A Decade of Namibian Fisheries Science
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A DECADE OF EXPLOITATION AND MANAGEMENT OF THE NAMIBIAN HAKE STOCKS

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The hake resource is the most important commercial fish species in the demersal sector of Namibia's fisheries, both in terms of annual catch and contribution to Gross Domestic Product (GDP). The fishery now spans four decades. In the 1960s and 1970s, hake were exploited heavily by mainly foreign fleets, total catches peaking at more than 800 000 tons in 1972. The first control measures, the use of a minimum mesh size of 110 mm and the allocation of quotas to each member country participating in the hake fishery, were implemented by the International Commission for the Southeast Atlantic Fisheries in 1975. In 1990, the Namibian Government took action to control fishing activities in Namibian waters, and the enactment of its Fisheries Policy (1991) and Sea Fisheries Act of 1992 provided for the control measures to be taken. The conservative management strategy adopted between 1990 and 1993 resulted in gradual increase in hake biomass, but thereafter the stock declined. The hake fishery is currently managed on the basis of a total allowable catch that takes into consideration the rate of increase or decrease in the size of the resource. Since 1990, the demersal trawl fishery has accounted for approximately 90% of the total hake catch. The resource is subjected to both directed fishing and bycatch, the latter taken in directed fisheries for species such as horse mackerel, monkfish and sole.

Key words: biomass, hake fishery, management, stock assessment

There are two commercially exploited species of hake off Namibia, shallow-water Cape hake *Merluccius capensis* and deep-water Cape hake *M. paradoxus,* but for stock assessment and management purposes they are considered as a unit (Lucks *et al.* 1973, Gordoa *et al.* 1995, Pennington and Strømme 1998). The hake resource is the most important commercial resource in the demersal sector of Namibia's fisheries, in terms of both landed mass and export value; since 1990, hake has contributed approximately 90% to the total catch of the demersal fishery. The proportion of hake taken as bycatch in the fisheries for monkfish *Lophius vomerinus* and *L. vaillanti* and sole *Austroglossus microlepis*, and for horse mackerel *Trachurus t. capensis*, is between 0.7 (horse mackerel) and 3% (monkfish and sole) annually. Hake bottom trawling contributed on average 93% of the total landings of hake between 1991 and 1999 (MFMR 1996, 1997a, unpublished data).

Exploitation has spanned more than four decades. The period following Namibia's Independence was characterized by adverse environmental conditions (severe anoxic conditions in 1993 and 1994 and a Benguela *Niño* in 1995; O'Toole and Bartholomae 1998). The latter delayed the hoped-for recovery of the resource as total allowable catches (*TAC*s) were reduced or maintained at relatively low levels. Furthermore, management of the Namibian hake resource was difficult because of great uncertainty as to its size.

Several nations (South Africa, Spain and the USSR) undertook research surveys targeting hake off Namibia prior to Independence (Komarov 1979, Gordoa *et al*. 1995), but a direct comparison with the research surveys conducted since Independence is not possible because the fishing gear and methods applied are different. The main aim of this study is therefore to provide an overview of the hake fishery in Namibia during the past decade, with special emphasis on fishery structure, resource status, stock assessment and management procedures. The information used is based mainly on analysis of fisheries data in the Namibian Ministry of Fisheries and Marine Resources (MFMR) databases, and synthesis of published and unpublished information.

THE HISTORY OF EXPLOITATION

During the 1960s and 1970s, foreign fleets from mainly nine countries, Cuba, Israel, Italy, Japan, Poland, Portugal, South Africa, Spain and the USSR, targeted hake off Namibia (Gordoa *et al.* 1995). Spain and the USSR were the main contributors to the annual landings. Catches increased drastically from <50 000 tons (in 1964) to more than 800 000 tons (early 1970s). As a result of the marked increase in landings and the

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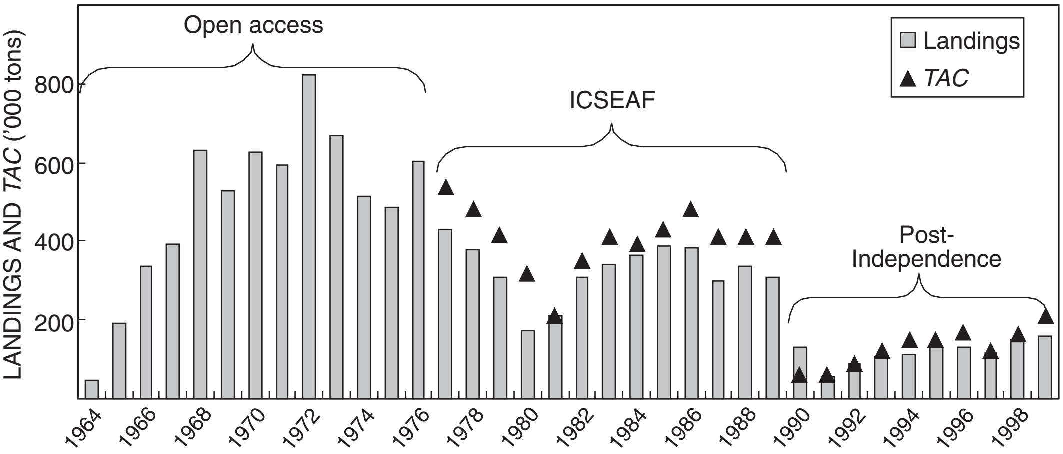

Fig. 1: Landings of Cape hake *Merluccius* spp. off Namibia, 1964–1999, and *TAC*s proposed, 1977–1999

development of a multinational fishery, the International Commission for the Southeast Atlantic Fisheries (ICSEAF) was established in 1969 to regulate the exploitation of marine resources in the South-East Atlantic. ICSEAF provided advice on the management of hake and other commercially important species until 1989 (Botha 1980, Gordoa *et al.* 1995). Despite ICSEAF's implementation of a minimum legal mesh size (110 mm) in 1975 (Anon. 1979) and member country quotas in 1976 (Draganik 1982), abundance declined after 1972, mainly because the level of exploitation was unsustainable. By 1980 the annual catch was only 170 000 tons. Between 1981 and 1989, the declared total annual landings declined (some 300 000 tons) and increased, mainly as a result of improved recruitment in the early 1980s, with especially strong 1982 and 1983 year-classes (Hamukuaya 1997).

At the time of Namibian Independence (1990), most commercial fish species were overfished and heavily depleted. Immediate measures taken included a moratorium on fishing by all foreign vessels and the declaration of a 200-mile Exclusive Economic Zone (EEZ). Initially, Namibia had no means of enforcing its EEZ and, during the first year after Independence, illegal fishing continued (Oelofsen 1999). Then, towards the end of November 1990, action was taken against the Spanish fleet, and three vessels were detained during March 1991, summarily halting illegal fishing activities (Manning 1998). During December 1991, the Government set out its fisheries policies in a document entitled "Towards Responsible Development of the Fisheries Sector" (MFMR 1991). Policies outlined in that document were translated into legislation by the new Sea Fisheries Act, which came into force in 1992 (MFMR 1992).

THE FISHERY

Fleet structure

The principal fishing method used in the hake fishery is bottom trawling by freezer/factory and wetfish trawlers. Cape hake are also caught directly by longline and as a bycatch by the fleets directed at monkfish and sole and at horse mackerel.

Promulgation of the Sea Fisheries Act in 1992 had a major impact on the development of the hake fishery structure in that the granting of new fishing rights and the development of fishing fleets were governed by the principle of Namibianization. Further, the Namibian fishing industry was to be developed in such a way as to ensure that it contributed maximally to the production of value-added products and ensured the creation of jobs in Namibia. It was with these aims in mind that the Namibian Ministry of Fisheries and Marine Resources put in place a policy that reserved an increasing percentage of the available *TAC* to enterprises and vessels landing their fish wet (on ice), rather than frozen (Oelofsen 1999).

The structure of the fleet therefore changed from 1992, mainly as a result of an increase in the number of wetfish vessels (Table I). Then, in 1994, a system was introduced in the hake fishery that had huge implications for the industry; increasing percentages of the *TAC* were allocated to wetfish vessels (20% in 1993, 40% in 1994, 60% in 1995; MFMR 1993). As the Namibian-based demersal industry before 1990 was tiny, there was a shortage of trained and experienced sea-going personnel in the country. Furthermore, by 1999 there were 11 hake-processing plants in the country (eight in Walvis Bay and three in Lüderitz), compared to the six (four in Walvis Bay and two in Lüderitz) in 1990. Consequently, the industry was forced to make big investments to upgrade its vessels and factories to comply with the quality standards for export to the European Union (EU; Blatt 1998, Stievenart 1998). This may have resulted in changes to the fishing power of the fleet over the years and may have influenced catch per unit effort (*cpue*).

Employment and exports

The hake fishery is the major contributor to employment in the fishing sector. Employment in the hake fishery as a percentage of the total employment in the fishing sector increased from ~3% in 1990 to 60% in 1999 (R. Gabeiras, Cadilu Fishing [Pty] Ltd, pers. comm.). By 2000, there were approximately 4 500 shore-based and 2 500 sea-based employees in the hake fishery.

The sector's contribution to gross domestic product (GDP) was 1.7% in 1990, but that figure had increased to >10% in 1999 (MFMR 1999). Earnings from exports contributed 95% of the total turnover in the demersal sector for 1999.

Landings

Exploitation of the Namibian hake resource can be categorized into three time-periods, based on the management at the time. These are the periods 1964–1976 (open access), 1977–1989 (ICSEAF) and from 1990 to date (post-Independence). The reported landings of hake in Namibia are depicted in Figure 1. Annual landings during the open access period averaged 495 498 tons. During this period, there were no management measures in place and exploitation of the hake stock was open to anyone who wished to fish off Namibia. During the period 1977–1989, *TAC*s were set by ICSEAF and the average annual catch was 325 311 tons. Fishing effort was much reduced in the early 1980s as a result of poor catch rates (Anon. 1983). After Independence, the overall management strategy was changed, with major implications for both the hake fishery and the resource. For the first few years, catches were low because the *TAC* was set very low. In 1990 and 1991, the *TAC* was 60 000 tons, but it was allowed to grow from 87 000 tons in 1992 to 160 690 tons in 1999.

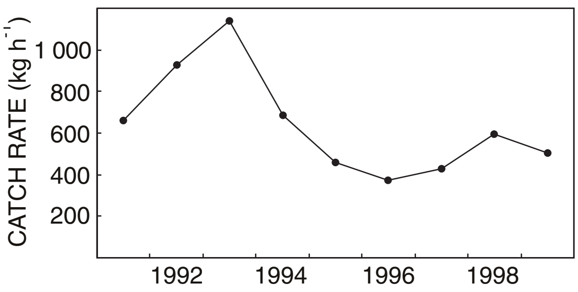

Fig. 2: Mean annual *cpue* of hake *Merluccius* spp. estimated using Generalized Linear Modelling (GLM) for the period 1991–1999 (courtesy L. Voges, Ministry of Fisheries and Marine Resources)

RESEARCH AND MONITORING

The data available for assessing the hake resource can be divided into fisheries-dependent (commercial) and fisheries-independent (research survey) data.

Commercial data

The statistics (daily logsheets) collected compulsorily from the hake fishery give the following information: licence number, vessel name, date on which fishing

Table I: Development of the hake fishing fleet (in numbers of vessels), 1991–2000 (after MFMR 1997a, unpublished data)

Vessel type	Number of vessels									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Freezer trawlers	4	27	23	19	18	10	16	18	19	20
Wetfish trawlers		11	26	37	37	50	57	47	54	62
Longliners	11	8	8	13	12	8	17	16	20	23
Total	55	46	57	69	67	68	90	81	93	105

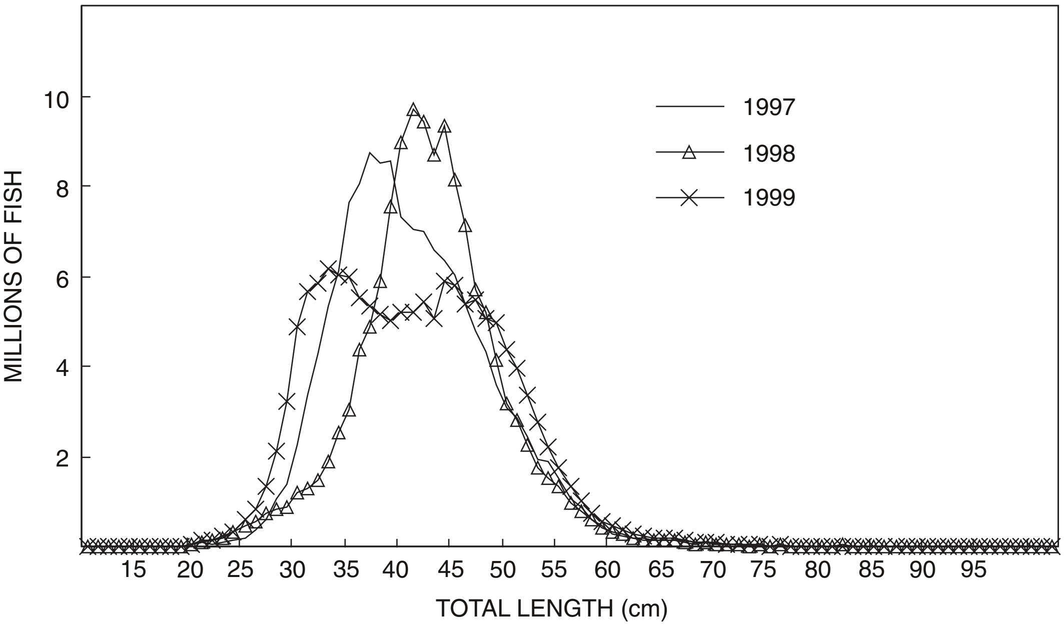

Fig. 3: Commercial length frequency distribution of *M. paradoxus* sampled from hake-directed bottom trawlers, 1997–1999

activity was undertaken, trawl duration, trawl depth, geographical trawl position, and total weight of the catch (divided into species).

Generalized Linear Modelling (GLM) provides a means of examining the effects that different factors (e.g. different vessel characteristics, different depths, different areas of fishing, month, year) have on abundance trends (Large 1992). Also, interannual changes in the environment (in particular sea surface temperature) may be another factor regulating changes in annual catchability of hake (Gordoa *et al.* 2000). The main factors influencing catch per unit effort (*cpue*) of the commercial fleet are year, month, gross registered tonnage and area. Analysis showed that commercial effort nowadays is mainly concentrated between 22 and 27°S (1992–1999). It was also established that certain areas and times of the year yield higher catch rates (L. Voges, MFMR, pers. comm.). However, catches by the fleet (and therefore fishing effort) do not reflect this phenomenon, so fleet characteristics (specifically catching capacity) may be the limiting factor. In general, *cpue* is highest in January, decreases between February and October and increases again during November and December each year (L. Voges, pers. comm.).

The mean annual commercial *cpue* of hake for the period 1991–1999 is shown in Figure 2. It increased between 1991 and 1993, but then declined from 1 138 to 375 kg h^{-1} between 1993 and 1996. Subsequently, it increased to 593 kg h^{-1} in 1998 before decreasing again (506 kg h^{-1}) in 1999.

In 1991, a fisheries observer system was initiated for monitoring, control and surveillance purposes. Until 1996, the observers only had to ensure that fishers adhered to regulations, but thereafter, with the establishment of a commercial sampling programme (CSP), observers also collected biological data on the fish caught (Davies 1999). Length frequencies, otoliths and stomach contents are now collected, and information on sex and catch composition is recorded routinely.

During the period 1997–1999, deep-water Cape hake dominated the catches (68, 58 and 64% respectively), confirming the belief that recent fishing effort has been directed more on deep-water than on shallow-water Cape hake. One of the reasons for this could be the apparent increase in biomass of *Merluccius paradoxus* in the south of Namibia, speculated to have originated from the large stocks of that species in South African waters to the south (Burmeister 2001). However, the introduction of a minimum fishing depth for trawlers of 200 m (to protect the sardine *Sardinops*

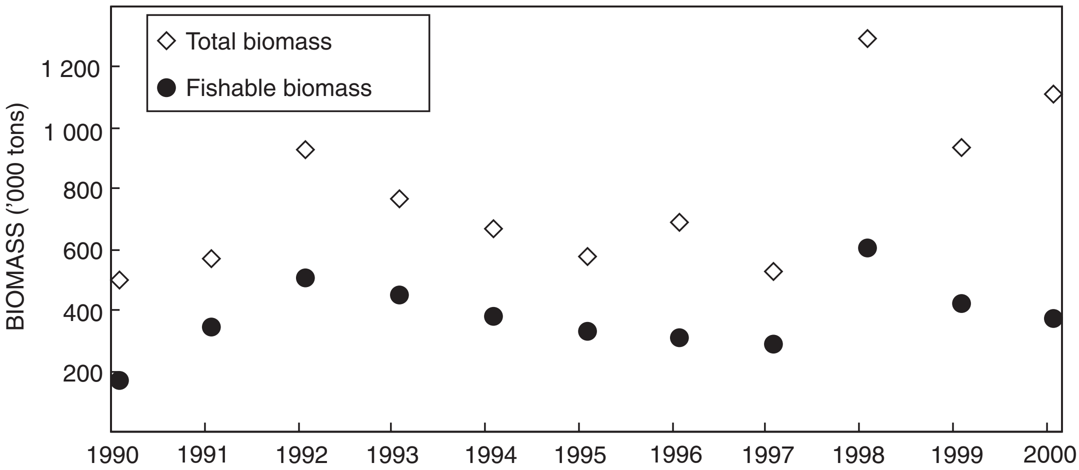

Fig. 4: Total and fishable (≥36 cm) biomass estimates for both species of hake combined obtained from research surveys conducted off Namibia, 1990–2000. The point estimates are the average of all survey values for a year

sagax stock) may also have contributed to the changes in fishing patterns of trawlers. Chłapowski (1978) and Payne (1989) showed that the two species have different depth distributions, so changes in the fishing pattern would automatically have influenced the contribution of the two species to the catches.

From the biological data collected in the CSP, length and age compositions by species, area, month and fishing gear are drawn up with a view, in due course, to utilizing analytical assessment methods such as virtual population analysis (VPA) to formulate management advice. Preliminary analysis of these data for the period 1997–1999 indicate that fishing effort is on a limited range of sizes of Cape hake (25–60 cm). In 1997 and 1998, deep-water hake of 30–55 cm total length were the most heavily exploited, but in 1999 there seemed to be fewer hake of size 35–45 cm (Fig. 3), possibly representative of one or two years of poor recruitment.

Research survey data

The main objectives of groundfish research surveys off Namibia are the determination of size composition and abundance of the two hake species to supplement and enhance the advice given to the Ministry of Fisheries and Marine Resources on the status of the hake resource.

From 1990 to 1999, 18 research surveys were carried out to estimate hake biomass. The surveys were conducted by the Ministry of Fisheries and Marine Resources on board the R.V. *Dr Fridtjof Nansen*, a research ship supplied by the Norwegian agency for Foreign Aid Development (NORAD) with assistance from the Institute of Marine Research (IMR), Norway. During 1998 and 1999, surveys were carried out in parallel with commercial fishing vessels to investigate the feasibility of conducting future research surveys on board commercial trawlers and to calibrate the resultant data to provide a single series. These experiments were successful and, as a result, the hake biomass research survey for the year 2000 was conducted on board a commercial fishing vessel.

The survey methodology used a swept-area technique. Trawls were distributed semi-randomly along transects (~20 nautical miles apart) perpendicular to the coast and covered the full depth range over which both hake species occur. Large catches were subsampled and small catches analysed in full for composition by weight and number per species. Length frequencies were recorded (to the nearest cm), sex was determined and the stage of maturity determined macroscopically. Fish were weighed to the nearest g. Detailed information on the trawl survey methods and gear rigging is given in Strømme *et al.* (1999). Hake in midwater and hence not assessed by the bottom trawl were assessed acoustically, so allowing a correction to the swept-area trawl estimate (Iilende *et al.* 2001). The survey data also provide indices of recruitment of <2-year-old hake (Strømme *et al.* 1999).

The conservative management strategy of 1990–

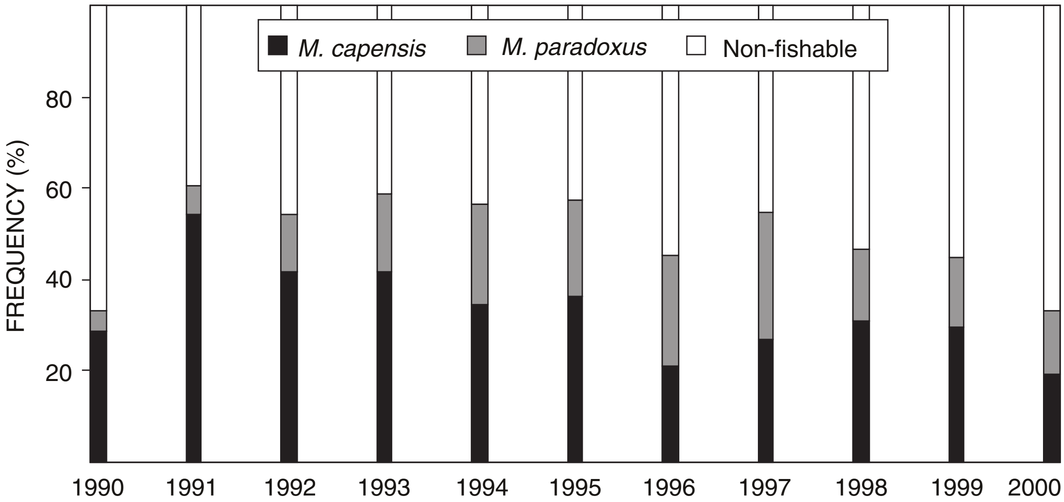

Fig. 5: Contribution of each species of Cape hake to the total biomass estimated from research surveys conducted off Namibia, 1990–2000

1992, allied to good recruitment in 1991, helped the hake biomass to increase from the start of the decade. The total biomass estimates (both hake species combined) increased from 500 000 tons in 1990 to 800 000 tons in 1992 (Fig. 4). However, biomass thereafter gradually declined, in 1997 reaching a level of total biomass close to that estimated for 1990. This decline was most probably the result of anomalous environmental conditions that occurred between 1993 and 1995 (severe anoxic conditions in 1993 and 1994 and a Benguela *Niño* in 1995) that seemed to have a negative influence on the availability of adults as well as on recruitment to the fishable population (O'Toole and Bartholomae 1998). Then, in 1998, the stock recovered as a result of an incoming 1996 year-class. Although the estimated biomass in 1999 was lower than that estimated in 1998, its overall size structure was good (Strømme *et al.* 1999).

The contribution of the two species of hake to total fishable biomass (≥36 cm) in relation to the overall biomass for each year is depicted in Figure 5. Since 1991, the fishable *M. capensis* biomass has been declining, whereas that of *M. paradoxus* increased from 5% in 1990 to 28% in 1997. There was also an increase in the geographic distribution of the *M. paradoxus* stock, as mentioned above. There could be a number of reasons for this expansion of the deep-water hake stock northwards. One is environmental. Another is that South Africa may have been harvesting its stock of the same species below optimum levels, allowing the stock to grow and hence expand its spatial distribution (Fig. 6). In any case, between 1998 and 2000, the non-fishable (<36 cm) portion of the stock of both species of hake combined contributed more than half the total biomass found on the surveys.

MANAGEMENT

At Namibia's Independence, the main aim was to rebuild the hake stock ("the desirable level of stock biomass for long-term exploitation should not be less than one million tons of exploitable stock"; MFMR 1991, p. 6) and, for this reason, catch restrictions and other regulations were imposed. Directly after

Table II: Management tools for the Namibian hake fishery for the three management periods defined

Measure	1964–1974	1975–1989	1990–2000
Limited entry licences	No	No	Yes
Quotas	No	Yes (1977)	Yes
Minimum mesh size	No	Yes (1975)	Yes
Closed areas	No	No	Yes
Catch monitoring	Yes	Yes	Yes
Discard monitoring	No	No	Yes
At-sea sampling of commercial catch	No	No	Yes (1997)

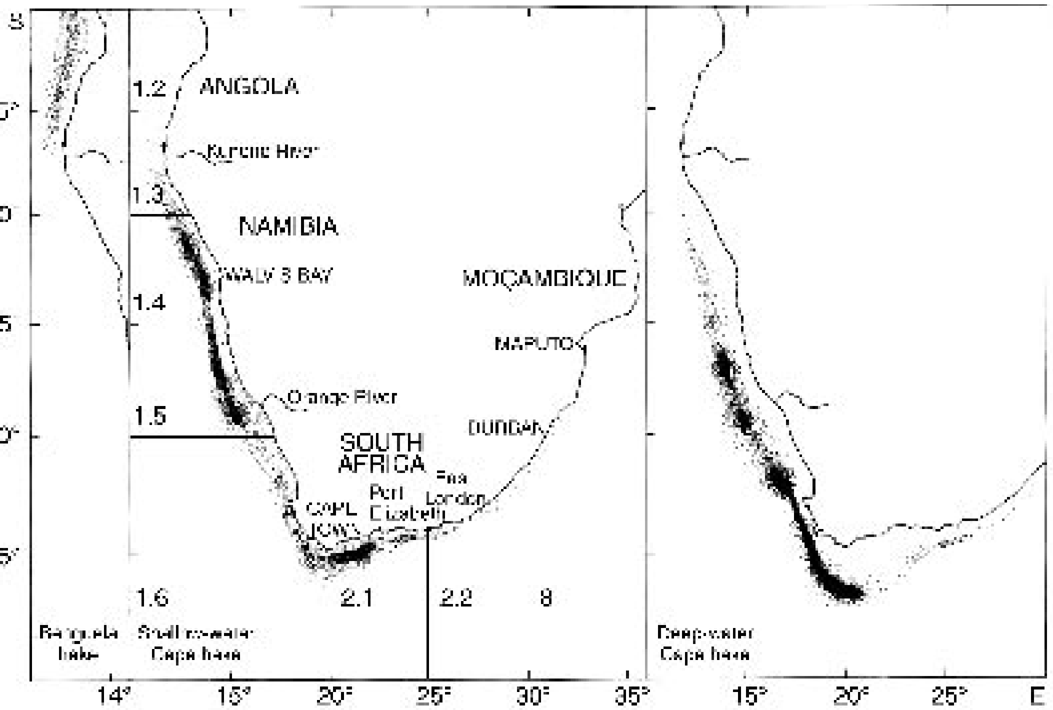

Fig. 6: Distribution of the three hake species in the Benguela ecosystem (after Payne 1989)

Independence (1990), the *TAC* was set at 60 000 tons for both 1990 and 1991. Between 1992 and 1997, the *TAC* was set as proposed in the Namibian White Paper on a Marine Fisheries Policy, based on the fact that fishing mortality on hake should be approximately 20% of fishable biomass until stocks had been considered rebuilt (MFMR 1991). A summary of the management regulations in place is given in Table II.

In the past decade, management of the hake resource has been confounded by uncertainties surrounding the size of the resource. There were two conflicting estimates of abundance, depending on whether the survey or the commercial *cpue* index was used, complicating the recommendation of a *TAC*. The survey index indicates that the resource declined after 1992 and that the population is currently overexploited. In contrast, the estimate obtained from a surplus production model based on commercial catch and effort data indicates that abundance is currently close to pristine levels (Butterworth and Geromont 1997, Pennington and Strømme 1998, Voges 1998).

These conflicting indices caused uncertainty in management and in the Namibian fishing sector. Therefore, a workshop (MFMR 1997b) was held in 1997 to try to determine the real status of the Namibia hake resource. This workshop was a joint project between the fishing industry and local scientists (including some from South Africa) and resulted in the introduction of an Interim Management Procedure (IMP). The IMP (Butterworth and Geromont 2001) was a short-term solution for recommending annual *TAC*s for the subsequent few years. The IMP can be explained by:

$$TAC_y = TAC_{y-1}\left[1 + \lambda s_y\right] \quad ,$$

where TAC_y is the total allowable catch in year y, TAC_{y-1} that of the previous year (in the case of 1997, 150 000 tons), λ a control parameter of which the value was pre-chosen (in this case $\lambda = 3$), and s_y is a measure of the trend in abundance indices at the start of year y (Geromont *et al.* 1999).

Depending on the rate of increase or decrease in the two abundance indices, application of the IMP would result in a lower or higher *TAC* for the following year. This IMP has been in place for three years, but in August 2000, another hake workshop on the future management of the Namibian hake resource was held, resulting in its re-evaluation and modification. The implementation of a more effective long-term management procedure, aiming for stability and sustainability in this vital fishery, is needed, and work is currently being conducted towards achieving this objective.

FUTURE PROSPECTS

The total biomass of hake is currently estimated from the research survey to be 1.2 million tons, substantially bigger than it was at Independence (500 000 tons). Indications of a strong year-class (~4 billion fish) were found during the year 2000 research survey, and this should enter the fishery by late 2001 (Iilende *et al.* 2000). Of concern, however, is the ongoing decline in fishable biomass of *M. capensis*, although this species was not the main contributor to the annual landings of hake during the three years 1997–1999. However, if the Namibian hake fishery continues to be based mainly on *M. paradoxus*, there could be management implications if South Africa were to increase its own catches substantially. Joint management of this shared stock (Fig. 6, Anon. 1995) would have to be considered if the United Nations requirement on management of straddling stocks were to be adhered to.

During the past decade, research concentrated on clarifying assessment uncertainties. Although these uncertainties are still not resolved, research is now being undertaken to relate the population dynamics of the hake stock to environmental stimuli. In 1999, a unit was established in Swakopmund to prepare and read large numbers of hake otoliths, so addressing the need for annual catch-at-age data. In the near future this may allow analysis of the age structure of the catch through VPA, so providing a much-needed additional assessment tool to those already in use. Other research projects that commenced recently concentrate on recruitment mechanisms and fecundity.

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