closely linked with the duration and intensity of mixing (O'Toole 1977). Nursery areas exist in both the southern and the northern parts of the Benguela ecosystem, adjacent to the spawning grounds but closer inshore, and there are substantial alongshore and cross-shelf migrations of both juveniles and adults.

Off Namibia, 95% of the diet of adult horse mackerel is euphausiids, whereas off the west coast of South Africa the species feeds opportunistically on euphausiids, polychaetes, chaetognaths, squid, various crustaceans and fish such as pelagic gobies *Sufflogobius bibartus*, lanternfish (Myctophidae) and lightfish (Photichthyidae; Konchina 1986). Older horse mackerel tend to feed deeper in midwater, and their diet is similar to that of Cape hake of similar size (Krzeptowski 1982). Accordingly, there may be interspecific competition between Cape horse mackerel and hake, with a decrease in the abundance of the one species benefiting the other, and *vice versa*.

HAKE

Hake spawn in midwater throughout the year, with a peak in early summer for both *M. capensis* and *M. paradoxus* (Botha 1980, Olivar *et al*. 1988). Most *M. paradoxus* spawning is thought to take place along the edge of the Agulhas Bank, but spawning also occurs over the shelf-break off central Namibia and west of St Helena Bay (Assorov and Berenbeim 1983). In the latter region, most *M. capensis* spawn between 160 and 250 m deep, with spawning starting earliest in the shallower waters (Porębski 1976). The eggs of both species are concentrated around the depth of the thermocline (NORAD-FAO/UNDP 1995). Juvenile *M. capensis* nursery areas appear to be near Walvis Bay, off the Orange River and south to about Cape Columbine (Payne *et al.* 1986).

Hake feed both close to the bottom and in midwater. They tend to be off the bottom at night, although this is variable (Iilende *et al.* 2001). No clear feeding periodicity has been demonstrated for either *M. capensis* or *M. paradoxus* (Botha 1980), except in the case of juvenile *M. capensis* which, off the west coast of South Africa, have been observed to move off the bottom at night to feed on pelagic prey such as juvenile anchovy, and to return to the bottom before dawn (Pillar and Barange 1995). Recent studies (Pillar and Barange 1998) have indicated that *M. capensis* adults on the South African west coast also rise into midwater at night in response to the vertical migration of their prey, but that they return to the bottom when satiated, regardless of time of day. This results in aperiodic, asynchronous vertical movements of individuals, depending on food availability and recent feeding activity. This lack of a distinct diel feeding rhythm has recently also been found off Namibia by Huse *et al.* (1998) and Iilende *et al.* (2001). Studies on the behaviour of *M. capensis* and *M. paradoxus* at a single location over the central Namibian shelf found some evidence of increased feeding in early evening, in common with earlier studies of *M. capensis* in the same area (Huse *et al.* 1998).

Hake are opportunistic feeders, resulting in considerable seasonal and spatial variability in their diet (Roel and Macpherson 1988, Traut 1996). Young *M. capensis* and *M. paradoxus* feed predominantly on planktonic crustaceans (particularly euphausiids), pelagic gobies and lanternfish (especially by *M. paradoxus*), the diet of both species becoming increasingly piscivorous with age (Punt *et al.* 1992). Squid, epipelagic fish and, to a lesser extent, mesopelagic fish such as lightfish and myctophids constitute a significant proportion of the diet of adult *M. capensis*, but the principal food items of larger fish are small *M. paradoxus,* small *M. capensis* (to a lesser extent) and other demersal species (Punt *et al.* 1992, Macpherson and Gordoa 1994). *M. paradoxus* becomes increasingly cannibalistic on young *M. paradoxus* with age.

Because of their catholic feeding habits and abundance, hake are extremely important predators in the Benguela. For example, Punt *et al.* (1992) have estimated that hake in South African waters could consume as much as 6 million tons of food annually. Based on estimates of stock size in Namibia, it would appear that consumption there could be as high.

MONKFISH

Monkfish spawn throughout the year, although at a lesser intensity in winter (Macpherson 1985). As noted previously, two separate areas of recruitment have been recorded in waters between 100 and 300 m deep off Walvis Bay and Lüderitz (Leslie and Grant 1990). Monkfish are classical sit-and-wait predators (Maartens *et al.* 1999), ambushing any prey small enough. Hake are the main prey and fish up to the same size as the monkfish itself are taken (Macpherson 1985).

DEEP-WATER SPECIES

Off Namibia orange roughy have a short spawning period of less than a month in late July, when they spawn in dense concentrations close to the bottom in small areas typically between 10 and 100 km^2 in extent (Boyer and Hampton 2001). They are exceptionally long-lived and slow-growing, possibly only reaching sexual maturity at around 25 years of age off Namibia, and may have a maximum lifespan of more than 100 years. They have a low reproductive rate, which together with their aggregating behaviour, makes them highly vulnerable to overfishing (Boyer *et al.* 2001b). Alfonsino are distributed over a wider area. As they are shorter lived than orange roughy, they are probably more productive. Little is known about their spawning behaviour or breeding habitat.

Crustaceans

WEST COAST ROCK LOBSTER

West Coast rock lobster have a well-defined moulting and spawning cycle. Adults moult once per year, the males in spring and the females during late autumn and early winter (Beyers 1979). Mating takes place after the females have moulted. Egg-hatching peaks in October–November and the phyllosoma larvae remain planktonic for several months (Lazarus 1967, Pollock 1986), drifting in oceanic sub-gyres until they reach the puerulus (free-swimming) stage and subsequently settle (Crawford *et al.* 1987). Females reach sexual maturity about 4–5 years after settlement, at a greater length off southern Namibia than north of about 26°S (Grobler and Noli-Peard 1997). Maturing males grow faster than females and reach a larger size, so the fishery, which is subject to size limitations, is based largely on males. Adults are generally distributed offshore of juveniles, except off central Namibia, where the population is constrained close to the coast by low-oxygen water (Pollock and Beyers 1981).

In Namibian waters, the depth distribution of adult rock lobsters (especially males) varies seasonally in response to changes in concentration of dissolved oxygen on the bottom (Tomalin 1993, Grobler and Noli-Peard 1997). Rock lobster feed largely on mussels, in particular the ribbed mussel *Aulacomya ater,* which is abundant in the rocky subtidal zone (Pollock and Beyers 1981, Griffiths and Seiderer 1980, as cited in Crawford *et al.* 1987). In areas of low mussel abundance, the diet consists mainly of echinoderms (sea urchins and starfish), gastropods, bryozoans, polychaetes and seaweeds. The principal predators of rock lobster are octopus, dogsharks, hagfish, whelks (on injured or weakened animals) and young seals (Crawford *et al.* 1987). Cannibalism is known to be common in overcrowded situations, particularly among juveniles.

DEEP-SEA RED CRAB

Deep-sea red crab appear to spawn throughout the year off Namibia, judging from the fact that no seasonal cycles in moulting and egg-bearing have been found (Le Roux 1997). Adult females generally live in shallower water than males, and virtually all egg production and larval release takes place on the shallower part of the continental slope (Beyers and Wilke 1980). The fact that the migration from Namibia to Angola consists almost entirely of females suggests that this is a spawning migration. The species is reported to prey on skates (Macpherson 1985) and deep-sea fish such as *Cottuncoloides macrocephalus* and *Alepocephalus rostralus* (Macpherson 1983).

Linefish

Spawning of silver kob occurs in summer when adults migrate to the south of Walvis Bay, the southern end of their distribution, returning northwards towards the end of summer. They feed primarily on euphausids and small fish in the surf zone.

De Jager (1955) concluded that snoek spawn along the edge of the shelf off southern Namibia, along the west coast of South Africa, and over the western Agulhas Bank, mainly from July to October. There is also some evidence of spawning farther north (Olivar and Rubiés 1985). Data from ichthyoplankton surveys (Griffiths in press) reveal that snoek eggs and larvae are present throughout the Benguela system in winter/spring, distributed as two disjunct bands separated by the Lüderitz upwelling cell. On the basis of these results, Griffiths surmises that snoek spawn simultaneously in both the northern and southern Benguela, counter to the spawning migration hypothesis of Crawford and de Villiers (1985). Adult snoek are found throughout their distributional range, and off South Africa move offshore and southwards to spawn. Other than this there do not appear to be any seasonal trends in longshore movements of adults in South African waters. Migration patterns of juveniles and adults in Namibian waters have not been established with any certainty. Griffiths (in press) hypothesizes that the inverse relationship between handline catches of snoek off Namibia and South Africa, which was noted by Crawford *et al.* (1990), is due to medium-term migrations in response to changes in prey distribution, and not to a regular seasonal migration as such. Snoek are largely piscivorous, consuming primarily small pelagic fish.

Albacore are believed to migrate across the southern Atlantic to South America, and then northwards to spawn in the tropical central Atlantic (Crawford *et al.* 1987). Juveniles occasionally recruit into waters off South Africa's Western Cape, but most fish caught are large, reproductively inactive adults, following and feeding on the rich pelagic prey in the Benguela and Agulhas Current systems. Their diet is reportedly mixed, consisting of approximately one-third each of fish, cephalopods and crustaceans (van den Berg and Matthews 1969).

Top predators

Cape fur seals breed on small rocky nearshore islands and, most importantly, at six mainland colonies on the Namibian and Northern Cape coasts where human access is restricted (David 1989). Several of these colonies (Cape Cross north of Swakopmund, Wolf and Atlas Bay near Lüderitz, and Kleinsee in South Africa's Northern Cape) are believed to be the largest mainland seal colonies in the world. The breeding

Table II: Total industrial catches of major species in Namibian waters (in thousand tons) for the past five decades. Catches of trawled fish from the 1960s, 1970s and 1980s were reported through ICSEAF and refer to areas 1.3, 1.4 and 1.5 (15–30°S)

Species	1950s	1960s	1970s	1980s	1990s	Total
Pelagic fish						
Sardine	2 371	7 428	3 699	527	703	14 728
Anchovy	0	416	2 095	1 310	250	4 071
Round herring	0	0	32	12	55	99
Juvenile horse mackerel	0	0	360	643	676	1 679
Trawled fish						
Horse mackerel (including as a bycatch)	0	576	2 410	4 871	2 966	10 535
Hake (including longline)	0	2 079	5 435	3 108	1 176	11 798
Monkfish (including as a bycatch)	0	0	19	101	98	218
Deep-water species	0	0	0	0	51	51
Other demersal species	0	59	651	286	18	547
Crustaceans						
West Coast rock lobster	0	68	22	15	3	117
Deep-sea red crab	0	0	0	71	27	98
Linefish						
Tuna	0	0	0	13	19	32
Snoek (including bycatch in trawls)	0	0	116	242	13	372
Total	2 380	10 626	14 839	11 200	6 056	45 101

season lasts for 6–8 weeks in October/November, and pupping is followed almost immediately by mating (David 1989). Pups are weaned at an age of 8–10 months, and thereafter forage widely. While attending their pups, adult cows feed within a few days range of the colonies, but the bulls appear to have separate feeding grounds, probably considerably farther offshore (David 1989). Much of the diet is made up of fish, of which the pelagic goby (a non-commercial species), horse mackerel and juvenile hake are the most important off Namibia (David 1989). It has been estimated that seals in the Benguela consume about a million tons of fish annually, approximately the same amount as the total annual fish catch of Namibia and South Africa combined.

Cape gannets breed on islands off southern Namibia and the west and south coasts of South Africa, peaking from September to November (Crawford *et al.* 1983b). They range widely during the non-breeding season, following their prey, which they capture by plunge-diving. Cape cormorants breed mostly on nearshore islands and guano platforms, but also on islands within estuaries and lagoons, sewage works and on mainland cliffs (Cooper *et al.* 1982). The breeding distribution extends from northern Namibia to Algoa Bay on South Africa's east coast. They are generally dependent on large surface schools of fish, which they capture by pursuit-diving, and do not forage as widely as gannets (Cooper *et al.* 1982). Anchovy and sardine are the preferred prey species, with pelagic goby an important prey off southern Namibia (Crawford *et al.* 1985). The breeding range of African penguins extends from Sylvia Hill (25°S) to Algoa Bay (Shelton *et al.* 1984). They generally breed on islands, although there are a few small mainland rookeries in Namibia and South Africa. Pelagic shoaling fish, particularly sardine and anchovy, used to be the most important prey, and were caught by deep pursuit-diving. As with the Cape cormorant, the pelagic goby is the most important prey off Namibia when sardine are scarce.

HISTORY AND CURRENT STATUS OF THE FISHERIES

Industrial catches of the major species during the past five decades are summarized in Table II. Catches of most of these species were monitored through ICSEAF (the International Commission for the South East Atlantic Fisheries) in the 1970s and 1980s and are part of that organization's official records. However, the values given for those years and discussed in some detail later should be treated as being of questionable accuracy because it is alleged that many countries either over- or under-reported their catch according to various political and/or management con-

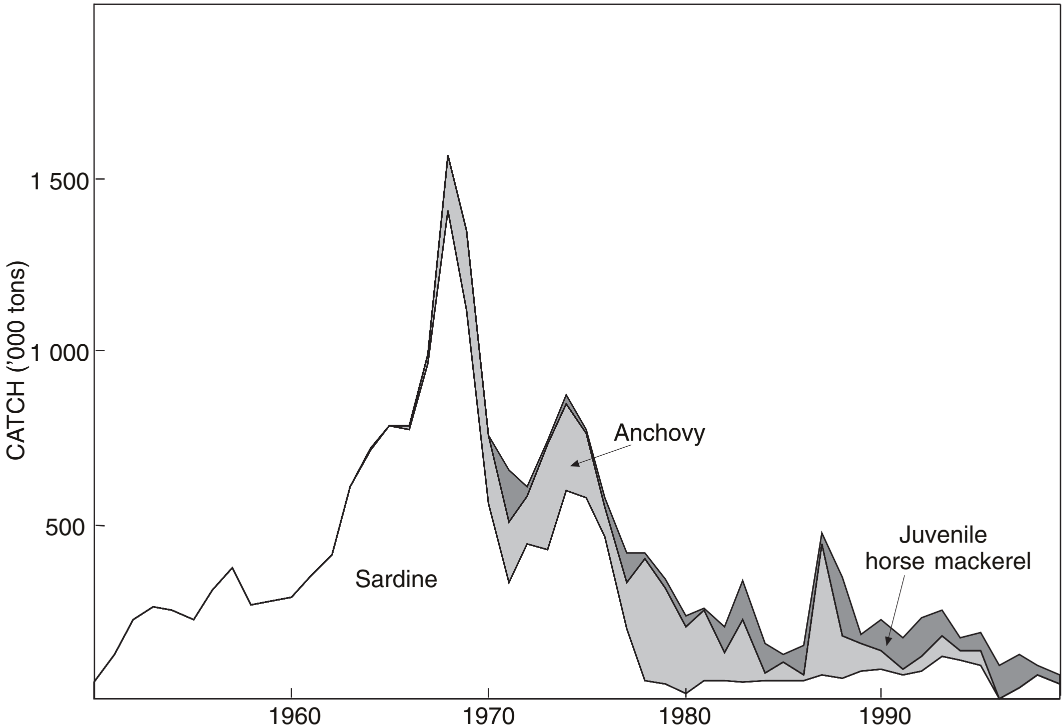

Fig. 5: Purse-seine catches in the Namibian region of the Benguela Current over the past five decades – sardine, anchovy and juvenile horse mackerel (data from ICSEAF Bulletins and the Ministry of Fisheries and Marine Resources)

siderations, and that the catches of other countries were simply inaccurately recorded. Additionally, catches were recorded in five degree bands of latitude (viz. 15–20°S, 20–25°S and 25–30°S) proposed by the F.A.O. during the early 1970s, which conform to neither national nor environmental boundaries (see Fig. 1).

Landings prior to 1970 frequently went unrecorded, but as the South-East Atlantic only became the focus of international fishing fleets in the mid to late 1960s, they are not likely to have been substantial. In contrast, the catches of the 1990s were closely monitored by Namibian fisheries control officers and are believed to be accurate.

Purse-seine fisheries

Annual landings of the major species exploited by the purse-seine fisheries of the region from the 1950s to the present are shown in Figure 5. They are discussed by species below.

SARDINE

In Namibia, sardine are taken for canning, with the offcuts and fish of inferior quality reduced to meal and oil. Annual catches rose rapidly from levels of around 200 000 tons in the 1950s to a maximum of some 1.4 million tons in 1968. In addition the Eastern European midwater fleet also targeted sardine in the late 1960s (Romanov 2001), although the catches were poorly recorded. Therefore, the peak catches of the 1960s must be regarded as a minimum. Thereafter, there was a sharp decline to less than 300 000 tons in 1971, followed by a slight increase in catches for a few years and another precipitous collapse in 1977 and 1978. Since then, annual catches have rarely exceeded 50 000 tons. The early 1990s saw a slight increase when catches exceeded 100 000 tons for several years, but this was followed by the lowest catch since commercial fishing on the species began; a little over 2 000 tons in 1996 (Boyer *et al.* 2001a). After the disastrous 1996 season, catches improved in 1997 and 1998 as the total allowable catch (*TAC*) was increased following several years of good recruitment (Boyer *et al.* 2001a). However, this respite for the pelagic industry proved temporary and by 2000 the catch was a mere 25 000 tons.

It is most likely that these collapses were largely attributable to overfishing, especially in the late 1960s when, in addition to the Walvis Bay fleet, there were two factory vessels operating outside territorial waters. A number of years of poor recruitment as a result of adverse environmental conditions exacerbated the decline (Cram 1981). A change from sardine nets to anchovy nets of smaller mesh in the late 1960s, which would have placed greater pressure on the recruits, may also have been a contributing factor. With the decline of the stock in the 1970s the fleet moved increasingly northwards in search of fish. The fleet changed from small, predominantly wooden-hulled, vessels to larger steel-hulled vessels that used refrigerated seawater to cool the catch and were thus capable of returning the fish from northern Namibia to Walvis Bay in a condition suitable for canning (Thomas 1986).

A number of Namibian vessels have fished under license in southern Angola since 1994, 47 000 tons of sardine being caught by those vessels in 1995. Although an unusual occurrence in recent years, de Campos Rosado (1974) reports that, between 1945 and 1972, Angolan purse-seiners caught, on average, 30 000 tons of "sardina" annually, of which most was believed to be sardine. Since 1996, other species, mainly Kunene horse mackerel and sardinella (*Sardinella aureti* and *S. maderensis*) have been targeted by Namibian vessels off Angola.

ANCHOVY

Little anchovy was caught off Namibia before 1966. Then, for most of the 1970s and 1980s, catches were less variable than those of sardine and fluctuated under quota control around a level of about 200 000 tons. An exception was the pronounced peak in 1987. Annual catches in the 1990s averaged less than 50 000 tons, but they declined to virtually zero after the anomalous environmental conditions in the mid 1990s. Surveys during the latter part of the 1990s indicated that the Namibian anchovy stock was severely depleted.

ROUND HERRING

Off Namibia, around 1 000 tons of juvenile round herring are usually taken each year by the purse-seine fleet as a bycatch of the horse mackerel and sardine fisheries, although catches as high as 14 000 tons (in 1996) have been recorded. The potential for canning the larger fish has been investigated, but they have generally been found to be too soft for this purpose.

HORSE MACKEREL

Horse mackerel were rarely recorded in purse-seine landings until 1971 when, following the first collapse of the sardine fishery, 140 000 tons were caught. Prior to that it seems that shoaling horse mackerel did not occur in the northern Benguela at commercially viable levels. Since then there have been sporadic catches in excess of 100 000 tons per year, with an average of 59 000 tons and a maximum of 116 000 tons in 1992. The fish are utilized entirely for meal and oil. During the latter part of the 1990s the catch declined to around 20 000 tons per year. Survey estimates suggest an abundance of juvenile horse mackerel in the northern Benguela during the late 1990s, and it is not clear whether the relatively small catch is due to a decrease in shoaling behaviour (and hence availability to purse-seiners) or a lack of demand attributable to poor market prices for fishmeal.

Trawl fisheries

ADULT HORSE MACKEREL

Adult horse mackerel are targeted by midwater trawlers, and this is the largest fishery by volume in Namibia. Trawl catches rose from less than 50 000 tons per year in the early 1960s to around 500 000 tons annually from 1978 to 1987 (Fig. 6), during which time most of the catch was taken by foreign vessels, mainly from Eastern Europe and Cuba. A large increase in catches in 1975 was attributed to a change in target species from hake (and to a lesser extent sardine) to horse mackerel (Romanov 2001). The fish were largely frozen and shipped to the Soviet bloc countries both for animal feed and human consumption. Trawl catches of horse mackerel have fluctuated around 350 000 tons per year since Independence in 1990, when Namibia took control of the fishery, but they have declined to between 200 000 and 250 000 tons per annum in recent years. The number of midwater trawlers in the fishery now is less than half that at Independence. The fleet is largely made up of ageing ex-Soviet bloc vessels, about half of which are now registered in Namibia, but still operated mostly by foreign crew. Most of the catch is frozen and transhipped to reefer vessels for export as a relatively

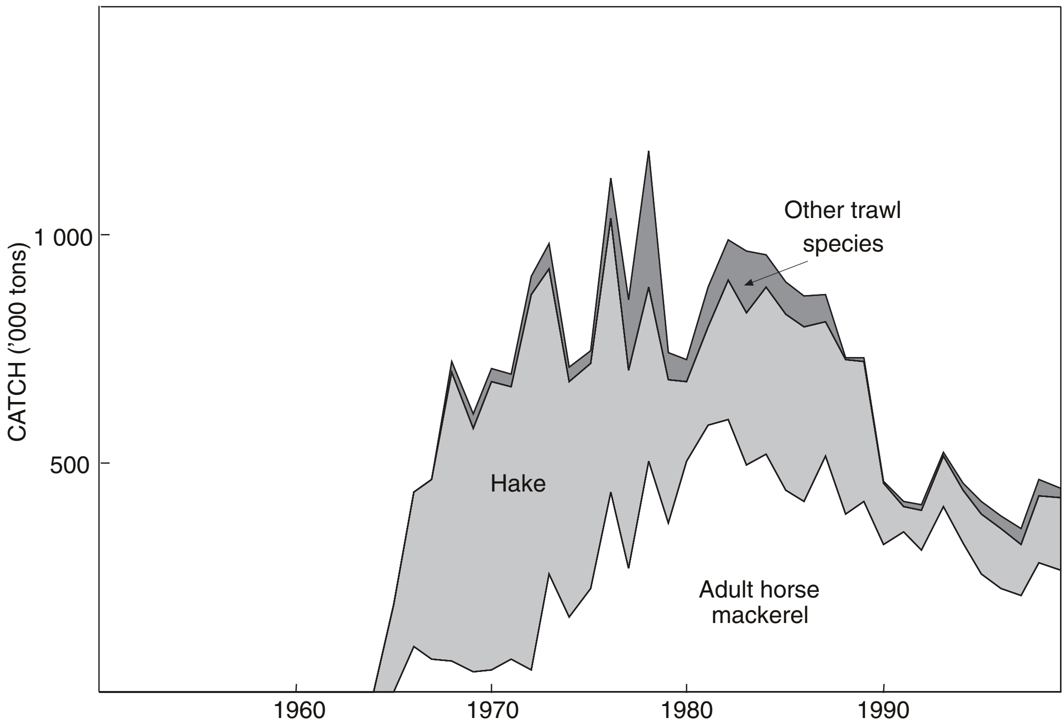

Fig. 6: Trawl catches in the Namibian region of the Benguela Current over the past five decades – hake, adult horse mackerel and other species (data from ICSEAF Bulletins and the Ministry of Fisheries and Marine Resources)

low-value product to West Africa, but a small amount is now being smoked or salted and dried ashore for export to southern African countries.

HAKE

The Namibian fishery for hake started in the late 1950s. In the early 1960s, with the arrival of foreign trawling fleets, there was an explosive increase in effort and hence landings throughout the Benguela and, by 1972, the annual hake catch in the South-East Atlantic exceeded 1.1 million tons (Payne 1989, van der Westhuizen 2001). Subsequently, catch rates and landings of hake declined sharply. Off Namibia, hake catches from 1973 to Independence in 1990 averaged 500 000–600 000 tons annually (Fig. 6), and were taken mainly by foreign fleets. At Independence, strict conservation measures were introduced, including the exclusion of foreign vessels. The hake catch is now taken exclusively by Namibian-registered vessels and has risen from 55 000 tons annually at Independence to almost 200 000 tons by the turn of the century, making this the most valuable fishery in Namibia. Around 80% of the catch is exported to Spain, although this proportion declined during the latter part of the decade as exports to other EU countries, the USA and Australia increased.

MONKFISH

Catch statistics for Namibian monkfish date back to 1974, when monkfish were taken as a bycatch in the hake fishery. In recent years the fishery has developed into a targeted one in response to increasing market demand and escalating value (Maartens 1999). At Independence in 1990 the fishery changed from an international to a local fishery. Since then annual catches, made mainly by small freezer trawlers, have risen from 1 500 tons to >15 000 tons, comparable to peak levels reached by the international fishery in the 1980s (Fig. 6, Maartens and Booth 2001a). The value of the product is high, making the fishery an important

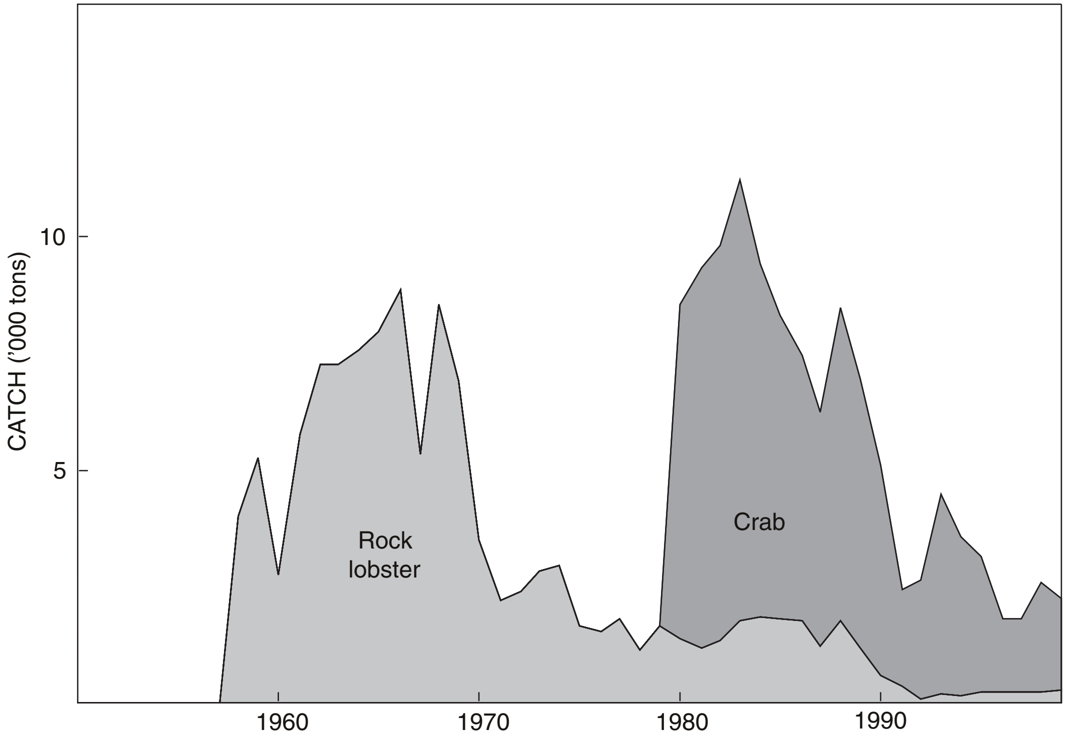

Fig. 7: Crustacean catches in the Namibian region of the Benguela Current over the past five decades – deep-sea red crab and West Coast rock lobster (data from ICSEAF Bulletins and the Ministry of Fisheries and Marine Resources)

contributor to the Namibian economy (Maartens and Booth 2001a), with most of the products exported to Europe.

DEEP-WATER SPECIES

Exploratory fishing for deep-water trawl species, particularly orange roughy, began in Namibia in 1994 (Boyer *et al.* 2001b). Small catches were made in 1995, but in the following three years annual catches averaged 13 000 tons, making it the second-largest orange roughy fishery in the world. This caused much optimism as it came at a time when many of Namibia's other marine resources were in decline. However, by 1998, catch rates had declined to such an extent that the 1999 and 2000 landings were reduced to about 2 000 tons per year. Despite extensive exploratory fishing for orange roughy, only four aggregations have been found in the Namibian Exclusive Economic Zone (EEZ), although signs of further aggregations outside the EEZ on the Walvis Ridge have been reported. The alfonsino catch during 1995 and 1996 was nearly 3 000 tons, but little has been landed since then. Three companies are active in the deep-water fishery as joint ventures between foreign and Namibian companies. The orange roughy and alfonsino catch is exported almost entirely, mainly in the form of high-value frozen fillets to the USA and Japanese markets respectively.

OTHER TRAWLED SPECIES

Large catches of chub mackerel were made by the midwater fleet for a brief period in the late 1970s and early 1980s. These exceptional catches were seemingly based on a single year-class that first appeared in 1977 and supported catches for the following decade. Other important species caught in bottom trawls are kingklip and sole, catches of which have averaged 1 275 and 340 tons respectively per year since 1990, down from more than 10 000 tons and about 2 000 tons in the mid 1970s respectively.

Crustacean fisheries

WEST COAST ROCK LOBSTER

This resource was clearly overexploited before Independence, annual catches having declined dramatically from a peak of nearly 9 000 tons in 1966 to about 3 000 tons in the early 1970s and to a few hundred tons in recent years (Fig. 7). During the 1990s a commercial fleet of about 20 vessels took part in lobster fishing activities. A gradual increase in catches during the latter half of the 1990s was allowed as the population showed modest signs of a recovery. During the 1960s and 1970s virtually the entire Namibian catch was exported as tails, but since the early 1980s the dominant product has been whole cooked rock lobsters, exported mainly to Japan.

DEEP-SEA RED CRAB

The red crab fishery in Namibia started in 1973, and by 1974 17 vessels were targeting the species. Catches rose to a peak of about 10 000 tons in 1983, after which annual landings declined steadily to less than 3 000 tons in 1991, clearly as a result of overexploitation of the stock (Le Roux 1997). Catches have fluctuated around or below this level since then. The *TAC* has only been reached in two of the years since the introduction of catch limits in 1989. Red crab are currently taken by Namibian-registered Japanese vessels (2–3 vessels in recent years) fishing with Japanese-style beehive traps; the entire catch is exported to Japan.

Linefisheries

Foreign longliners caught tuna in Namibian waters under South African licence prior to Independence in 1990 (F. Botes, pers. comm.). The Namibian-controlled tuna fishery started in 1991, and since then an annual average of 2 330 tons of tuna (predominantly albacore) has been taken by a fleet of about 30 local and foreign-owned pole or longline vessels. A foreign longline tuna fishery started in 1993 and targets bigeye tuna for the high-value sashimi market. Catches have varied between 52 tons in 1996 and 1 005 tons in 1994. Experimental catches of swordfish *Xiphias gladius* taken by surface longlining were initially low (50 tons in three years), but they increased to about 730 tons in 1999 and 2000.

Snoek was possibly the first marine fish species to be caught commercially off Namibia. Records of snoek being "found in quantities … in Sandwich Harbour, Walwich Bay [Walvis Bay] …." date from 1872 (Lees 1969), and attempts to can the species were made in the early 1940s. Annual catches peaked at 70 000 tons in the late 1970s and early 1980s, but an average of only 630 tons of snoek has been taken per year by commercial vessels since Independence, mostly by handline.

Recreational fishing in Namibia is pursued by rock-and-surf anglers, who have access to about 20% of the coastline, and skiboat fishermen operating primarily from Swakopmund. Catches of silver kob from commercial linefish vessels have averaged about 500 tons per year over the past three decades. It is estimated that the present recreational catch of silver kob is roughly equal to the commercial catch (Kirchner 1998). The recreational sector has grown rapidly in recent years and attracts many visitors to the coast, particularly from Namibia and South Africa, and it generates considerable employment and revenue in the coastal towns. However, with the recent increase in fishing pressure, the number of fish caught per angler has declined significantly (Kirchner 1998).

Finally, mention must be made here of shallow-water Cape hake, primarily a trawled species, and kingklip, which are also caught by line off Namibia, using hydraulically hauled longlines. A lucrative fresh fish export market (mostly Spanish) for high-quality longlined hake has been developed in recent years. Between 5 000 and 10 000 tons of hake are caught annually by longline, but only a few hundreds of tons of kingklip are landed.

Top predators

The southern African seal population was heavily overexploited in past centuries and the breeding colonies around the Cape Peninsula were exterminated soon after the arrival of European settlers in the 17th century (Shaughnessy 1979). Subsequently, as a result of conservation measures applied over many years, and probably the establishment of new mainland colonies in areas of restricted human access, the seal population in southern Africa has flourished. Aerial surveys of pups and tag-recapture studies indicate that the total population increased from around 100 000 animals in 1900 to between 1.5 and 2 million animals by the early 1990s (David 1989, 1997).

In terms of seabirds, aerial censuses have shown that, between 1956 and 1995, the population of Cape gannets at the Namibian colonies fell from more than 200 000 adults to about 50 000 (Cordes 1998). This decline was probably due to the collapse of the Namibian sardine stock during the same period (Crawford

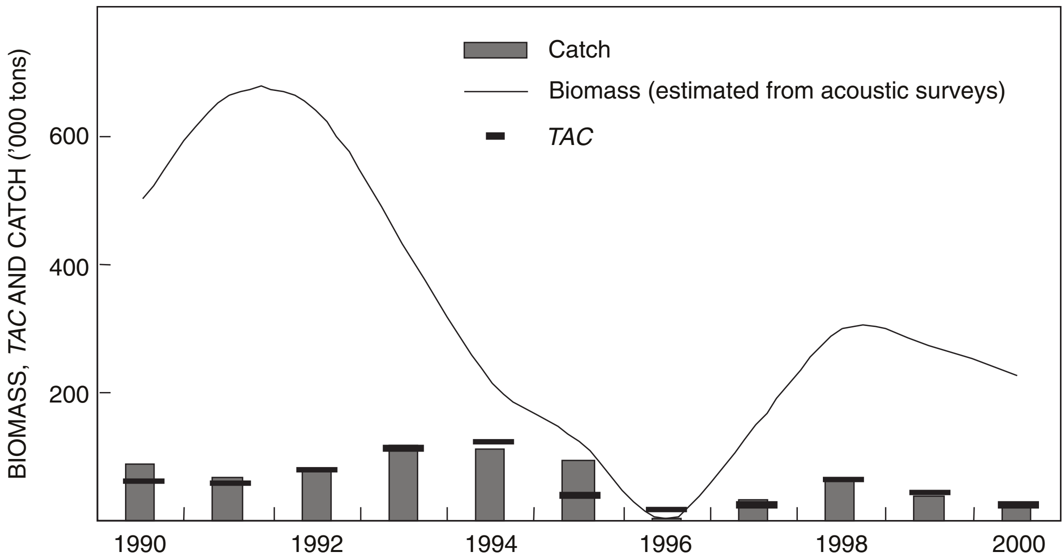

Fig. 8: *TAC*, catch and mean annual estimated biomass for sardine off Namibia and Angola during the 1990s

et al. 1991). The censuses also revealed a substantial decline in the number of Cape cormorants, from more than a million birds in the early 1970s to about 120 000 pairs in the mid 1980s (Crawford *et al.* 1983a). During the last few centuries, the African penguin population in southern Africa has been falling, to about 180 000 individuals in 1995, with the Namibian part of the population declining from about 100 000 in the 1950s to 27 500 currently (Kemper *et al.* 2001). The reduction is attributed to various causes, including the prolonged and excessive egg collection and disruption to breeding during the guano rush in the 1840s (Crawford *et al.* 1995). As with Cape gannets and Cape cormorants, the distribution and abundance of penguins has changed over the past three decades in response to changes in the distribution and abundance of sardine and anchovy (Crawford 1998).

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION OF MAJOR RESOURCES

Pelagic resource

Estimates of the sardine biomass in Namibia between 1952 and 1988, obtained by Virtual Population Analysis (VPA), indicate that the stock collapsed from more than 11 million tons to well below 1 million tons by the mid 1970s (Butterworth 1983). Acoustic survey estimates of sardine on the Namibian/southern Angolan shelf since 1990 indicate that the adult stock is still depleted, with an all-time low estimate of only a few thousand tons in the summer of 1995/1996, subsequent to the Benguela *Niño* at that time (Boyer *et al.* 2001a). By the end of the 1990s the stock had increased slightly, but the fishery was still almost totally reliant on each year's incoming cohort, making for highly variable *TAC*s (Fig. 8).

Survey estimates of anchovy and juvenile round herring combined (they were not distinguished acoustically in the earlier surveys) have dropped from around 200 000 tons between 1990 and 1993 to below 100 000 tons since then. The decline is reflected in anchovy landings, which have been negligible since 1996.

The juvenile and adult components of the horse mackerel stock are discussed as a unit below.

Trawled species

HORSE MACKEREL

Through a VPA of catch data from the former Soviet bloc fleet, Vaske *et al.* (1989) estimated that the biomass of *Trachurus* spp. in ICSEAF Divisions 1.3, 1.4 and

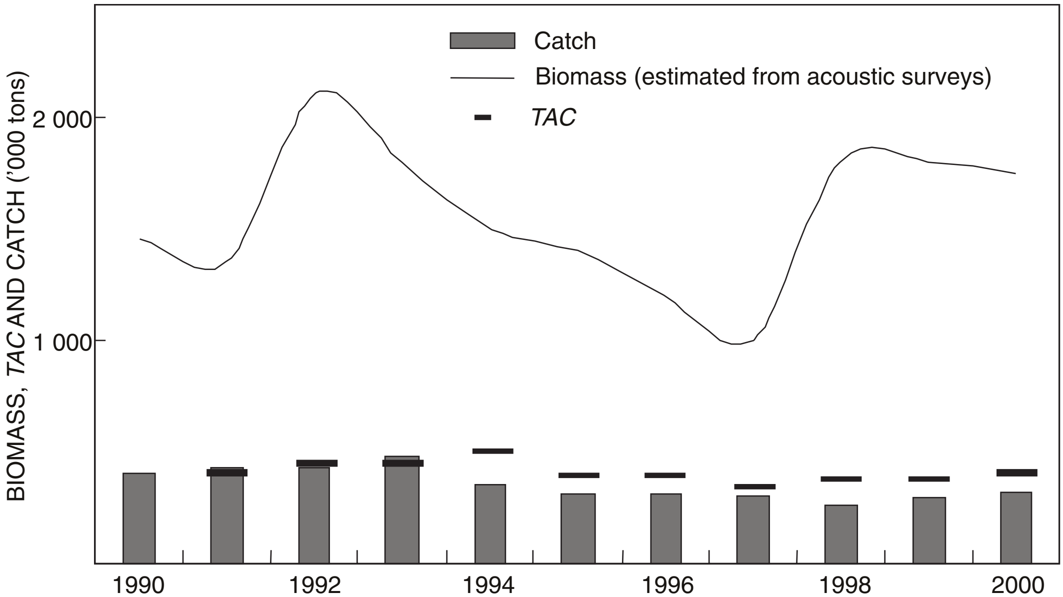

Fig. 9: *TAC*, catch and mean annual estimated biomass for horse mackerel (juvenile and adults combined) off Namibia during the 1990s

1.5 (i.e. from southern Angola at 15°S to just south of the Orange River at 30°S) between 1973 and 1987 fluctuated between about 1.5 and 2.3 million tons. This estimate must be treated with caution, however, because, *inter alia,* there is uncertainty in some of the catch data and the age-length keys are unreliable. Since 1990, the combined biomass of adults and juveniles off Namibia and southern Angola has been estimated by annual acoustic surveys. The estimates generally fall between 1 and 2 million tons, with a maximum of 2.1 million tons in 1992. The absolute values of these estimates are questionable because of the large uncertainty in the target strength expression used. For example, use of a target strength expression for *T. capensis* developed in South Africa (Barange and Hampton 1994) would lower the estimates by a factor of approximately 3. Furthermore, some of the differences between the surveys have been attributed to variations in the proportion of the population that is detectable acoustically rather than to fluctuations in the biomass (NORAD-FAO/UNDP 1998). Catches, fishable biomass estimates and *TAC*s of horse mackerel in the past decade are shown on Figure 9.

HAKE

Surplus production and VPA estimates were used to assess the hake resources throughout the 1970s and 1980s, although as Newman (1977) noted, these are likely to be unreliable owing to combining the two species in catch records, discarding of small hake, changes in mesh size, changes in the age structure of the population and, finally, altered relationships between catch rates and effort.

Survey estimates of hake abundance off Namibia over the past decade are derived from swept-area trawl surveys supplemented by acoustic estimates of fish above the trawl (Burmeister 2001, Iilende *et al.* 2001). It is notable that there has been a marked increase in survey estimates of the abundance of deep-water hake off Namibia since 1992 (Burmeister 2001, Iilende *et al.* 2001), which is confirmed by a similar increase in the proportion of deep-water hake in the Namibian hake catches in recent years (van der Westhuizen 2001). This may indicate northward displacement or expansion of the stock from South Africa (Burmeister 2000) or, alternatively, a shoreward displacement in response to changes in the oxygen content of bottom waters (Hamukuaya *et al.* 1998). Off Namibia, the shallow-water Cape hake stock grew between Independence in 1990 and 1992, but thereafter declined for the next four years (Fig. 10). The most recent survey results indicate good recruitment since 1997, with an increase in the fishable biomass,

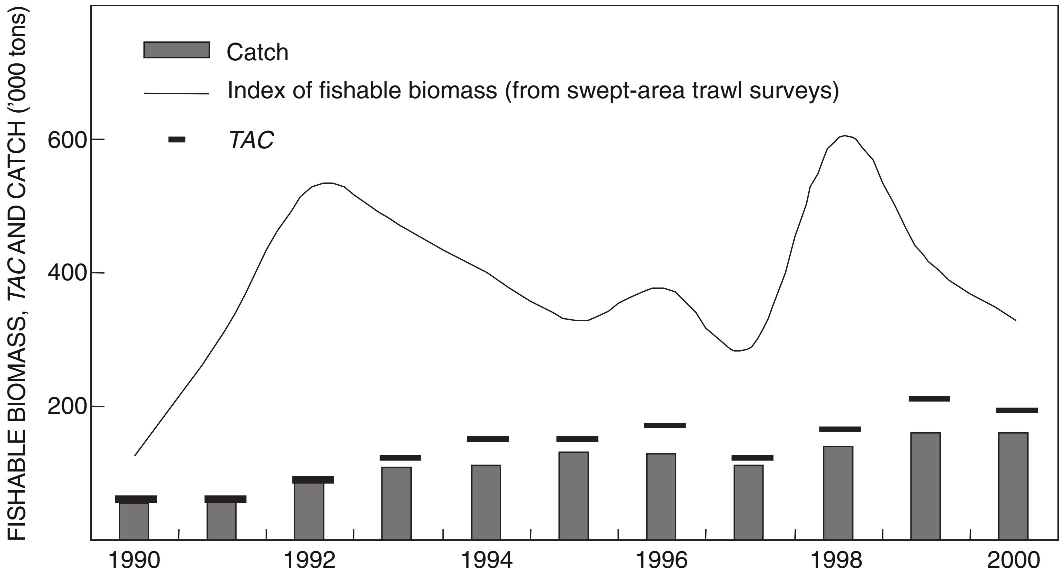

Fig. 10: *TAC*, catch and mean annual estimated biomass for Cape hake off Namibia during the 1990s

followed by a clear decline since then (van der Westhuizen 2001).

MONKFISH

Little information is available on the stock dynamics of monkfish prior to the mid 1990s. Macpherson and Gordoa (1992) estimated abundance by trawl swept-area techniques to be between 12 000 and 59 000 tons in the 1980s, but these are suspected to be underestimates because the surveys were targeting hake (Maartens 1999). Catches declined in the late 1980s and early 1990s, probably because of changes in the fleet structure during the Independence period rather than to underlying population trends. Current catches and results of assessment models suggest that the stock is fully utilized or overexploited (Maartens and Booth 2001a). Of particular concern is the high proportion of juvenile monkfish being landed.

DEEP-WATER FISH

Initial estimates of abundance of orange roughy suggested a total spawning biomass in excess of 200 000 tons (Branch 1996, Branch and Roberts 1998), whereas swept-area and acoustic surveys in 1997 indicated that the abundance may have been about half that figure (Boyer and Hampton 2001). Since then all indices have shown a decline in the stock, apparently at a rate greater than can be accounted for by fishing alone. Other possible causes include disturbance of the aggregations by fishing activities, or changes to the aggregating behaviour attributable to natural causes or habitat alteration (Boyer *et al.* 2001b).

Crustaceans

Various methods have been attempted to assess rock lobster abundance, primarily tag-and-recapture, line-transect surveys by SCUBA divers and length-based as well as surplus production models. During the late 1990s a modified De Lury model was used to assess the stock, and the results suggest a fishable stock of around 10 000 tons in the early 1970s that declined to a current size of between 2 000 and 3 000 tons (Grobler 2000).

Deep-sea red crab have been assessed using a number of different methods: trawl surveys, photography, effective fishing area, tag-recapture, Thompson and Bell yield per recruit and currently surplus production models (Le Roux 1997). Recent assessments indicate that the Namibian component of the stock declined from about 40 000 tons in the early 1980s to around

10 000 tons in the 1990s, as reflected in the decline in the catch rate during this period.

Linefish

There has been a general decline in catches and mean size of albacore in the South Atlantic. This is likely the result of years of overfishing throughout the southern Atlantic, rather than any local environmental changes or local fishing (F. Botes, pers. comm.).

Judging from commercial handline catches, the abundance of snoek off Namibia increased approximately threefold between 1970 and 1980, probably in response to an increase in the abundance of prey in the form of juvenile horse mackerel, which was then the dominant pelagic fish species in the region. This increase was also reflected in catches of snoek by the international midwater trawl fleet operating off Namibia at the time; catches rose sharply during this period to levels of more than 20 000 tons per year. The trawl catches are now an order of magnitude lower than in the 1970s and 1980s. It is not clear whether the decline in catches reflects a major reduction in biomass, or whether it is due to a change in distribution and/or fishing strategy.

Commercial catches of surf-zone linefish in Namibia have been fairly stable since Independence. Kirchner (1998) recently estimated the current exploitable biomass of the most important of these (silver kob) at around 11 000 tons. While earlier abundance estimates are not available, Kirchner (1998) estimated the stock to be at about 50% of its unfished level.

Top predators

The Namibian seal population declined (probably by about one-third) in the mid 1990s as a result of breeding failure and high mortalities of pups and adults brought about by the effects of low-oxygen water and the Benguela *Niño* on the seals' main prey species (MFMR 1997, Roux 1998). In 1994 and 1995 there was also a northward shift in distribution, Cape fur seals being found as far north as Luanda feeding on sardinella. Recent information suggests that the distribution has now returned to normal, and that the population is recovering.

The Cape gannet population seems to have shown signs of an increase from below 20 000 birds in the 1980s to currently >30 000 (Cordes 1998). The most recent estimate of the Namibian African penguin population is about 27 500 birds and this part of the population is considered to be "critically endangered" (Robertson *et al.* 1998). The rate of decrease has declined since 1985 and the northernmost regularly monitored breeding colony, Mercury Island, has even shown an increase (Kemper *et al*. 2001). This suggests that the more southern colonies, which are outside the current distributional range of penguins' favoured prey (sardine and anchovy), are suffering because of insufficient suitable food.

EFFECTS OF THE ENVIRONMENT ON DISTRIBUTION AND ABUNDANCE

Although a number of Benguela resources have clearly been overexploited in the past, some of the changes in their abundance and distribution is also likely to have been influenced by major environmental perturbations. The probable effects of these perturbations on some of the major resources of the region, when known, are discussed briefly.

Pelagic resources

In a recent Principal Components Analysis of satellite sea surface temperature (SST) imagery from the northern Benguela between 1981 and 1987, Cole and McGlade (1998) identified three spatial/temporal patterns that characterized the physical dynamics of the system. They related two of them (the balance between cross-shelf and longshore SST gradients, and the warming of the central region in relation to conditions to the north and/or south) to conditions affecting clupeoid production in the region. Other, more specific impacts of the environment on pelagic resources of the region have been observed, as detailed below.

The biomass of sardine in both the northern and the southern Benguela declined sharply following a system-wide Benguela *Niño* in 1963, which in the northern Benguela caused the fish to be concentrated close to Walvis Bay, where fishing pressure was high (Stander and de Decker 1969). The collapse of the Namibian sardine after 1974 (Fig. 5) followed a protracted but less intense Benguela *Niño* between 1972 and 1974, the effects of which were probably aggravated by overfishing (Cram 1981).

O'Toole and Shannon (1997) postulated that the recent decline in stock size of Namibian sardine, which started in 1993, was largely the result of the advection of low-oxygen water from Angola in 1993 and 1994, aggravated by a major Benguela *Niño* in 1995. Research surveys indicated a northward shift in distribution in 1994, when the majority of the stock was off southern Angola. In March 1995, the entire shelf from Cabinda to central Namibia was covered by anomalously warm water (up to 8°C above average in places) to a distance of more than 300 km offshore (Gammelsrød *et al.* 1998). During this Benguela *Niño*, the stock shifted some 4–5° latitude southwards in front of the advancing warm waters. Observed mortalities of sardine, horse mackerel and silver kob, and poor recruitment and declining catch rates of a number of other key resources in Namibia at the time, are further indications of a broad-scale environmental effect on sardine and other resources. Despite these apparently adverse conditions, there was an increase in the availability of sardine to the Walvis Bay fishing fleet. This was caused by a southward displacement of sardine from northern Namibia and Angola, bringing them closer to the fish factories.

In the case of anchovy, a Benguela *Niño* in 1984, which followed an extended cold period on the shelf, seems to have had an adverse effect on the Namibian resource. The exceptionally good catches in 1987 were probably largely the result of recruitment from the strong year-classes of 1986 and 1987 in the southern Benguela, rather than from a recovery of the Namibian stock. Following the most recent Benguela *Niño* in 1995, when the abundance was already low, the Namibian anchovy resource virtually disappeared and as yet shows no signs of recovery.

On a larger scale, the meridional distribution and the abundance of sardine and anchovy in the Benguela Current may be affected by shifts in the major wind belts across the African continent (Schwartzlose *et al.* 1999). However, there is some evidence that regime shifts in the Benguela, involving switches between sardine and anchovy dominance, which according to scale-deposit studies have a characteristic periodicity of around 50 years (Crawford *et al.* 1987, Shackleton 1987), tend to be out of phase with those in the Pacific (Lluch-Belda *et al.* 1989). It is also notable that, over the past two decades, there has not been a close correspondence in abundance trends in the northern and southern Benguela for either sardine or anchovy. This could possibly be due to the major differences in the spawning and recruitment processes in the northern and southern Benguela, or to fishing suppressing natural population changes. Several studies to elucidate the relationship between the environment and, in particular, recruitment success are currently ongoing.

Trawled species

Little is known about the reaction of adult horse mackerel to environmental perturbations in the Benguela. There is a clear positive correlation between seasonal trends in catch rate and sea surface temperature (SST) along the 200 m isobath (Boyer *et al.* 1998), and studies of historical catch data show a large-scale southward shift in the distribution of both *T. capensis* and *T. trecae* in the northern Benguela in the late 1950s/early 1960s, coinciding with the intrusion of warm, highly saline water from the north. This was followed by a northward movement from the mid 1970s, following a period of cooling. The effect of the environment on the distribution and migration of horse mackerel in the Benguela as a whole is an important transboundary question, *inter alia* for interpreting and comparing survey results in neighbouring countries.

Recent studies are starting to elucidate some important characteristics of the behaviour of Cape hake in the Benguela ecosystem, and of their responses to environmental variability and change. Adult hake can tolerate a range of temperatures, and are particularly well adapted to low oxygen, adults being able to tolerate concentrations as low as 0.25 $m\ell\ \ell^{-1}$ (Woodhead *et al.* 1996). They are therefore well able to survive in less favourable environments, and being opportunistic feeders, long-lived and inhabiting a wide area, should be robust to all but major environmental perturbations (Huse *et al.* 1998). There is a clear positive correlation between monthly catch rates and SST off Namibia in many years, although this broke down when the SST seasonal cycle was weak (e.g. 1997, Gordoa *et al.* 2000). The response of hake to hypoxic conditions is of particular interest in Namibia, where oxygen levels over a large part of the shelf can become intolerable even to hake, possibly causing major shifts in distribution, affecting recruitment strength (Woodhead *et al.* 1996), and causing increased mortality of juveniles and older fish if extensive and persistent enough. Another possible effect is vertical migration away from adverse bottom conditions, as postulated by Iilende *et al.* (2001). Improved understanding of the effects of temperature and oxygen fluctuations on the distribution, abundance and behaviour of hake in the Benguela Current is the focus of a number of local, regional and international research efforts.

The possible effect of environmental changes on monkfish and the deep-water resources of the region is unknown, but it could be substantial. For example, the fact that orange roughy concentrate off Namibia within a narrow temperature range and spawn on very specific sites suggests that any significant change in the near-bottom temperature or currents could have a major impact on the distribution and perhaps the spawning process, which could severely disrupt the fishery targeting these sites. Maartens and Booth (2001b) report a seasonal pattern in catch rates that indicate environmental forcing. However the process is not clearly understood.

Crustaceans

There is evidence that the decline in West Coast rock lobster production in Namibia and South Africa, which occurred towards the end of the 1980s, was at least partly environmentally induced. Off Namibia it was attributed to changes in availability related to oxygen fluctuations in bottom waters, aggravated by overfishing (Gammelsrød *et al.* 1998), whereas in the southern Benguela, the decline was a result of reduced somatic growth rates. As there is relatively little longshore migration of rock lobster, and it is improbable that fishing impacted all areas simultaneously, it seems most likely that the resource responded to some large-scale change in the environment (Pollock and Shannon 1987).

Table III: Value (in N$million) of the major industrial fisheries in Namibia in 1991 and 1999 (N$1 ≈ US$ 0.125 in early 2001; data from Ministry of Fisheries and Marine Resources)

Fishery	Landed value		Processed value	
	1991	1999	1991	1999
Pelagic	49	77	161	166
Demersal	195	1 001	195	1 465
Midwater	227	550	227	555
Deep-water	0	44	0	63
Tuna	1	16	1	16
Linefish	2	14	2	14
Crustaceans	39	50	52	51
Other	4	11	4	11
Total	520	1 761	644	2 341

Linefish

Relationships between linefish species and the environment in the Benguela have not been formally studied or quantified in any way. As most linefish are predators, the effects of environmental perturbations on their distribution and abundance is likely to be secondary, through more direct effects on the abundance and distribution of their prey. During the recent Benguela *Niño* large numbers of kob were recorded dead and dying close to river mouths, apparently caused by the high levels of sediment-loading (Gammelsrød *et al.* 1998).

Top predators

Major changes in abundance of the top predators appear to be controlled by prey availability, rather than the effect of the environment directly. A drastic deterioration in the condition of both pups and adults and the high mortality and breeding failure of Cape fur seals at all Namibian colonies in 1994 and 1995, was clearly the result of poor food availability over most of their habitat (Schwartzlose *et al.* 1999). This lack of prey availability is confirmed by the low estimates of abundance of the major pelagic stocks in the period between 1994 and 1996.

As noted earlier, the major seabird colonies are situated in southern Namibia, whereas their preferred prey species, the commercially exploited small pelagic fish, have been largely concentrated north of Walvis Bay during the past decade. Therefore, it seems likely that any recovery of the penguin and gannet populations is limited more by the lack of availability of suitable food, rather than directly through environmental constraints. Kemper *et al*. (2001) noted a decline in numbers during the 1994/1995 environmental anomaly. This was probably also related to a lack of prey rather than to any direct effect of oceanographic conditions.

SOCIO-ECONOMIC IMPORTANCE OF NAMIBIAN MARINE RESOURCES

Data summarizing the economic value of Namibian commercial fisheries in 1991 and 1999 are presented in Table III.

Fishing is the third-largest sector of the Namibian economy, behind agriculture and mining. The sector has generated more than 10% of GDP since 1998, up from 5% in 1991, and the projected export value for 2000 is N$2 900 million (N$1 ≈ US$0.125 in early 2001), which will make the fishing sector the second-largest export earner behind mining. It is the second fastest growing industry in the Namibian economy (behind tourism) with the value of exports now approximately six times greater than at Independence.

Not surprisingly, the fisheries sector is extremely important in the economy of Namibia, particularly in Walvis Bay and Lüderitz, the major fishing ports where most of the processing plants are situated. Local employment in the sector grew rapidly after Independence, and an estimated additional 6 000 jobs were created between 1991 and 1994. The integration of Walvis Bay into Namibia in 1994, and the removal of the uncertainty regarding the port's future, stimulated an influx of investment in the fishing industry and subsidiary service industries, with a further growth in employment. The number of people directly employed in the fisheries sector in 1998 was about 15 000, of which some 7 500 were fishers. Of these, 34% were

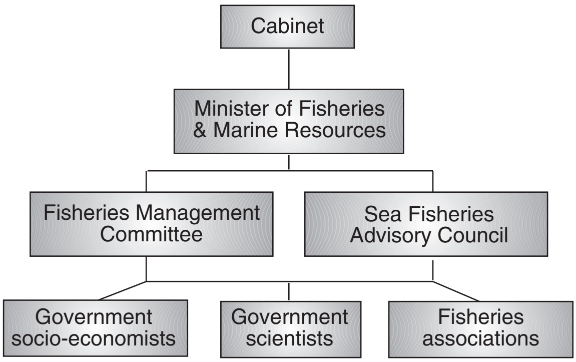

Fig. 11: Management scheme of Namibian fisheries. Note that, for hake and deep-water species, the three groups having input into this system do so through formally established working groups

foreigners, mainly in the horse mackerel and tuna fisheries, a proportion that has decreased from around 66% in 1993.

The demersal fishery is the most valuable in Namibia. In 1996 the catch had a landed value of N$593 million, and a final value after product enhancement of N$718 million. About 90% of the catch is either sea-frozen or wetfish hake, and currently 58% is processed ashore compared to just 6% in 1992. Monkfish make up most of the remainder of the demersal catch, with the average landed value of the catch in recent years amounting to >N$100 million per year. Almost the entire demersal catch is exported.

The pelagic fishery is second in importance, with canned sardine the most valuable product. In recent years the total annual export earnings from the pelagic fishery was around N$400 million, except in 1996 when no fish were canned, causing the export value of this fishery to fall to N$91 million. In most years, canned fish make up more than 90% of the export earnings of the fishery, with almost all of it exported to South Africa, and fishmeal contributes most of the remainder.

The midwater trawl fishery for horse mackerel has contributed some N$250 million per year in exports in recent years, mostly in the form of relatively low-value frozen fish, with minor contributions from fishmeal (around 10%) and dried fish (some 3% in 1996). There is little product enhancement, and the export value of the catch is typically only about 10% above the landed value. Horse mackerel is one of the few marine species consumed in any quantity by Namibians, with about 3% of production consumed domestically.

The deep-water fishery has made a significant contribution to the fisheries sector in recent years, with exports to the value of N$171 million in 1996. Orange roughy contributes more than 90% by value, and alfonsino most of the remainder. Processing (mainly the production of high-quality fillets for the USA and Japanese markets) approximately doubles the value of the catch and is labour-intensive, providing much-needed employment in Walvis Bay.

The above four industries contribute more than 90% in terms of product value of all Namibia's industrial fish production. Of the remainder, only the tuna (3%), crab (1.5%) and rock lobster fisheries (1.5%) contribute more than 1% in most years. To these must be added the recreational linefishery. Kirchner *et al.* (2000) estimated that, between October 1997 and September 1998, some 8 800 anglers spent 173 000 days angling, and had direct expenditures totalling almost N$30 million. Value added to gross national income within the shore-angling fishery during that period was estimated at N$14 million.

ASSESSMENT AND MANAGEMENT

Policy and legal framework

In Namibia it is national policy to utilize living marine resources on a sustainable basis for the benefit of the nation, and to manage them according to scientific information and principles (Oelofsen 1999). Ultimate responsibility for control measures rests with the State. A 200 nautical mile Exclusive Economic Zone was declared after Independence in 1990, followed by the introduction of a new national policy on exploitation rights and quota allocation in 1991 (MFMR 1991) and the promulgation of a new Sea Fisheries Act in 1992 (MFMR 1992). A major emphasis was placed on Namibianization of all sectors of the fishing industry and the establishment of local research and management capacity.

All catches of the major fisheries sectors are limited by *TAC*s in conjunction with limited vessel rights. These rights were previously issued for 4, 7 or 10 years, but recently were changed to 7, 10 and 15 years, depending on a number of criteria. The longer rights are issued to companies who, essentially, are majority-owned by Namibians, employ Namibians at sea and on land, have a proven track record in the industry and have demonstrated a long-term commitment by investing in the fishing sector.

Most of the primary research on fisheries resources has been conducted by state-run research institutes operating within the Directorate of Resource Management of the Ministry of Fisheries and Marine Resources; the National Marine Information and Research Centre (NatMIRC) in Swakopmund and the Lüderitz Research Centre. Research is funded by levies on all commercial catches and more recently through the use of commercial vessels to assist with resource surveys on hake, orange roughy and sardine. A major partner in the research on resources has been the *Nansen Programme in Namibia*, a Norwegian development aid project.

Scientific recommendations for the harvesting of all major resources are presented to the Namibian Sea Fisheries Advisory Council (Fig. 11), which makes recommendations to the Minister of Fisheries and Marine Resources after considering socio-economic factors and the industry's subjective perception of the state of the resource. The Minister, after consultation with the Ministerial Fisheries Management Committee and other senior managers within the Ministry, submits *TAC* recommendations to Cabinet for final endorsement. Legislation is implemented effectively; all fish must be offloaded under inspection at either Walvis Bay or Lüderitz, and a fisheries observer accompanies all vessels large enough to carry extra personnel. These observers also conduct basic biological sampling. Surveillance is carried out by patrol vessels and aircraft, and a satellite vessel-monitoring system is currently being implemented.

Assessment and management measures

PELAGIC FISHERIES

Various management measures were used to restrict pelagic catches in the decades prior to Independence (see Butterworth 1983). Since then *TAC* restrictions on sardine and, in recent years, juvenile horse mackerel, have been the main control measure, although pelagic catches are also restricted somewhat by a closed season. Juvenile horse mackerel and anchovy catches are also limited if the bycatch of juvenile sardine is considered too high (nominally above 5%, but in practice the industry usually stops fishing voluntarily before such a level is reached). Since Independence recommendations on sardine *TAC*s have been based on acoustic biomass surveys conducted by the Namibian research ships *Benguela* and *Welwitchia* and the Norwegian RV *Dr Fridtjof Nansen*. In recent years extensive use has been made of fishing vessels as scouts to find shoal groups and check that fish have not been missed close inshore or outside the area surveyed (Boyer *et al.* 2001a). Attempts have also been made by NatMIRC to deduce population trends of sardine from VPA and De Lury-type assessment models, but this work has been severely hampered by the lack of reliable age determination and insufficient information on population parameters.

Since Independence the sardine *TAC* has been based on a projected fishing mortality ($F = 0.2$) of the fishable stock (>16 cm). A recent analysis of the spawning stock biomass–recruitment relationship indicates that average recruitment may improve if the stock reaches a minimum spawning biomass of 500 000 tons (Fossen *et al*. 2001). That analysis is based on several different calculations of spawner stock biomass–recruitment thresholds, as described by Myers *et al.* (1994), using VPA estimates of spawner biomass and recruitment for the period 1952–1987 and acoustic survey estimates from 1991 to 1996. While the validity of such a precise threshold is questionable, it has proved a useful tool to demonstrate to fisheries managers and industry that recruitment overfishing has occurred. Largely as a result of this analysis, only a nominal catch has been granted in recent years by the authorities to enable this important industry to survive.

TRAWL FISHERIES

Adult horse mackerel were assessed and managed from 1980 to 1989 according to *TAC*s set by ICSEAF agreements, based on VPA models applied to catch data from the international midwater trawl fishery. No distinction was made between Cape and Kunene horse mackerel, although the former dominated the catches. *TAC*s were partitioned between interested nations by ICSEAF according to their historic interest and performance in the fishery. Since 1990, when the fishery came under Namibian control, *TAC*s for the midwater trawl fishery have been based on the most recent acoustic survey estimates, and in recent years have been supported by length-based and age-based VPA estimates obtained using commercial catch data.

Between 1975 and 1989, the assessment and management of Namibian hake stocks was carried out under the auspices of ICSEAF (van der Westhuizen 2001). Various surplus production models based on catch and effort data from the Soviet and Spanish fleets were used. The fishery was managed by mesh regulations and a *TAC*, which was apportioned between nations in a similar manner to the horse mackerel *TAC*. Since Namibia's declaration of an EEZ in 1990, and the subsequent withdrawal of foreign fleets, the hake *TAC* has been based on biomass estimates obtained from bottom trawl surveys made by the *Dr Fridtjof Nansen* and, more recently, commercial trawlers (Iilende *et al.* 2001, van der Westhuizen 2001). The surveys produce estimates of the fishable (>36 cm) and non-fishable

(<36 cm) components of the population for both *M. capensis* and *M. paradoxus*. From Independence until 1998, the recommendation was set at 20% of the estimated fishable stock. In 1998 a working group consisting of members of the hake industry and Ministry scientists implemented an interim management procedure (IMP) with the intention of replacing this with a full operational management procedure by 2002. The IMP was based on a simple formulation, in which the *TAC* was adjusted up or down according to trends in catch rate and survey estimates of the fishable stock (Butterworth and Geromont 1997).

The fishery for monkfish is controlled by limited access (currently 18 vessels) and a 800 hp restriction on vessel power together with a 30 m vessel size limit. Bycatch of monkfish by the hake trawl fishery is discouraged by punitive bycatch levies. Research and management of the species was negligible until the mid 1990s, when the economic value of the species increased. Current assessments are conducted using age-based production models (Maartens and Booth 2001a), although the first swept-area trawl survey was completed in 2000. A *TAC* limitation system was introduced in 2000. Of particular concern is the high proportion of juvenile fish harvested in this fishery, and experiments to improve the selectivity of the commercial gear are being conducted (Maartens 1999).

Management of the deep-water fisheries off Namibia is based on assessments conducted under the auspices of the Namibian Deep Water Fisheries Working Group, with subsequent *TAC* recommendations to the Namibian Sea Fisheries Advisory Council by Ministry scientists. The Working Group consists of Ministry scientists and industry representatives, and receives input from a number of foreign scientific and industry consultants (Boyer *et al.* 2001b). For orange roughy, recommendations for *TAC*s for individual grounds were, until recently, based on an age-structured population model that used Bayesian methods to fit acoustic and swept-area survey estimates of abundance, and swept-area estimates calculated from commercial catch rates (Boyer *et al*. 2001b). Currently, an age-structured population model fitted to the acoustic data is used. The recent decline in all of these indices has led to a recommendation that a precautionary approach be followed until more data are available to determine optimal catch levels more reliably. Incentives to encourage exploration for new orange roughy grounds are offered to the discoverer in the form of guaranteed access to any new grounds.

Trawling within the 200 m isobath is prohibited for all fisheries. This restriction was introduced in 1993, primarily to eliminate the accidental, or otherwise, catch of sardine, but the measure has also served to protect juvenile hake and other juvenile fish.

CRUSTACEAN FISHERIES

In Namibia the West Coast rock lobster resource is assessed and managed according to a modified De Lury model based on catch, effort and size distribution data. Fishing is controlled by limits on the *TAC* per area, closed areas and seasons, minimum size and trap number limits, and various other restrictions on catches (e.g. no females in berry to be landed).

Assessment of deep-sea red crab in Namibia is based on length-based cohort analysis and prediction models, adapted to fit the growth dynamics of the species, using growth rates established by tagging (Le Roux 1997). The models are used to project future stock size as a function of catch, from which *TAC*s are recommended. The catch is also controlled by a minimum size limit (85 mm carapace width) and prohibition on fishing inside the 400 m isobath.

LINEFISHERIES

Although not yet a member, Namibia is following the regulations of ICCAT, and implements effort control over both national and foreign tuna vessels. The commercial line fishery for snoek and angling species in Namibia is at present unrestricted, but recreational catches of angling species are controlled by closed areas, bag limits and, in the breeding area of silver kob, a closed season.

SEALS

The Namibian seal harvest is primarily controlled through an annual *TAC*, with separate quotas for pups and bulls and for the different colonies. *TAC* recommendations are based on aerial censuses and estimates of biological parameters for the population (fecundity rate, mortality of pups and adults, sex ratios, etc.). These are used in a deterministic, age-structured model of the female component of the population to predict harvesting levels that will give sustainable yields. The seal *TAC* in recent years (which has not always been harvested) has varied between 17 000 animals in 1991 and 72 000 animals in 2000, with pups contributing about 80% of the total in all years. As the products from bulls are more valuable, they tend to be harvested preferentially to the pups, so distorting this ratio.

CONCLUSIONS

The marine fishery of Namibia is in a transitional stage. Following years of overexploitation of many of the resources by foreign fleets, management was taken over by the Namibian government in early 1990. Faced with the monumental task of rebuilding the stocks, and hence the fisheries, strict controls were enforced, both in the number of vessels licensed to fish, and in total allowable catches. In parallel, an extensive research programme was instituted to monitor and assess the state of the various stocks. This programme was initially supported by foreign donors (notably Norway), but in more recent times has been increasingly conducted by Namibians. Studies of biological and environmental processes, and experiments to improve assessment methods, have assumed greater prominence in recent years and are now largely conducted through international co-operation via regional programmes such as the Benguela Environment, Fisheries, Interaction and Training (BENEFIT) Programme and similar internationally funded research efforts. Research is being conducted regionally and internationally into common problems, such as improving survey methods, developing appropriate assessment tools, understanding the dynamics of key life history stages such as recruitment, and the investigation of important biological parameters such as age, growth and mortality. This is promoting standardization of research methods, both within the Benguela Current and farther afield, and will ultimately permit joint monitoring and assessment of stocks shared with neighbouring countries.

At Independence, few Namibians had any experience or training in marine fisheries research. Through assistance from the donor countries and exposure to the international research community Namibia has, a decade later, a core group of fisheries scientists able to conduct monitoring and assessment work at a level comparable to that found in many countries with a much longer history of fisheries research. The Namibian research programme is now central to international programmes, such as the BENEFIT Programme, and is likely to be of major importance in the natent Benguela Current Large Marine Ecosystem (BCLME) Programme.

After several decades of overexploitation, several of Namibia's marine resources are showing signs of recovery. Monkfish catches have increased and this fishery is now an important component of the trawl industry. Similarly, the hake fishery has grown since Independence, although catches are still considerably below those of earlier years. However, whether this increase is sustainable is not clear, particularly as it is based largely on an influx of deep-water hake rather than an increase in abundance of local stocks. The midwater horse mackerel fishery continues to make good catches, and there are signs that the rock lobster fishery has at least turned the corner towards recovery. In contrast, the orange roughy fishery, which in the mid 1990s promised so much, seems likely to become a relatively minor, although still lucrative, fishery. Of much greater concern is the failure of the pelagic stocks, and in particular sardine, to recover. Indeed, at the end of the 1990s the stock was in a similar state to that of the late 1980s, and the anchovy stock, which helped carry the purse-seine fishery through the poorer years of the 1980s, has all but disappeared.

If the recoveries are to be sustained, and the factors preventing the remaining stocks from increasing are to be understood, further developments in research and the management techniques will be needed. Transboundary effects and environmental teleconnections around the globe are being increasingly recognized as having a major effect on national fisheries. Increased international scientific cooperation is needed to investigate and understand these issues and to incorporate them into the management process.

Management procedures themselves also need to be developed. At present, harvesting levels are set to enable stocks to return to levels that will provide maximum sustainable yields, without any clear idea of what such levels may be, or even if they are attainable. While adherence to constant proportion harvesting rates has worked well for several stocks during the past decade, more sophisticated procedures will be needed in the future. The formal incorporation of such concepts as reference points (biological, economic, or both) and the precautionary approach needs to be considered and long-term management strategies adopted.

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