Swordfish

Global lessons

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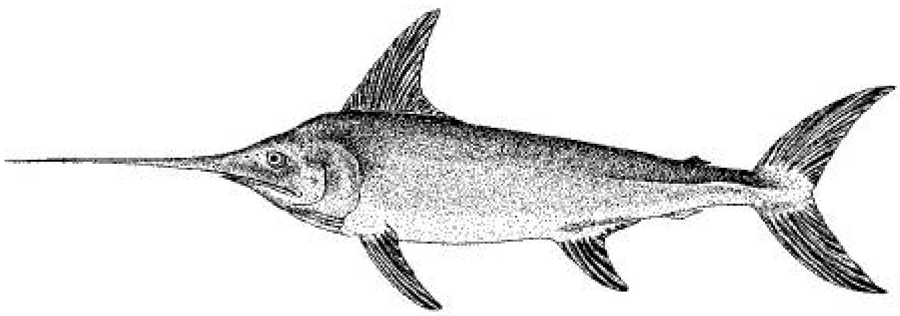

This report, prepared on behalf of WWF-South Africa, provides a critical overview of the world's fisheries for swordfish. It is intended that this report will provide useful information and guidance to those with responsibilities in the conservation and sustainable development of the newly emerging South African swordfishery.

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Executive Summary

The swordfish or broadbill, *Xiphias gladius*, is a large oceanic fish of high commercial value, which is widely distributed in tropical and temperate waters of the world's oceans. Swordfish are wide-ranging species and although little is known about their large-scale movements some have been shown to undertake long-distance migrations. They are opportunistic predators, which feed on a variety of fishes and invertebrates. Swordfish have poorly defined spawning seasons and spawning grounds. The females are highly fecund, releasing millions of eggs at a time. Four genetically distinct breeding units have been identified as follows: in the Mediterranean, north-western Atlantic, tropical to South Atlantic and the Indo-Pacific. Swordfish reach at least 25 years of age, although females appear to have a longer life span than males and grow faster.

The majority of commercial swordfish catches are taken by pelagic longlines, with smaller catches taken by driftnets and harpoons. Globally 66 countries reported fishing for swordfish in 1999, and the total mass landed in 1999 was estimated at 97110mt. Global fisheries are characterised by initial rapid growth followed by large declines in landings. The U.S. is the world's largest market for swordfish, although swordfish is also consumed in Europe, Japan and throughout the developed world, where it is purchased either fresh or frozen.

Swordfish are managed on an international basis, as they are found throughout the world and are highly migratory. There are three major organisations concerned with the study and management of swordfish and tuna. The International Commission for the Conservation of Atlantic Tunas (ICCAT) has the mandate to manage swordfish and other large pelagic species in the Mediterranean and Atlantic Oceans up to Cape Agulhas (20° E). Swordfish landings in the Indian Ocean, east of Cape Agulhas fall under the jurisdiction of the recently established Indian Ocean Tuna Commission (IOTC), while the Inter-American Tropical Tuna Commission (IATTC) manages swordfish of the eastern tropical Pacific.

In the Mediterranean over 50% of the catch is comprised of juveniles and it is generally agreed that the stocks are over-exploited. This is principally because nations fishing in the Mediterranean manage their stocks independently. Although the ICCAT working group in the Mediterranean makes management recommendations and promotes data exchange, they do not enforce regulations. Landings in the North Atlantic peaked at 20 339mt in 1988 and then declined in the 1990's and it is believed that the North Atlantic stock is over-exploited. ICCAT introduced stricter quotas in the North Atlantic to prevent further overfishing and although the TAC is regularly exceeded, the North Atlantic stock has shown signs of improvement. Catches in the Indian Ocean have increased considerably since the 1990s and in the light of declining catch rates the IOTC has recommended no further increases in catch and effort in this region. It should be noted that declining catch rates of swordfish are not always directly attributable to depleted stocks. In some cases changes in fisher behaviour and other social and economic causes have an impact on landings.

In Hawaii, the relatively new swordfishery is considered by some to be stable because the landings, catch rates and average size of harvested swordfish have not declined significantly. In South African waters swordfish are caught in a growing experimental pelagic longline fishery, which is directed at tuna and swordfish. They are also caught by foreign longliners and by hook and line in the sport fishery. The experimental fishery was established in 1997 and 26 permits are currently issued. Swordfish currently comprise 21% of the total catch in this fishery. Taiwanese and Japanese longliners have been fishing for tuna and swordfish in South African waters for the past 30 years. Catches are largely unrecorded, however, the number of permits issued to foreign vessels has been reduced in recent years and it is proposed that most foreign access to South African swordfish will be terminated by 2004.

To date, South Africa does not have a defensible commercial swordfish management plan in place and unless there is effective management intervention, the South African swordfishery may experience the same fate as the North Atlantic one. While harvesting is being allowed on a precautionary basis, it is most urgent to develop a scientifically based plan for the sustainable use of this valuable resource. The following are recommendations that fisheries managers in South Africa should consider during the development of South Africa's swordfishery and are based on international experience in this fishery:

- In a developing fishery, when little is known about the dynamics of the fishery, it is imperative to proceed with development using the precautionary approach (FAO 1995). This approach can, in principle, reduce the likelihood of excessive fishing effort and overcapitalisation early in the fishery. It is well recognised that it is easier to limit effort in a developing fishery than to reduce it in a fully developed one.
- As a member of ICCAT, South Africa should strongly motivate to participate in discussions within Panel 4. This is probably the most feasible avenue open to South Africa to gain a country specific quota for swordfish in the future.
- South Africa should become an active member of the IOTC, as swordfish caught off South Africa are derived from an Indian Ocean stock and international management of this resource is imperative.
- All commercial fishers, both local and foreign, should be obliged as a condition of their permits to provide accurate catch and effort information to the Chief Directorate: Marine and Coastal Management (CD: MCM) for swordfish catches made in South Africa's EEZ. Recreational anglers should submit information via the National Marine Linefish System to the CD: MCM.
- A monitoring system should be set up to collect biological, fishery and socio-economic information from local and foreign vessels. An onboard and harbour-based observer programme would be the ideal means to achieve this aim.
- A multi-species stock assessment needs to be undertaken for this fishery and an OMP developed.
- The problem of by-catch (e.g. birds) needs to be assessed and addressed through the use of gear modifications (such as dyed bait) and restricting fishing to night time only.
- Currently the South African swordfishery is mainly an effort-limited fishery i.e. the number of entrants to the fishery is restricted while catches are limited by the ICCAT quota in the South Atlantic. It would be wiser to combine effort limitation with an annual quota derived from an OMP.
- Areas where juveniles are more abundant need to be identified and closed to fishing.
- Vessel monitoring systems (VMS) should be mandatory for foreign and local vessels fishing in South African waters (VMS aid in the enforcement of regulations, especially in areas closed to fishing.
- Regulations need to be enforced through effective monitoring and control.

CONTENTS

1. INTRODUCTION

"If the North Atlantic [swordfish] stock continues to decline at the same rate it has since 1978…the commercial fishery may not be viable in approximately 10 years."

A United.States National Marine Fisheries Service warning announced in 1997.

The swordfish or broadbill, *Xiphias gladius* is the only living species of the family *Xiphidae*. Like all billfish[1], swordfish have a large sword (or rostrum) which makes up a third of their total length. The blackish-brown swordfish are distinguished from other billfish species in that they have one only pair of caudal keels (others have two), no pelvic fins and no scales or teeth (Molteno and Riley 1986). This large oceanic fish can reach a maximum length of 445cm total length and can weigh up to 540kg, it can live for 25 years and is highly fecund (Nakamura 1985). Swordfish are the most widely distributed of billfish and are found wordwide in tropical, subtropical and temperate seas. Swordfish display a wide temperature tolerance (5 to 27°C) and are able to undertake extensive vertical migrations to depths of up to 1000m (Nakamura 1985). Swordfish, and other billfish, have a "brain heater" which allows them to elevate the temperature of their brain and eyes, while diving to great depths (Carey 1982).

Evidence of the harvesting of swordfish can be traced back over centuries. For example in Japan to between 3 000 and 4 000 BC, and in the Mediterranean to the time of Aristotle (384-322 BC). Today, swordfish is consumed as a luxury table food in many countries, although more than 25% of the world's catch is consumed in the United States (US). It is marketed either fresh or frozen and can be made into sashimi, teriyaki or fillets (Nakamura 1985). Although swordfish are harvested throughout most of their range, there has not always been an even distribution of effort, with most catches, until recently being taken in the North Atlantic. Swordfish are taken either as a commercial target, as a bycatch in longline and trawl fisheries or as a recreational species. Ward and Elscot (2000) estimated that 50% of the current swordfish catch is taken as a bycatch. This complicates management, as it is extremely difficult to manage a bycatch species. The sport fishery for swordfish, worldwide, is small compared to other billfishes but may nevertheless be significant to certain local economies. The sport fishery takes only a few hundred swordfish from the world's oceans each year.

Since 1996, North Atlantic swordfish has been listed as endangered on The World Conservation Union's (IUCN) "Red Data List" of threatened animals (http://www.redlist.org). This is principally due to the overexploited status of the swordfish stock in the North Atlantic, a result of poor management that was ineffective in preventing overfishing. Nearly two-thirds of the North Atlantic catch taken today are immature fish that have never spawned. In 1996 U.S. fishermen discarded some 40 000 North Atlantic swordfish mainly because they were too small to legally bring to market, the minimum size limit is 25kg (Ward and Elscot 2000). The status of swordfish in other areas is largely unknown because of a lack of information and data, although it is believed that the Mediterranean stock is also over-exploited.
Prior to 1997 there was very little longlining by South African operators. Local longlining was first initiated in 1960, primarily to target tuna, but great variability in landings impeded development of this fishery (Shannon et al, 1989). For this reason, swordfish were seldom caught, except as a bycatch, either by longline or by trawl. Furthermore, there was no local market demand for swordfish. In 1992, sport anglers successfully petitioned the then

[1] **Billfishes** – The collective name given to fish that have a sword-like extension to their upper jaw, this includes swordfish, marlins, sailfish and spearfish.

minister of fisheries to declare swordfish a recreational species, in an attempt to prevent commercial exploitation that had caused stock depletion in several regions of the world.

Longlining in South Africa was later revitalised when it was found that targeting of demersal large hake and kingklip appeared lucrative. However, this proved non-sustainable and as a result all longlining by South African vessels was prohibited in 1990. In 1995 tuna fishers agitated for access to longline permits and as a result these were issued on an experimental basis, specifically for tuna. This proved viable, particularly because of the high level of swordfish as a bycatch. As a result, in 1997 the industry motivated for additional experimental longline permits, which could target tuna and swordfish, with 30 permits then being made available (Penney, 1998).

There were also other reasons for the growing interest in swordfish. Since 1990, recreational anglers off Cape Town, and elsewhere, were successful in catching and landing swordfish with rod and reel (Penney 1998). Many of these fish were of record size and larger than most caught elsewhere in the world (van der Elst de Wet 1994). Japanese and Taiwanese longliners had been fishing for tuna and swordfish in South African waters for the past thirty years. In addition, the catch limitations introduced by the International Commission for the Conservation of Atlantic Tunas (ICCAT) for the swordfish fishery in the North Atlantic Ocean induced a shift of fishing effort to South Atlantic waters. As a result, South African ports were increasingly used to land swordfish. This further raised international and local awareness of the availability of swordfish in the South Atlantic Ocean.

It is evident that swordfish have in the past decade become an important target species for South African fishers, strongly influenced by its high dollar export value. In the light of non-sustainable harvesting of swordfish in some regions of the world, it is clear that South Africa needs to urgently be pro-active in developing a wise management strategy for the emerging swordfishery in her territorial waters. Furthermore, South Africa needs to be equipped to participate to the wider regional management initiative of this migratory species.

In 1999, a group of concerned commercial and recreational fishers formed the Broadbill Swordfish Interest Group (BSIG), with a view to collaboration in the wise management of this prime species. As a result, the BSIG approached the Oceanographic Research Institute and WWF-SA, to assist them in undertaking a review of swordfish conservation worldwide, so that lessons could be learned. This would then be of assistance to the South African fishery management authorities so as to avoid a biodiversity threat through overfishing.

In this document the international experience in the management of swordfisheries has been synthesized in order to guide decision makers and other stakeholders in the sustainable development of the South African swordfishery.

2. BIOLOGY

Distribution

Swordfish are a cosmopolitan species, found throughout the world's oceans and seas (Figure 1). Based on data from commercial longliners' catches, the species' latitudinal range extends from 50°N to 45°S in the western Pacific, from 50°N to 35°S in the eastern Pacific, from 25°N to 45°S in the Indian Ocean, from 50°N to 40°-45°S in the western Atlantic and from 60°N to 45°-50°S in the eastern Atlantic (Nakamura 1985).

Swordfish are generally found in waters with surface temperatures greater than 13°C, although they show a great temperature tolerance, ranging from 5° to 27°C. Swordfish are known to congregate at ocean fronts, where temperature and current differentials tend to concentrate baitfish. Juveniles are most common in tropical and subtropical waters, and only move to higher latitudes after they are mature (Kailola *et al.* 1993).

Little is known about the large-scale movements of adult swordfish, but tagging studies have indicated that some undertake extensive long-distance movements, the greatest distance a tagged swordfish has moved is 2 700 nautical miles (nm) (Carey and Robinson 1980; Ward and Elscot 2000). It is generally believed that adult swordfish move into temperate waters to feed in summer and return to warmer tropical waters during winter (Nakamura 1985). Pelagic species, such as swordfish, are difficult to manage as they frequently move between the Exclusive Economic Zones (EEZ) of various countries and into international waters (the high seas). However, more recent genetic analyses of swordfish populations are suggesting that there are genetically distinct populations in the major ocean basins. While mixing of these populations does occur, they are adequately separate to be genetically discrete. (Rosel and Block, 1996)

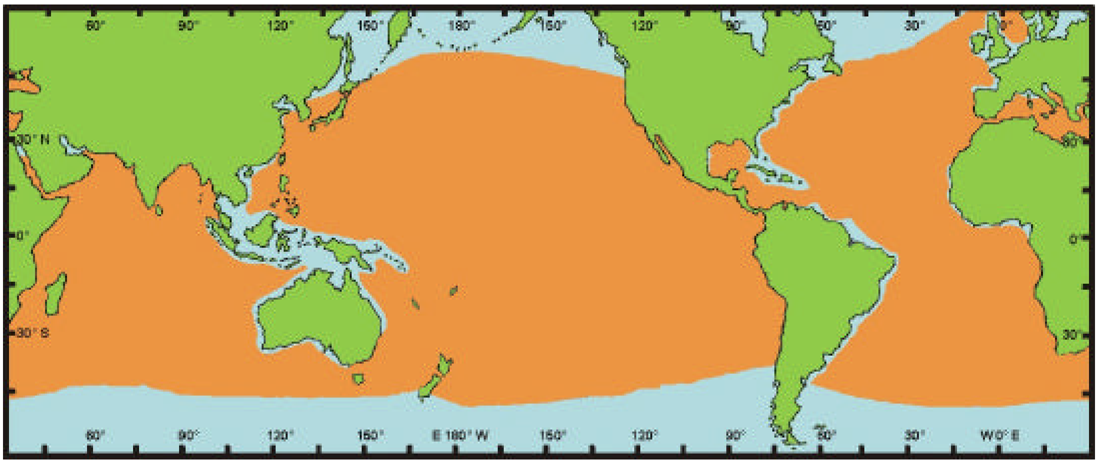

Figure 1. Global distribution of swordfish (adapted from Nakamura 1985).

Feeding

Swordfish are voracious predators that feed primarily on pelagic fishes and invertebrates, particularly squid (Hernandez-Garcia 1995). Adult swordfish are diurnal feeders, feeding throughout the water column as they follow the migration of the 'deep-scattering sound layer', which is an assemblage of small shrimp, fish and squid (Ward and Elscot 2000). In inshore waters swordfish are found near the seabed during the day, where they feed on benthic species. In oceanic waters swordfish migrate to great depths during the day, possibly as deep as 1000m (Ward and Elscot 2000). They rise to the surface waters to feed at night, and it is then that they are actively targeted by longliners (Carey and Robinson 1981). In some temperate regions of the North Atlantic and North Pacific large female swordfish bask in the surface waters for short periods during the day, and it is then that they are vulnerable to harpoon fishing (Ward and Elscot 2000).

Swordfish are able to withstand rapid changes in temperature during their diurnal migrations because they have developed a specialised "brain heater", which allows them to keep their eyes and brain at a near-constant 28°C. The heater is developed from a muscle of the eye, which is rich in mitochondria and cytochrome-C that generate heat (Carey 1982; Tullis and Block, 1996).

Spawning

Swordfish do not normally gather in large schools to spawn and it is believed that fertilization, which is external, occurs between a solitary male and female in the upper layers of the water column (from the surface to a depth of 75m) (Kailola *et al.* 1993). Swordfish are highly fecund, with large females releasing several million eggs at a time in batches. Such batch spawning, meaning that they spawn every few days throughout the peak spawning season (IOTC 2000). The number of eggs released is related to the size of the female. A 68kg female may release between1 to 16 million eggs at a time, while a 272kg female may release up to 29 million eggs (Kailola *et al.* 1993). Swordfish do not necessarily have discrete spawning grounds and spawning seasons. Spawning in the North Atlantic occurs throughout the year with a peak from April to September in the Caribbean, the Gulf of Mexico and off Florida. In the central North Pacific it occurs in spring and summer (March through to July), in spring (September to December) in the western South Pacific and all year round in equatorial Pacific waters (Nakamura 1985).

The best-known spawning regions are found in the Mediterranean Sea. Here intensive spawning occurs from June to August when males may be observed pursuing females at the surface. In the Indian Ocean, spawning has been recorded mainly between October and April off southern Madagascar and La Reunion Island (Kroese 2000; Poisson and Marjolet 2001).

Stock Structure

From nuclear and mitochondrial DNA analyses, four genetically separated breeding units of swordfish have been identified (Chow and Takeyama 2000). These are the Mediterranean, northwestern Atlantic, tropical to South Atlantic and the Indo-Pacific. However, as is the case with most migratory species, the precise boundaries and amount of interbreeding between stocks is not well defined and poorly understood known (ICCAT 1999).

Age and growth

The determination of growth in large pelagic species is often troublesome, as it is usually difficult to validate age estimates. Studies have found that swordfish can attain an age of 25 years. Females grow larger than males and attain maximum size at about 15 years, while males reach their maximum size at 9 years (Ward and Elscot 2000). Males mature at a younger age (1-2 yrs) than females (5-6 yrs) (Taylor and Murphy 1992). Young swordfish grow very rapidly reaching about 140 cm LJFL (lower jaw-fork length) by age 3, but thereafter growth slows down. Females grow faster than males after 3 years of age. The shorter life span and slower growth rate of males result in very different sex ratios at a given age/size. Generally, juvenile swordfish display a 1:1 sex ratio but in large swordfish (>200 cm) 90 to 100% are biased in favour of females i.e.1 male: 9 females. Differences in sex ratios are frequently reflected in the catch (Ward and Elscot 2000). There is some evidence to suggest that in the Indian Ocean, swordfish seem to have a slower growth rate than other oceans (Poisson *et al.* 2001).

3. THE WORLD'S FISHERY FOR SWORDFISH

Fishing gear and technology

The greatest proportion of the global swordfish catch is taken by pelagic longlines, while smaller harvests are taken by driftnets and harpoons. Longlining accounted for 85% of world catches in 1997, while driftnets accounted for 10% and harpoon 5% (Ward and Elscot 2000).

Harpoons

Subsistence fishermen have harpooned swordfish that are basking or finning at the surface for thousands of years. However, in the 1960s longlining, which is more effective, became the dominant fishing method (Ward and Elscot 2000). Fishers in Japan and Chile still capture swordfish using a manual harpoon while fishing from a small boat (Barbieri *et al.* 1998). Harpoon fishing is restricted to months of calm weather when swordfish are found in surface waters. Harpoon fishing is highly selective[1], in that large swordfish, basking at the water's surface, can be targeted.

Driftnets

Swordfish are also captured using drift gillnets (Figure 2a) in several areas such as Chile, Mexico, Japan, Africa and the Mediterranean (Ward and Elscot 2000). The nets used are about 2 500m long with a depth of 55m and a stretch mesh size of ± 56cm (Barbieri *et al.* 1998). To improve the efficiency of the driftnets, chemical light sticks are tied every 37m to the net. The light attracts either swordfish, or their prey, to the net. The nets are set at dusk, at a setting depth of between 9 and 55m, and hauled in at dawn the following day.

Although the mesh size can predetermine the size of fish that will be caught, there may often be a high incidence of bycatch, especially of shark and other billfish species.

Longlines

Longlining for swordfish employs hundreds of branch lines attached to a single main line set horizontally (Ito *et al.* 1998). The main line can be over 80 km in length and is stored on a large hydraulic powered reel. The number of hooks can range from 400 to over 2000 per set. Floats are attached to the main line to support it and can be fitted with radar reflectors, radios or strobe lights to help in locating the gear. Chemical light sticks[2] are frequently attached to the lines or bait to act as lures and greatly increase the efficiency of catching swordfish. The use of light sticks has been a very important innovation in swordfish longlining.

Other technologies employed by longline boats to locate swordfish include temperature probes, global positioning system (GPS) navigation, automated track plotting, satellite weather imaging and electronic communication systems. Sea surface temperature (SST) satellite images, which can give information in real time over a wide area, are also used to find probable swordfish grounds (Ito *et al.* 1998).

Longlines inadvertently capture immature swordfish along with a wide variety of other bycatch species including tunas, sharks, marlins, sailfish, sea turtles and seabirds (especially albatrosses and petrels). Because of their poor selectivity, longline gear is increasingly viewed as "multi-species". Longline modifications to reduce the wasteful capture and killing of seabirds have been explored. These include acoustic scarers, (these have had

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[1] **Selectivity** is the "ability" of a type of fishing gear to catch a certain size or kind of fish.

[2] Two types of **light sticks** are employed: those that are break activated and those that are thaw activated. The sticks contain chemicals that emit a glowing green light that attracts the swordfish. The lights may also attract baitfish, which further enhances the ability to attract swordfish.

limited success) and offal lures to tempt birds away from lines. The most effective measures for seabirds are restricting setting hours to night time, as albatrosses are mainly diurnal and the use of tori poles (Japanese for bird), which have scarers attached to the lines, these move unpredictably in the vicinity of the setting area (Moore and Jennings 2000). In Hawaii the use of dyed bait, which is less visible to birds, is being investigated (WPRFMC 1998).

A further problem that has arisen is the interaction between longliners and killer whales. Both the orca and false killer whales have "learned" the operational procedures of fishers in La Reunion and Cape Town, so that pods of these large mammals follow longliners to "steal " the squid bait. This has become a major problem in some regions, where it harms both the fishery and the mammals, which are shot at or otherwise chased away.

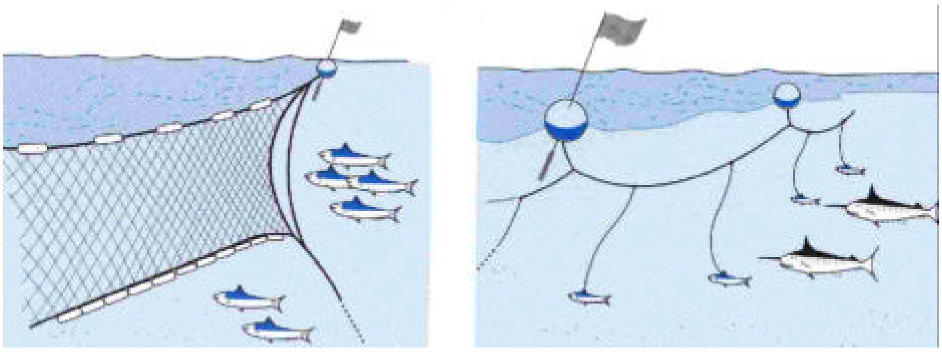


Figure 2. Pelagic fishing gear: (a) driftnets, and (b) longlines (after Moore and Jennings 2000).

Who fishes for swordfish?

Globally, sixty-six countries reported fishing commercially for swordfish in 1999. The total weight landed worldwide in 1999 was estimated at 97 110mt (FAO, 1999), although this amount is an underestimate as several countries with developing fisheries do not report their catches to the FAO (Ward and Elscot 2000). In terms of weight landed[3], the top six countries are Japan, Spain, Chinese Taiwan, Italy, USA and Chile with South Africa lying in 50th position. Between 1986 and 1997 these six countries, together, caught 77% of the world's swordfish catch in the following proportions: Japan (23%), Spain (19%), Chinese Taiwan (12%), Italy (10%), USA (8%) and Chile (5%). South Africa, in the same period, reported 0.004% of the world's swordfish landings (This was prior to the start of the experimental longline fishery and does not include catches taken by foreign vessels in South Africa's EEZ). The majority of catches are taken in the Atlantic Ocean and Mediterranean Sea, with 41% of the world's swordfish catch taken in these two areas in 1997 (Ward and Elscot 2000). In Table I the areas fished by various countries are given.

[3] **Landings** are the total number or weight of fish unloaded on shore and excludes fish that are discarded at sea. Landings are reported at the locality at which fish are brought to shore. Note that landings and catch define different things. **Catch** is the total number or weight of fish from a specified area over some period of time. This includes fish that are caught but released or discarded. The catch may take place in an area far away from where the fish are landed.

Table I. The main countries, the oceans where they catch swordfish and the area of the fishing zones covered by them.

Ocean	Area (million km^2)	Total catch in 1999 (mt)	Main countries targeting swordfish
Atlantic	87	25 000	Canada, USA, Spain, Portugal, Japan, Brazil, Chinese Taiwan
Mediterranean & Black Sea	3	15 000	Greece, Italy, Spain
Pacific	168.5	25 000	Japan, New Zealand, Chile, Ecuador, Chinese Taiwan, USA, Philippines
Indian	59.8	30 000	Chinese Taiwan, Sri Lanka, Japan

Global catch trends

Since 1965, world swordfish landings reported to the FAO (1997; 1999) have been increasing (Figure 3). The minimum landings, estimated to be 23 850mt, were taken in 1972, while the maximum were taken in 1996 (95 534mt). Sharp dips in world swordfish landings were recorded in the early 1970s and 1990s, although overall landings still appear to be increasing (Figure 3). The decline in the early 1970s can be attributed to the mercury contamination scare. In 1971 the United States Food and Drug administration, concerned about the level of mercury in swordfish, established a 0.5ppm tolerance level for mercury in swordfish. Most swordfish exceeded this level, which caused demand to decline and effort to be reduced. However, in 1978 the FDA revised its limits and from then on swordfish landings increased exponentially. Global landings of swordfish almost doubled between 1984 and 1997 as catches in the Pacific and Indian Ocean increased (Ward and Elscot 2000).

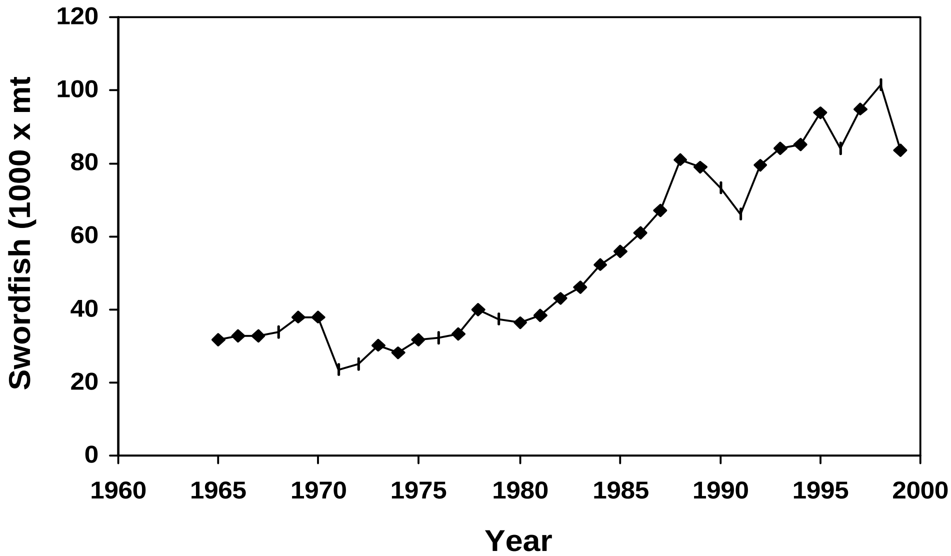


Figure 3. Global swordfish landings (FAO 1997, 1999).

The trend in landings of swordfish in the different oceans and seas of the world are given in Figure 4. Landings in the Pacific, Atlantic and Mediterranean increased significantly between 1984 and 1987. Landings in the Atlantic and Pacific peaked in the 1990’s and then started to decline, while landings in the Mediterranean peaked in 1989 and then declined. High levels of effort, low catch rates and almost complete dependence on one or two year-classes[4] of swordfish characterise the fishery in the Mediterranean (Bouchelle *et al.* 1991). Landings in the Indian Ocean were low throughout the 1970's and 1980's and then increased substantially in the 1990's.

Most swordfish fisheries are characterised by rapid initial expansion, followed by large declines in landings and this has prompted concern over the ability of swordfish to sustain intensive harvesting (IOTC 2001). Overall, global landings have increased because fishing zones have expanded and fishing effort is concentrated in the areas of the highest fish densities (IOTC 2001). If just the Atlantic Ocean landings are broken down into two fishing areas (i.e. the North and South Atlantic) an indication of shifting fishing effort emerges (Figure 5). Landings in the North Atlantic rapidly increased from the late 1970s, reaching a peak in 1990. Landings then declined as swordfish abundance decreased and ICCAT introduced quotas and size limits to reduce effort in the North Atlantic (see below). Commercial fishers responded by diverting effort into the South Atlantic to maintain their catch rates, and consequently landings in the South Atlantic increased in the 1990s, in a similar pattern to that observed in the North Atlantic in the 1970s (Scott 2001).

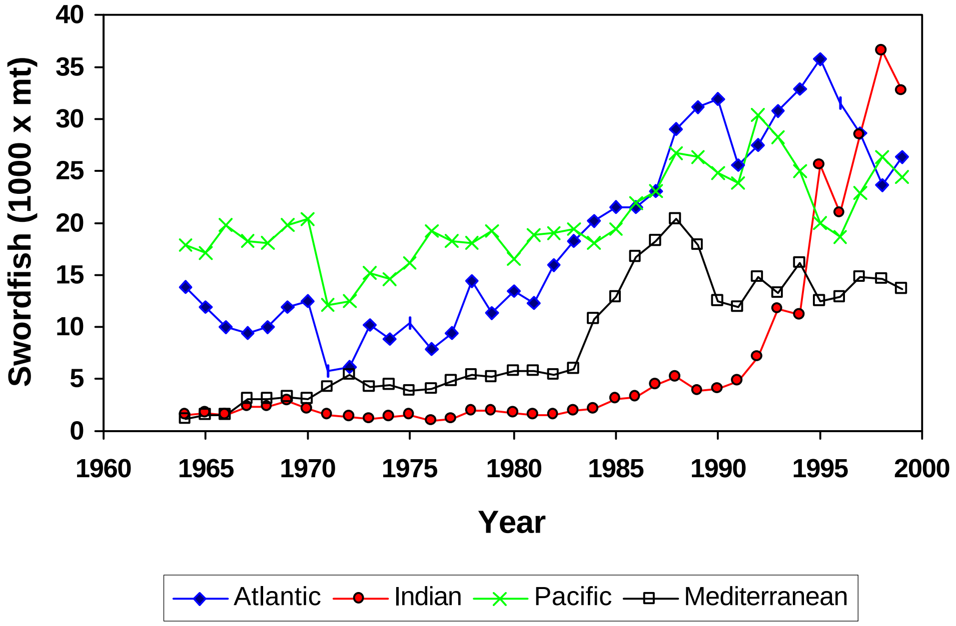


Figure 4. Swordfish landings in the world's oceans and seas (FAO 1997, 1999).

[4] A **year class** refers to a group of fish that are spawned and hatched in a given year and can be traced in the catch over several years.

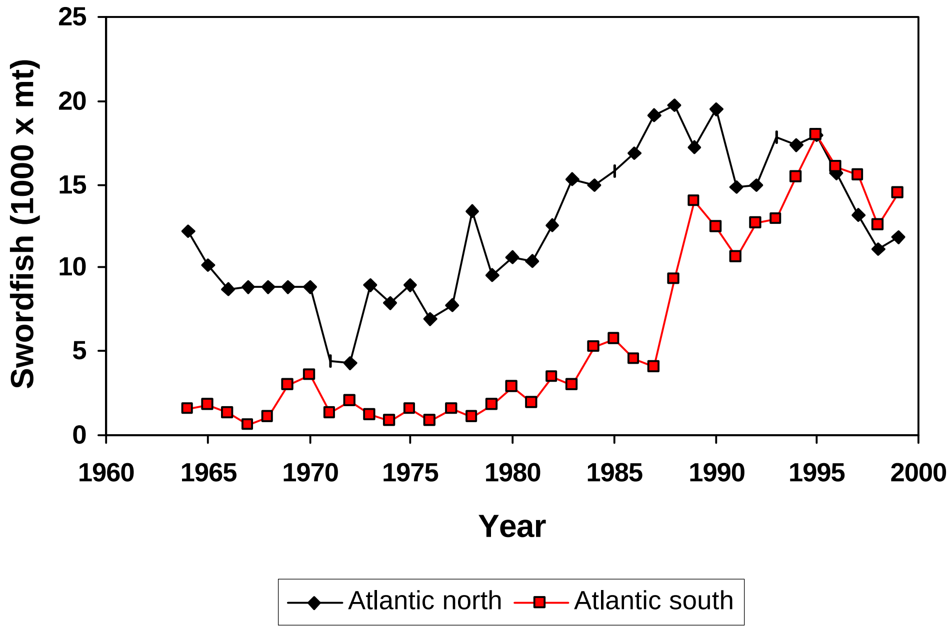


Figure 5. Atlantic swordfish landings (FAO 1997, 1999).

Markets

Swordfish is a much sought-after table fish and consumer demand is increasing. The U.S. is the world's largest market for swordfish and consequently, prices paid for swordfish in the U.S. provide a guide to world trends (Ward and Elscot 2000). U.S. caught Atlantic swordfish are marketed primarily for domestic consumption. The fish are usually sold in fresh form rather than frozen (i.e. kept on ice). In addition to the domestic landings, a large amount of swordfish caught in the Atlantic and elsewhere, by other fishing nations, enters the U.S. In the five-year period 1992-1996, the U.S. imported an average of 26 000mt of swordfish annually from 51 different countries, with imports from Brazil, Canada and Chile comprising 61% of these imports. Imports account for about 46% of the swordfish consumed in the U.S. and equate to about one third of the global landings of swordfish.

In response to the growing number of juvenile swordfish in catches, SeaWeb and the Natural Resources Defense Council started the "Give Swordfish a Break" campaign. The campaign calls on chefs in the U.S. not to prepare and serve swordfish as part of their menus until the government develops an effective recovery plan for the species (Buck 2000). Some 300 American chefs currently support the campaign. As a result of the campaign and combined with the increased supplies of swordfish from South America and the south-west Pacific, the U.S. price of swordfish fell from US$ 7.00/kg in 1996 to US$ 5.00/kg in 1999 (Ward and Elscot 2000).

Swordfish is also consumed in Europe, Japan and throughout most of the developed world, where it is purchased either fresh or frozen. In Japan, the average price of swordfish increased markedly during the 1970s. This was a result of technological improvements in on-board freezers, which increased the quality of fish meat used for sashimi. Blast freezers were capable of quick-freezing fish to below -55°C, which were then stored in the hold at below -40°C (Ueyanagi *et al.* 1989). Under these conditions, the price of swordfish destined for the sashimi market could command a higher price than usual. Prior to 1970, the price of swordfish was less than 300 yen/kg[5] but increased rapidly to around 700 yen/kg in the late

[5] At current currency exchange rates, 1 US $ = 125.8 yen.

1970s. The price peaked at around 900 yen/kg in 1984 and has since decreased gradually to 700 yen/kg in 1992 (Uozumi and Uosaki 1998).

In La Reunion, the marketing of swordfish was innovatively enhanced. Instead of using large vessels to catch maximum tonnage, much smaller vessels were developed that involved far fewer crew but placed emphasis on quality. Fish are rapidly processed and packaged at sea for maximum market value. In addition, a proportion of the swordfish catch is smoked and finely sliced to be sold as a delicacy, fetching high prices. This has allowed for smaller catches with high returns.

The situation in South Africa is somewhat unique. Technically, swordfish may not be sold on the domestic market because it is listed as a non-commercial recreational species. However, permits are granted to local and foreign fishers to catch swordfish for export. Consequently, there is virtually no swordfish consumption in South Africa and the fishery is thus driven by foreign demand and economic considerations.

4. INTERNATIONAL MANAGEMENT OF SWORDFISH

Swordfish management structures

Swordfish are a migratory species and found throughout the world's oceans. Consequently, over-exploitation in one region can lead to decreased harvests in other areas. Multi-national collaboration in management of the species is therefore imperative and several international management agencies have been established to co-ordinate research and management of swordfish and related migratory species. Each of these agencies has different regulatory measures, data monitoring capabilities and stock assessment approaches, which complicates the management of swordfish. Some swordfish harvesting countries refuse membership of these various commissions, which further complicates management. There are three major international organisations concerned with the study and management of tuna and tuna-like species (which includes swordfish). These are the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the recently established Indian Ocean Tuna Commission (IOTC), which replaced the Indo-Pacific Tuna Research and Development Program (IPTP).

The International Commission for the Conservation of Atlantic Tunas (ICCAT) has the mandate to manage swordfish and other large pelagic species in the Mediterranean and Atlantic Oceans round to Cape Agulhas (20° E). ICCAT was established in 1969 following the signing of the International Convention for the Conservation of Atlantic Tunas in Rio de Janeiro, Brazil in 1966. The objectives of the commission are to maintain the populations of tuna and tuna-like species at maximum sustainable levels. ICCAT currently has 29 contracting countries and South Africa has been one since 1969. Prior to 1990, ICCAT concentrated only on tuna, ignoring swordfish stock assessments and paying no attention to the management of the Atlantic or Mediterranean swordfish fisheries. In fact, up until 1983 the Atlantic swordfishery was essentially unmanaged and unregulated (Bouchelle *et al.* 1991). In 1983, permit requirements were instituted by ICCAT for the North Atlantic fishery. However, no restrictions were imposed on the number of permits issued or which country was eligible.

The Inter-American Tropical Tuna Commission (IATTC), which was established in 1949, studies and makes recommendations on the management of tuna and other fish caught by tuna vessels within the eastern tropical Pacific. The IATTC currently has 12 member nations (U.S., Costa Rica, Panama, Ecuador, Japan, France, Nicaragua, Vanuatu, Venezuela, Mexico, El Salvador and Guatemala) (IATTC 2001). There is no international commission currently set up to manage swordfish or other large pelagic fishes in the western and central Pacific. Nevertheless, in June 1997 a process began with the aim of developing a regime to manage highly migratory fish stocks, mainly tuna in the western and central Pacific. This Multilateral High-Level Conference on Fisheries (MHLC) brought together all the Pacific Island states and territories, Australia, New Zealand, France and other nations who operate in the region (U.S., Japan, Korea, Taiwan, China and the Philippines). Indonesia joined the process in 1998.

The Indian Ocean Tuna Commission (IOTC) was created to contribute to the management of tuna and other migratory fish species in the Indian Ocean, east of Cape Agulhas. The IOTC was formed in 1997, replacing the research-oriented IPTP, into a fisheries management commission. Members of the IOTC include Australia, China, European Community, Eritrea, France, India, Japan, Republic of Korea, Madagascar, Mauritius, Malaysia, Oman, Pakistan, Seychelles, Sudan, Sri Lanka, Thailand and the United Kingdom. South Africa is not a member of the IOTC, although it has observer status and was present at its foundation. To date most of the attention has been devoted to tuna, especially focussed on the sizeable operations centred at Mahe, Seychelles. With the exception of some French studies, virtually no swordfish stock assessments have been undertaken. The

IOTC is therefore currently in no position to make recommendations on the harvesting of swordfish in the Indian Ocean. In fact, countries fishing for swordfish in international waters of the Indian Ocean do so without restriction (Penney 1998).

Management of the Mediterranean swordfishery

The Mediterranean Sea is a highly productive system that has produced catches comparable to the North Atlantic, despite it being a smaller area. Landings in the Mediterranean peaked in 1988 at 20 339mt, and then declined rapidly so that in the 1990s landings fluctuated between 11 987mt and 16 078mt per year (FAO 1997; 1999). The average size of swordfish captured in the Mediterranean has decreased from approximately 48kg in the 1980s (during peak catches) to 10kg in 1997 (IOTC 2001). Over 50% of the catch is now comprised of juveniles that have never spawned and it is generally agreed that stocks in the Mediterranean are over-exploited (Ward and Elscot 2000). Remarkably, nations that edge on the Mediterranean Sea manage their swordfisheries independently. The General Fisheries Council of the Mediterranean and the ICCAT Working Group on Stocks of Large Pelagic Fishes in the Mediterranean Sea, the so-called “GFCM-ICCAT Working Group” do make management recommendations and promote data exchange between nations, but they do not enforce regulations.

European Union fishers adopt recommendations agreed to by the European Council. These include a minimum size limit for swordfish of 120cm and a maximum length limit for pelagic driftnets of 2.5km and these are required to remain fixed to the boat at all times (GFCM-ICCAT 1998). Non-European Union members like ***Turkey*** and ***Croatia*** also observe this minimum size limit. Turkey has also implemented a closed fishing season between July and September.

Italy has imposed a minimum size regulation that specifies that <10% of the swordfish catch can be smaller than 140cm (ICCAT 1993). However, It is unclear how this regulation is enforced (Ward and Elscot 2000). Driftnets are also limited to 2.5km in length and, since 1988, Italy has been reducing its driftnet fleet. To protect cetaceans Italy has banned the use of driftnets in the Ligurian Sea, situated just north of the island of Corsica.

Morocco limits fishing effort on swordfish by a combination of limiting entry to the fishery, time and area closures, size limits and gear restrictions. The minimum size limit is set at 125cm and driftnets are restricted to 2.5km in length with mesh sizes greater than 40cm. Only boats with capacities exceeding 15hp may use driftnets and in the case of longliners only one longline may be carried per boat.

To protect juvenile swordfish (<1 year), ***Greece*** has banned fishing between the months of October-January each year. The ban is ineffective as other nations can still target juveniles by fishing close to Greece’s territorial waters. Also, when the Greek swordfishery opens in February the fishery still catches juvenile swordfish indicating that the fishery is being opened too early. Further, fishers who land swordfish during the closed season can still retain them because they can claim the catch as a bycatch.

Spain*,** besides following the European Union's 120cm size limit, restricts its longliners to 2 000 hooks per set. ***Cyprus closes its swordfishery from October to February and limits the number of boats to 60 per year. Since 1985, ***Japan*,** has limited its fleet in the Mediterranean, to a maximum of 35 longliners and disallows fishing by longliners larger than 24m between June and July (Takeuchi 1996; Ward and Elscot 2000).

Summary

The enforcement of minimum size limits in the Mediterranean appears to have been ineffective, as a high proportion of the catch is comprised of juveniles. In addition, the mortality rates for swordfish released after capture by longlines is high. Unilateral approaches to management, as is the case in the Mediterranean, lead to poor monitoring and management of the stock (Ward and Elscot 2000). In response to declining catch rates and the high proportion of juveniles in the catch GFCM-ICCAT proposed that quotas be set to maintain or reduce current catch levels, that closed seasons or closed areas be implemented to protect juvenile swordfish and that improvements be made in gear selectivity (Ward and Elscot 2000). If all the countries fishing in the Mediterranean Sea adopted these measures, they would hopefully be effective in reducing effort in this fishery and decreasing the catch of juveniles.

Management of the North Atlantic swordfishery

Several nations fish for swordfish in the North Atlantic, with the largest landings being taken by Spain, the U.S., Canada, Portugal and Japan. Landings peaked in 1988 at 20 339mt and then declined in the 1990s (FAO 1997; 1999). Declines occurred as new regulations were introduced, the abundance of swordfish decreased and fleets shifted to other areas (such as the South Atlantic) and changed their operating procedures to opportunistically target other species, such as tuna and sharks (ICCAT 2000). ICCAT coordinates the assessment and management of Atlantic swordfish and sets regulations such as TACs, which are divided into country-specific quotas, minimum sizes, closed seasons and bycatch and mortality limits. Each regulation is legally binding and effective upon each contracting party within six months of ICCAT meetings (Raymakers and Lynham 1999). The onus is on the individual parties or states to implement ICCAT's recommendations within their own domestic management regimes.

Scientific advice is given to ICCAT by the Standing Committee on Research and Statistics (SCRS), which is made up of scientists from different countries. (Raymakers and Lynham 1999). While the scientific advice given to ICCAT is sound, politically appointed commissioners, many of whom have close ties with the swordfish industry, set the quotas[6]. Recently (1997) SCRS scientists recommended to ICCAT that to stop the declining trend in the North Atlantic swordfish landings and to rebuild the stock to a more productive level over a 10-year period, the total catch should not exceed 10 000mt per year. Commissioners set the 1997 catch at 11 300mt and opted for a catch-phasing-down strategy for the next couple of years (Table II). The committee expressed concern in 1999 when 11 914mt of swordfish were caught, which is 11% above the TAC (ICCAT 2000). However, swordfish show a high degree of resilience and although landings were still above the TAC, the stock responded positively to the decreased catch rate. Despite the depressed state of this North Atlantic stock, high recruitment was observed in the age 1 year class in 1997, 1998 and 1999 (ICCAT 2000).

[6] A **quota** refers to the maximum number or weight of fish that can be legally caught and landed in a given time period for a particular country or area.

In the **U.S.**, the National Marine Fisheries Service (NMFS) has authority for the management of swordfish within the Exclusive Economic Zone (EEZ) of the USA[7]. Within this zone it can, for example, ban swordfish longlining or declare closed fishing areas where young swordfish congregate (nursery areas) or institute any other management measures. However, the NMFS cannot increase or decrease the U.S. swordfish quota recommended by ICCAT. The reason for this goes back to 1990 when lobbyists for the longlining industry got the U.S. Congress to link the U.S. quota to the recommendations of the 23-nation tuna commission, ICCAT. This places enormous obstacles to the efforts of U.S. fisheries managers to unilaterally limit U.S. swordfish catches (Safina 1998).

Table II. A brief history of ICCAT recommendations for the North Atlantic swordfishery (Bouchell *et al.* 1991, Ward and Elscot, 2000)

Year	Recommended Regulations	Comments
1983	Permit required to fish swordfish in the North Atlantic	No restriction on the number issued or who qualified.
1991	Reduction in fishing mortality by 15% on fish larger than 25kg. Recommended minimum size = 25kg (125cm LJFL) with 15% of catch allowed to be undersized.	In 1990 most fish were in the 13-24kg size class. After the minimum size introduction the most frequently landed size class was 25-36kg.
1996	Recommended that the 1997 total allowable catch (TAC) be reduced to 11 300mt, the 1998 catch to 11 000mt and the 1999 catch to 10 900mt. The minimum size was amended to 119cm with no tolerance or 125cm with 15% tolerance.	In 1998, reported landings (11 690tmt) exceeded TAC by 6% and if discards are added to the landings (12 175mt) it exceeded the TAC by 11%.
1997	Compliance committee of ICCAT introduced penalties for member and non-member nations that do not concur with ICCAT recommendations	
1999	Recommended that the 2000 total allowable catch (TAC) be reduced to 10 600mt, the 2001 catch to 10 500mt and the 2002 catch to 10 400mt.	

Summary

As with the Mediterranean fishery, the effectiveness of minimum size limits in the North Atlantic is doubtful, as there has been an apparent increase in the discard of undersized swordfish and longliners have not moved away from areas where small swordfish are abundant (Ward and Elscot 2000). The implementation of stricter quotas in 1997 appears to have had some success as catch rates in the North Atlantic showed signs of improving in 1999. In 1999 The NMFS made Vessel Monitoring Systems (VMS) mandatory for U.S. boats operating in the North Atlantic. These systems aid in the enforcement of time and area closures, which may afford greater protection to juvenile swordfish (Buck 2000).

Management of the Indian Ocean swordfishery

Catches of swordfish in the Indian Ocean have been increasing steadily since the early 1990s. Japanese, Taiwanese and Korean longliners have been taking swordfish as a bycatch throughout the Indian Ocean for many years. However, Taiwanese boats started to target swordfish in the early 1990s and it is estimated that the Taiwanese fleet catches more than 50% of the swordfish landed in the Indian Ocean (IOTC 2001). Also involved in the fishery are French fleets, which have been operating off Reunion since 1991, Spanish fleets (operating since 1993), Seychelles fleets operating since 1995 and Australian fleets,

[7] The **exclusive economic zone** or **EEZ** is all waters out to 200 nautical miles from the shore of a coastal state.

targeting swordfish since 1997. South Africa started an experimental longline fishery in 1997, which operates in the southern Indian and Atlantic Oceans.

Nations fishing for swordfish in the Indian Ocean manage their swordfisheries independently, although the recently developed IOTC promotes data exchange between nations, and will soon make management recommendations for this area. The French longlining fleet based at Reunion is monitored by IFREMER through a logbook monitoring system and regular at-sea sampling. Logbooks provide information on daily fishing effort, catches by species, discards and vessel operations (F. Rene *pers.com.*). The Australian longline fishery is also monitored through a logbook system and an observer programme will be initiated in 2002 (IOTC 2001). Although some fisheries in the Indian Ocean are monitored there are very few restrictions placed on catch and effort.

Localised depletion of swordfish has been observed in several Indian Ocean swordfish fisheries, including South Africa, with quick declines in CPUE recorded after a few years of high catch rates. This has been attributed to the limited movement of some fractions of stocks (IOTC 2001). Two of the recent swordfish fisheries in the Indian Ocean will be discussed briefly, as they illustrate the trends observed in the development of many swordfish fisheries world-wide.

The Reunion Fishery

The French longline fleet, based on Reunion Island has been fishing for swordfish in the south-western Indian Ocean since 1991. Since the inception of the fishery the number of vessels and fishery effort (number of hooks) has been increasing steadily. The longline catch of swordfish increased from 278mt in 1991 to 2 076mt in 1998. It has since declined to 1 741mt in 2000. The monthly swordfish CPUE decreased between 1994 and 1996 and then stabilised. Swordfish comprise an average of 66% of the total longline landings. There has also been an expansion of the fishing grounds as the fishery developed (Poisson and Taquet 2001).

The Australian Fishery

Effort in the Australian longline fishery operating in the south-eastern Indian Ocean has increased considerably in recent years from 10 vessels catching an average of 10mt of swordfish in 1997 to 39 vessels catching an average of 1 500mt of swordfish in 1999. The fishery began in inshore waters (within Australia’s EEZ) using American style monofilament gear and light sticks. However, rapid expansion of the fishery in the 1990’s lead to localised depletion of swordfish stocks and vessels started operating offshore, outside Australia’s EEZ on the high seas. According to Gunn (Dr. J. Gunn, unpubl. data) there has been a decrease in catch rates in each area fished for more than two years.

Summary

Most swordfish fisheries in the Indian Ocean are fairly recent and are characterised by localised depletions of swordfish stocks followed by expansion of the fishing grounds. Analysis of catch and effort data by the IOTC has shown significant declines in CPUE of swordfish for the Japanese fleet in areas of the south-western Indian Ocean where swordfish are primarily targeted by the Taiwanese fleet. Catch and effort data submitted to the IOTC by Taiwan are questionable. There is also evidence of significant declines in CPUE for swordfish by the Reunion fleet after 1996 (IOTC 2001). In the light of declining catch rates for the Japanese fleet in the south-western Indian Ocean and localised depletions of stocks the IOTC recently recommended that the status of swordfish stocks in the Indian Ocean should be closely monitored. In addition it recommended that further increases in catch and effort should not be allowed (IOTC 2001).

5. THE HAWAIIAN LONGLINE FISHERY: A CASE STUDY FROM THE PACIFIC

There are numerous descriptions of various swordfisheries around the world but many are not of direct relevance to South Africa. Some swordfisheries are very old, e.g. Japan, while others are largely artisanal, e.g. Chile. While there are lessons to be learnt from these fisheries, South Africa's swordfishery is a more recent one and is likely to be a longline fishery with strong commercial interests. Moreover, it is likely that the fish will be mainly exported instead of being used for local consumption. The Hawaiian swordfishery is a recent one and as it shares several characteristics with the South African fishery, it will be discussed in more detail as a case study.

Longlining for swordfish in Hawaii is a relatively recent phenomenon. In 1988, and using fishing techniques based on the Florida longline fishery, a single vessel began experimentally targeting swordfish (Ito *et al.* 1998). By the following year, other tuna and lobster boats were also attempting to catch swordfish using longlines. Good catches were recorded and this increased national interest in the fishery. The national interest, coupled with the decline in Atlantic swordfish landings (low catch rates and small average sizes recorded in the late 1980s) influenced many Atlantic swordfishers to relocate to Hawaii, with prospects of better catches (Berkeley 1989). The characteristics of the Hawaiian longline boats and their gear are summarised in Table III.

Fishing effort

Between the years 1989 to 1993 the number of Hawaiian-based longliners targeting swordfish increased more than ten-fold, from one in 1989 to 98 in 1991 after which it decreased to 30 vessels in 1998 (Ward and Elscot 2000). The number of swordfish directed longline trips declined correspondingly from a high of 319 trips/year in 1993 to 84 trips/year in 1998 (WPRFMC 1998).

A typical fishing procedure and time schedule in the Hawaii longline fishery is outlined in Table IV. Swordfish longline gear is set in the late afternoon or evening. The gear is usually soaked for 6 to 10 hrs and retrieval of the gear begins early in the morning. Fishing trips can last for up to 30 days.

Table III. Characteristics of the Hawaiian longline boats (Ito *et al.* 1998) and the gear used (Dollar 1991).

Boats	**Hull type**	**Mean age**	**Mean length**
	Steel	11 years	23m
	Fibreglass	12 years	19m
Gear	Lines	Monofilament stored on hydraulic reels	
	Main line length	30-80 km	
	Distance between floats	90-160 m	
	Branch line length	13 m	
	Hooks	8/0 to 10/0	
	Hooks per set	Range 450-1800, Mean 724	
	Light-sticks	Thaw-or break-activated	
	Bait	Squid	

Table IV. A typical operating schedule of a Hawaii longline vessel fishing for swordfish (Ito *et al.* 1998).

Time	Activity
16h30-17h30	Preparation of longline gear for setting.
17h30-19h30	Start setting gear. The start time can vary daily.
21h30-23h30	End set and clean up. It takes about 4 hours to set the gear.
23h30-0500	Soak gear overnight and crew sleep.
05h00-06h00	Search for gear using light or radio buoy as a beacon.
06h00-14h30	Haul gear, process and store fish. It takes about 8 hours to haul gear. But it is dependent on amount of gear set, number of fish caught, tangles and breakage in main line and weather conditions.

Landings and catch rates

The Hawaiian-based longline swordfishery grew rapidly from its inception in 1989. Rapid growth in new fisheries is not unusual. It is sometimes coupled with overcapitalisation because the developing fishery attracts many new entrants. However, some fishers then leave the fishery for various reasons and the fishery then tends to reach some bio-economic equilibrium. This has been the case for the Hawaiian swordfishery. Estimated catches of swordfish for longliners operating in Hawaiian waters (Figure 6) increased dramatically from 22mt in 1987 to 5 941mt in 1993 (WPRFMC 1998). By 1990, swordfish was the dominant species caught by the Hawaiian longline industry. These increases were attributed to greater knowledge acquired by fishers, expansion of the fishing area and modification of fishing techniques (Ito *et al.* 1998). However, by 1996 catches had declined to 2 503mt and for the rest of the 1990s remained under 3 300mt (WPRFMC 1998). By 1994 many of the Gulf boats that had entered the fishery returned to the Gulf of Mexico, while other longliners had switched back to targeting tuna, as market prices for swordfish dropped (Ward and Elscot 2000).

Catch rates for swordfish (on swordfish trips) expressed as the number of fish caught per 1 000 hooks declined from 15.4 in 1991 to 10.3 in 1993, catch rates then increased again to 14.5 in 1998 (WPRFMC 1998). Between this same period, catch rates (and landings) within Hawaii's EEZ were lower than that outside the zone. It is possible that this is a result of seasonal movement of swordfish out of Hawaii's EEZ. However, this meant that to sustain high catch rates boats had to travel greater distances to fishing grounds outside the EEZ.

In 1991 and 1992, swordfish (by number) comprised 22% of longline catches in Hawaii. However, by 2000 swordfish comprised only 9% of the catch. The drop in swordfish catches has in part be attributed to fishers switching targets from swordfish to tuna and shark, in response to lower swordfish prices (WPRFMC 1998). By 2000 tuna comprised 41% of the total longline catch by number, as opposed to 24% in 1991 (NMFS 2001a).

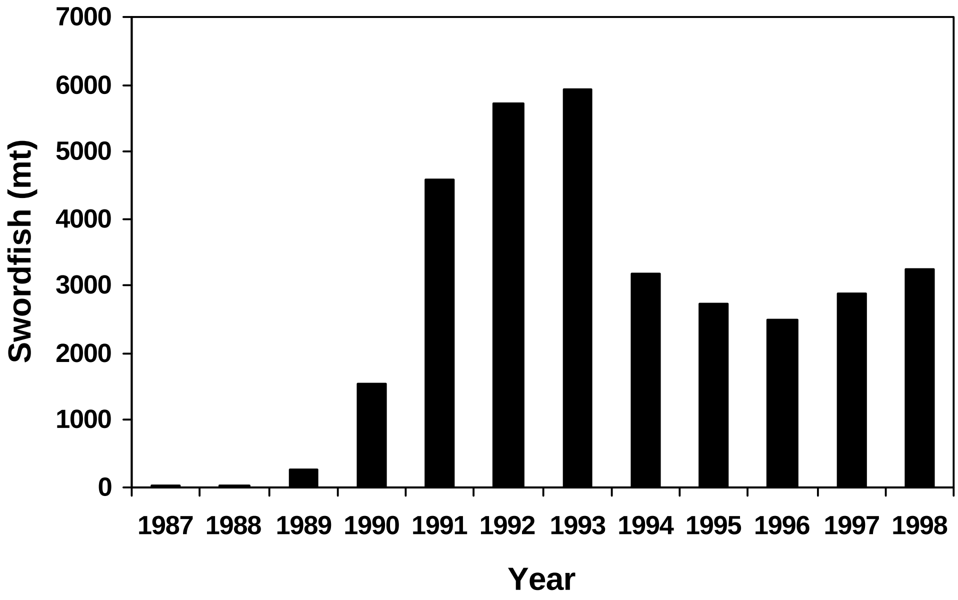


Figure 6. Swordfish catches by Hawaii-based longline vessels fishing for swordfish between 1987 and 1998 (WPRFMC 1998).

Between 1989 and 1993 the mean whole weight of swordfish caught increased from 58.5kg in 1987 to 80.7kg in 1992. In subsequent years it has fluctuated between 71 and 80kg (WPRFMC 1998). However, increases in mean size should be interpreted with care, as they do not include unknown discards of small swordfish.

Markets

The domestic demand for swordfish is low in Hawaii, as local consumers are not familiar with the product. Most Hawaiian swordfish is exported to the U.S. mainland cities of Boston, New York, Los Angeles and San Francisco (Ito *et al.* 1998). The fish is sold by open auction or brokered by Hawaiian seafood dealers. The swordfish are chilled using gel ice packs placed in the gut cavity, individually wrapped in plastic, packed in insulated containers and exported via airfreight.

The revenue from longline-caught swordfish in Hawaii is given in Figure 7. The revenue generated by swordfish caught in Hawaiian waters has been substantial, from US$ 980 000 in 1989 to US$ 26.5 million in 1993. The exponential growth in the early stages of this fishery illustrates the demand and lucrative market that swordfish commands internationally. However, from 1994 the revenue generated by swordfish declined, as market prices dropped.

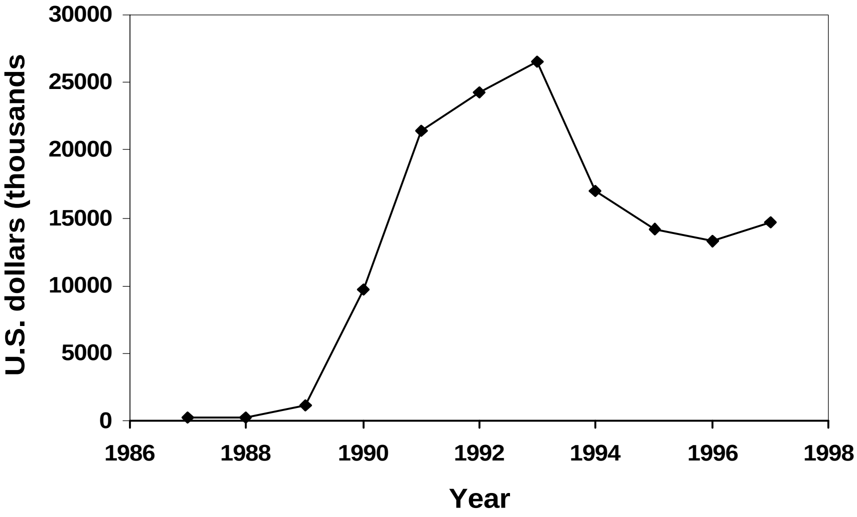


Figure 7. Revenue from longline-caught swordfish in Hawaii (Skillman 1998; NMFS 2001b).

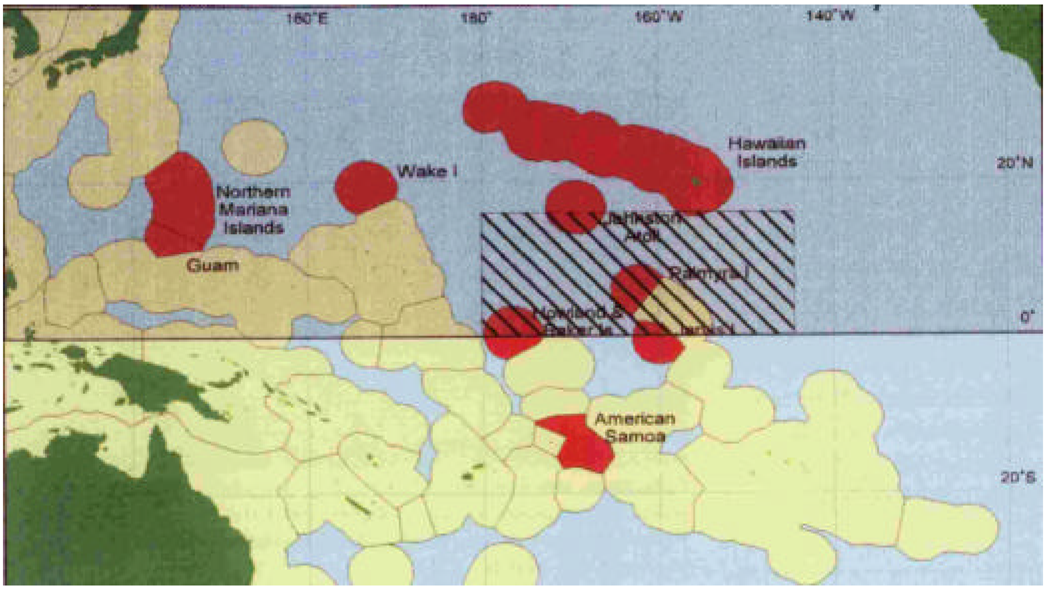
Management

The Western Pacific Fishery Management Council, after consultation with the U.S. National Marine Fisheries Service, sets management policies for all Hawaiian fisheries (Ward and Elscot 2000). An overview of the regulations set by WPFMC is given in Table V.

Table V. Management regulations set by the WPFMC (after Ward and Elscot 2000).

Year	Recommended Regulations	Comments
1990	Permit required for all longliners in Hawaiian waters	Includes information on boat dimensions and characteristics
1991	Longlining is prohibited from within 50nm of the North western Hawaiian Islands	This measure is to reduce the number of interactions with the endangered Hawaiian monk seal
1991	The total number of longliners is limited to 166	Applies to all longliners
1994	Unlimited transfer of permits is allowed	
1996	112 longliners are equipped with satellite based Vessel Monitoring Systems as part of a pilot project	VMS systems are a major deterrent to fishing in closed areas

Of growing concern is the bycatch of seabirds and turtles in this fishery, the local Hawaiin longline fishery is responsible for approximately 3400 Albatross deaths per year (WPRFMC 1998). Between 15 March and 30 March 2001, a U.S. district judge closed the entire Hawaii longline fishery pending the results of an environmental impact statement (EIS) on the effects of longline operations on sea turtles (prepared by NMFS). After reviewing the EIS the court banned Hawaiian longliners from targeting swordfish in the entire North Pacific, from the equator to the Pole (Figure 8) (WPRFMC 2001). As most of this area is outside the U.S. EEZ fishermen from other countries are allowed to fish in this area (Buck 2000).



No fishing area (entire North Pacific Ocean) year-round for U.S. Pacific Island vessels only.
No fishing area (1.9 million square miles) April and May for U.S. Pacific Island vessels only.

Figure 8. Hawaiian no fishing areas (after WPRFMC 2001).

Summary

The Hawaiian swordfishery, which is an effort limited fishery, is considered by some as a stable fishery because the landings, catch rates, revenue generated and the average size of harvested swordfish have not declined significantly. Low catch rates for swordfish can at times be attributed to social and economic causes, rather than decreases in swordfish abundance (Ward and Elscot 2000). However, a stock assessment needs to be undertaken for this fishery.

6. GLOBAL FISHERIES: LESSONS LEARNT

Swordfish are a global resource that straddle national and international waters. As global marine resources reach their maximal limits, so the world's fishing fleets pursue potentially "new" species and operate in more distant seas. Swordfish are implicated in these global trends, a fact clearly demonstrated in the post-1980 growth in global landings (see fig 3). The international nature of this species, coupled to its high value and export driven market demands, present complex challenges for sustainable development and management of swordfish. The response to these challenges has been remarkably different for different countries and generally lacks a cohesive regional approach. Swordfish are managed by a variety of different approaches, including catch quotas, limiting entry into the fishery, minimum size limits, closed areas and closed seasons. The lesson here is that no single management strategy appears to be effective in managing this resource and that a combination of input and output controls, as part of a larger operational management procedure (OMP) is desirable.

With wide-ranging pelagic species such as swordfish, co-ordinated monitoring and management is crucial to their sustainable development. In the Mediterranean Sea several nations fish for the same stock but there is a lack of co-ordinated management and enforcement, and as a result catch rates have declined sharply. In contrast, the North Atlantic swordfish are subjected to the more co-ordinated ICCAT management regime. Yet here too the swordfish resource is regarded as over-exploited, largely because effective management was delayed so that fishing capacity increased when catch trends were already negative. Fortunately, there is now some evidence that reduced effort and tighter quotas are assisting the rebuilding of swordfish stocks, even though the TAC is still frequently exceeded. The lesson here is to ensure that regional management structures are in place and, especially, that they are effective in setting and adhering to both input and output controls.

While landings of swordfish declined in many parts of the world, so catches in the Indian Ocean have been increasing steadily since the 1990s. This should have been the catalyst to developing a regional management structure. But, despite the concerted efforts by those promoting the IOTC, lack of resources, and especially political will, has hampered its development. Indeed, South Africa should have been a much keener participant from the beginning. As is the case of the Mediterranean, there remains a lack of co-ordinated management and further expansion of effort needs to be managed. The advent of NEPAD and SWIOFP may provide impetus to this.

The high proportion of juvenile swordfish taken in global catches is a cause for concern. While it may suggest that there remains a high level of recruitment because of high species' fecundity, it also points to potential growth over-fishing, which compromises total landings. The enforcement of minimum size limits appears to be ineffective because small specimens are simply discarded at sea. In any event, it is doubtful if many of these specimens would survive after being captured. Clearly, minimum size regulations will only be effective in the context of strict compliance arrangements, probably with on-board observers, which could result in juvenile nursery areas being avoided in fishing operations. In addition, gear modifications and time and area closures, in conjunction with Vessel Monitoring Systems to ensure compliance, would also be a more effective means of reducing the catch of juveniles (ICCAT 1999).

The fact that swordfish are frequently caught in association with other species, especially tuna, complicates management. The setting of realistic quotas in such a multi-species fishery without the use of reliable models has proven most difficult. In the absence of such an approach it is necessary to minimise the level of swordfish taken in non-directed fisheries.

In many cases of longlining, target switching has been reported, often in response to changes in pricing or market conditions. It has been shown that such multi-species fisheries can mask the true status of one or other species, and this needs to be considered in the interpretation of South African data.

Bycatch is a problem in global longline fisheries, for example the Pacific longline fishery, where endangered species such as the Hawaiian monk seal, birds and turtles are taken. This problem was addressed in Hawaii through closed areas and the use of dyed bait. The interaction with large marine mammals, such as false killer whales, adds a further complication to management of this fishery. This matter is of growing concern, including in the SW Indian Ocean. On the one hand it may pose a threat to potentially vulnerable cetaceans, but it also impacts on the viability and hence livelihoods of the fishery. Here too by-catch reduction techniques need to be developed. Clearly these are valuable lessons that should be adopted locally.

Notwithstanding the valuable information and lessons learnt from the global swordfishery experience, it is clear that fishery and biological information from local stocks still needs to be collected. The genetic separation of stocks, possible components of residency, reproductive behaviour and migration patterns need to be understood. This places considerable responsibility on the various management agencies.

7. THE SOUTH AFRICAN SWORDFISHERY

South Africa has been slow to initiate a swordfish industry in relation to other regions of the world, despite knowledge that the species did exist in local waters. In part this was attributable to the protective legislation in place, but also because local demand for this product had not developed. However, since 1990 swordfish have been caught in growing numbers in several fisheries, including the experimental pelagic longline fishery, by foreign (legal and illegal) longliners and by hook and line in the sport fishery.

Experimental longline fishery

Development of the fishery

Swordfish directed longlining (by South African vessels) is relatively recent in South Africa. Prior to 1997 swordfish formed a bycatch in longline fisheries for tuna and trawl fisheries for hake and shark. In 1990 all South African longlining was prohibited (although foreign longliners still operated in South African waters). This was in response to the increased amount of hake being caught by longliners holding T-permits (tuna permits). This move was strongly opposed by the existing shark and tuna longliners. An experimental joint venture longline permit was issued in 1995, and high catches of tuna and swordfish were recorded, creating interest in the capture of swordfish. In response to industry motivations an experimental longline fishery was started in 1997, with 30 permits issued. Twenty permits were issued to existing tuna fishers and the rest to previously disadvantaged groups. A total of 23 permits were activated in 1998, while 26 permits were issued in 2002. Practically, only between 10 and 26 vessels were actually active, depending on vessel and fish availability. This fishery remains as an experimental fishery, although long-term rights are likely to be issued. A draft policy document for longlining was circulated early in 2003.

The fishery primarily targets large tunas (bigeye *Thunnus obesus* and yellowfin *Thunnus albacares*) that are exported to Japan for the Sashimi market and swordfish, which are iced and exported fresh to the United States. The FOB selling price of high quality tuna and swordfish is in excess of R60 per kg. Around 2001 vessels reported fishing for an average of 155 days per year and catch an average total catch of 100mt per vessel per year (tuna and swordfish) (Penney 2002). Based on U.S. import data, the South African experimental longline fishery was estimated then to take an annual swordfish catch of just over 1 000mt (dressed weight) (M. Griffiths, unpubl. data). The recent introduction of vessels with super freezers operating in international waters of the Indian Ocean is expected to increase effort in this fishery. The characteristics of the South African longline boats and gear are summarised in Table VI.

Table VI. Characteristics of the South African longline boats and the gear used (after Penney 2002).

Boats	**Hull type**	**Mean Age (yrs)**	**Length range (m)**
	Steel	27	30-54
Gear	Lines	American monofilament fishing gear	
	Main line length	35nm-40nm	
	Buoy line length	20m	
	Trace line length	20m	
	Hooks per set	750-1500	
	Light sticks	Break activated	
	Bait	Squid	

The rational development of this fishery has not been easy because in 1997, when the first permits were issued, South Africa was not eligible for a country allocation of swordfish in the South Atlantic. ICCAT quotas are allocated on the basis of past performance and in 1997 ICCAT recommended that South Africa and several other contracting parties should share a quota allocation of 804.1mt for the South Atlantic. Ninety percent of the total allocated quota for the South Atlantic (14 620mt) is held by Spain, Japan, Brazil and Taiwan.

Since 1998 South Africa and other coastal states of the region have been motivating for a quota of at least 1 000mt in the South Atlantic. As yet there has been no legal agreement, but ICCAT has recognised that South Africa has a right to a swordfish quota and it appears that South Africa will receive a quota of 1 000mt. Because there has been no legal agreement on quotas, countries sharing the 804.1mt quota have been required to declare 'voluntary' catch limits. South Africa declared a 1 500mt swordfish quota for 2001 and 2002, this includes catches taken in the Indian Ocean. The IOTC has not set a TAC for the Indian Ocean, but this will probably take place in the next few years (Penney 2002).

Distribution of the fishery

In the initial stages of the fishery (1997 to 1998) the majority of vessels were fishing off an area ranging from East London to the southeast coast of Namibia (Figure 9). Increasingly, vessels have started fishing further north, west and east of this area, and longline fishing effort is now occurring in three broad regions: along the shelf of the Agulhas Bank and west coast (region 1), the east coast (region 2) and further offshore along the Walvis Bay Ridge in the eastern Atlantic (region 3) (M. Griffiths, unpubl. data). In February 2002, up to three vessels initiated swordfish longlining off Durban with initial catch rates and individual fish sizes being high. Since then the fleet has shifted its operations substantially. While the original three vessels were still operating out of Durban in mid 2003, up to 18 boats have at times been using this port. In addition, 4-5 boats have also been using Richards Bay as a base.

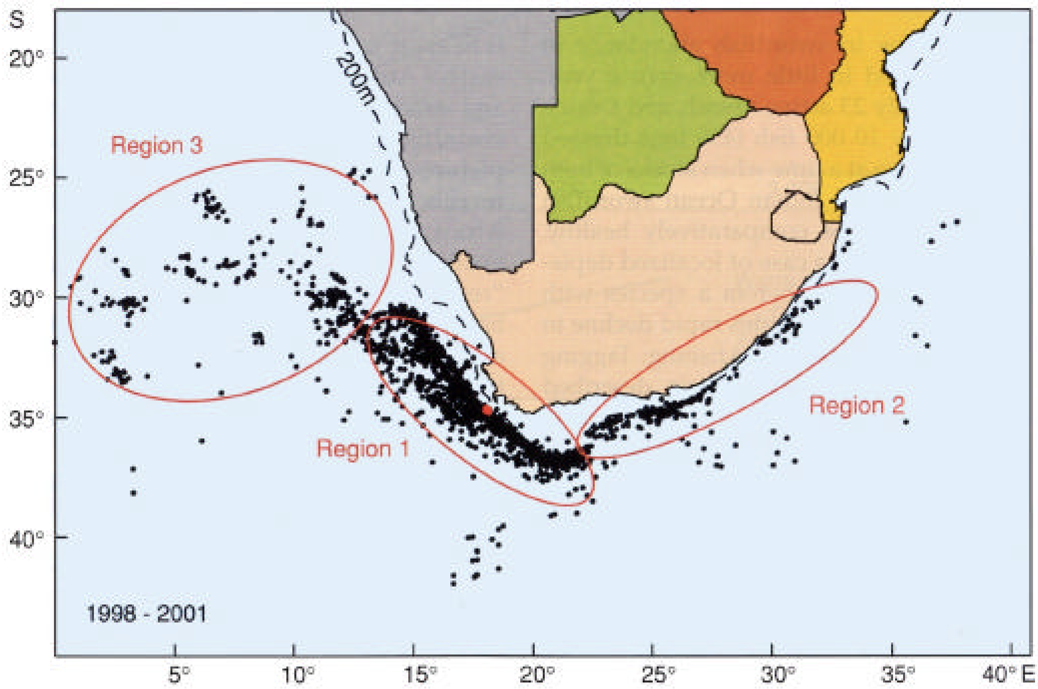


Figure 9. Distribution of longline fishing effort from 1998 to 2001 in three regions. (after Griffiths 2002)

Catch composition

At the inception of this experimental fishery (between 1997 and 1999) swordfish was the most abundant species caught, comprising 70% of the landed catch (Kroese 1999). The catch composition has since changed. As fleets move into temperate and offshore waters, more temperate tuna are caught, such that swordfish now comprise 21% of the catch (Bremer 2001; Penney 2002). The species composition of observed catches between July 1998 and July 2001 (based on 30 observer trips) is shown in Figure 10.

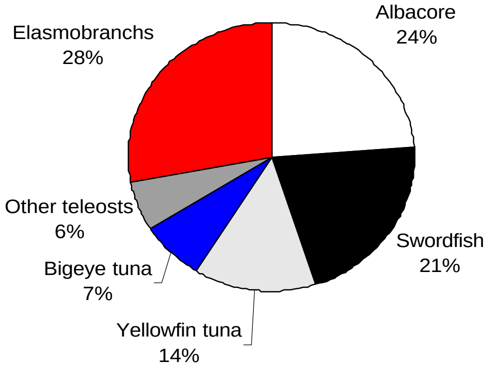


Figure 10. Species composition of observed catches by South African experimental longlines between July 1998 and July 2001 (after Penney 2002).

Size composition

Swordfish caught in the South African longline fishery are quite large when compared with those caught in the North Atlantic and other areas of the South Atlantic. Based on 30 observer trips swordfish caught ranged in size from 170 to 190cm LJFL, with a mean size of 182cm LJFL. There is very little difference in size between swordfish caught in the Atlantic Ocean (W of 20°E) and the Indian Ocean (E of 20°E) (Penney 2002). There is as yet no information published on trends in the size distribution of South African caught swordfish, although such data is being collected by Marine and Coastal Management. Preliminary indications from the Durban-based operations suggests that the size range has not altered significantly, though it varies substantially from month to month. (R. Broker (July 2003- *pers com)*

Catch per unit effort

As expected, catch rates for swordfish in the South African fishery were relatively high at the beginning of the fishery. At the inception of the fishery (1997 to 1998) an average CPUE of 3.4kg/hook was recorded in Region 1 (Kroese 1999). In other areas of the South Atlantic, CPUE rarely exceeds 0.3kg/hook (Penney 2002). CPUE in South Africa has since declined to well below 1.0 kg/hook, as effort reaches saturation levels in the main fishing areas (Kroese 1999).

Some preliminary data is available on catch trends in the experimental fishery as reflected in Figure 11.

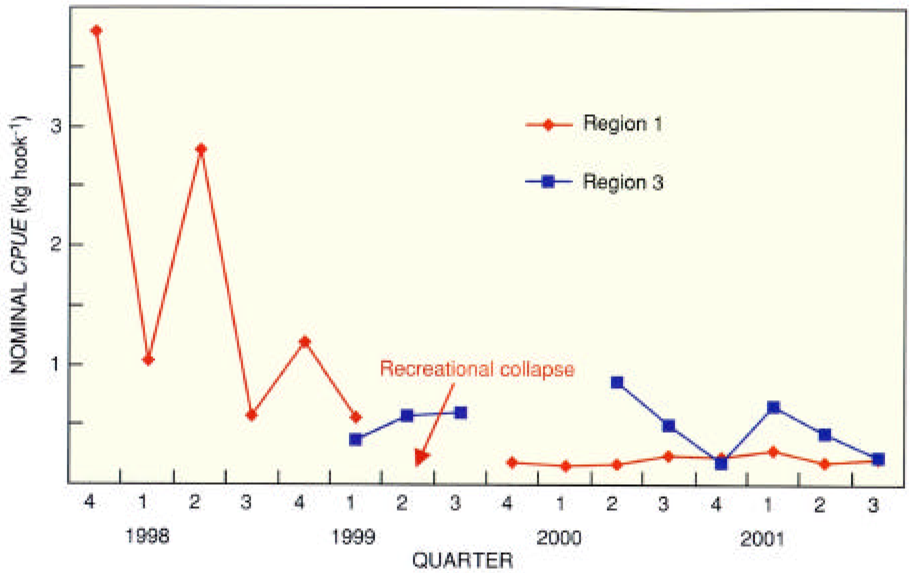


Figure 11. Quarterly catch per unit effort (1998 to 2001) for South African longliners operating in regions 1 and 3. (after Griffiths, 2002)

These preliminary data raise considerable concern as they reveal the same "boom and bust" trend that is so well documented for other regions of swordfish activity.

Distribution of the swordfish stock

Although South African swordfish are administratively divided into a separate Atlantic and Indian Ocean stock for management purposes, the high catch rates, large average size of swordfish caught in the Atlantic (W of 20°E) and genetic analysis suggest that swordfish caught off southern Africa may well be derived primarily from an Indian Ocean stock (Penney 2002). South African swordfish concentrate along the edge of the continental shelf, where the Agulhas Current is strongest. Here they can benefit from both the rich Agulhas and Benguela upwelling systems.

It was noted earlier that the world's swordfish are not a homogeneous population and that there is strong evidence suggesting that there are distinct populations that have different geographic distributions within ocean basins. ((Rosel and Block 1996). There is also compelling evidence that some local populations may be quite discrete and possibly resident in a particular area. This may well be the case off Cape Point and Griffiths (2002) suggest that this would explain the sharp drop in CPUE, indicating that there has been local overfishing.

Foreign longline fisheries in South African waters

Background

Fishing permits have been issued to Japanese and Taiwanese vessels to fish in South African waters using longlines for the past 30 years. Historically there have been few restrictions placed on these longliners. Permits stipulated that vessels may only use longlines, may not operate within our 12-mile territorial limit and may not catch hake or kingklip. These vessels were entitled to catch any quantity of other species (including swordfish). Japan and Taiwan are, however, members of ICCAT and as such are bound by their country specific quotas in the South Atlantic. Foreign permit holders were required to submit a summary of total days fished and total catch of each species caught every six months as a licence requirement. In reality there has been very little monitoring of these fisheries, (such as sampling or observer programs), and as a consequence catch returns have not been validated (Penney 1995).

The question of granting access to foreign fishers has increasingly become an issue of public concern. As a result of this, and according to the Fisheries Policy, the minister has decided that all foreign fisher rights will be withdrawn or terminated by the end of 2004. This decree does allow for joint ventures and possibly access to southern bluefin tuna that are not easily harvested by South African vessels.

Japanese catches
Japanese longliners catch, in order of importance: yellowfin tuna (46%), bigeye tuna (27%), albacore (12.8%), swordfish (6.7%) and marlin species (1.6%). There are also believed to be large catches of shark, but these are not reported (Penney 2002). Table VII shows the catches reported by Japanese longliners fishing in South African waters between 1997 and 2000. The number of permits issued to Japan decreased in recent years, from 100 in 1991 to 69 in 2001 (Penney 2002).

Table VII. Reported catch (mt dressed weight) of swordfish caught by Japanese longliners in South African waters between 1997 and 2000 (after Penney 2002)

Year	**Tons of swordfish reported in catches**
1997	262.4
1998	240.8
1999	159.0
2000	163.3
Total	825.5

Taiwanese catches
Taiwanese longliners target albacore (with shallower sets) for canning, bigeye tuna using deeper sets for the sashimi market and swordfish for frozen export. Over the past five to ten year period their catches of swordfish and bigeye tuna have increased (Penney 2002). The swordfish catch is included in the 'other' category on Taiwanese catch records and are therefore not quantifiable (Penney 1995). The number of permits issued to Taiwan has declined from 60 to 12 in the last ten years and South Africa has indicated its intention to terminate Taiwanese fishing permits at the end of 2002.

The Sport fishery

Background
Recreational anglers catch swordfish in modest numbers throughout South African coastal waters, but most commonly in southern Cape waters. The gear employed is primarily rod and line gamefish tackle, using squid bait in association with light sticks. Although small skiboats are involved (5-8m), most catches are taken from the larger gamefishing craft (8-15m). At the instigation of sport fishers in South Africa, the then minister of fisheries categorised swordfish as a recreational linefish species. This classification has been maintained in the Marine Living Resources Act (No. 18 of 1998) and consequently linefishers may not sell their catch, are restricted to a bag limit of five swordfish per person per day and a minimum size limit of 25kg or 125cm LJFL. This regulation was promulgated in an attempt to curtail the anticipated future commercial targeting of swordfish.

Recreational fishing for swordfish intensified in 1986 when sportfishers discovered an aggregation of swordfish some 50 km off Cape Point (Best *et al* 1997).This evoked international interest and large tournaments were developed around this "discovery". Numerous international line-class records were broken during these tournaments with many of the fish being of unusually large size. (van der Elst and de Wet 1994). The catch rates of these tournaments were also noteworthy, with up to 33 fish caught in a single tournament. However, these high rates did not persist and by 1999 had dwindled to zero, resulting in the cancellation of further tournaments (see Figure 12).

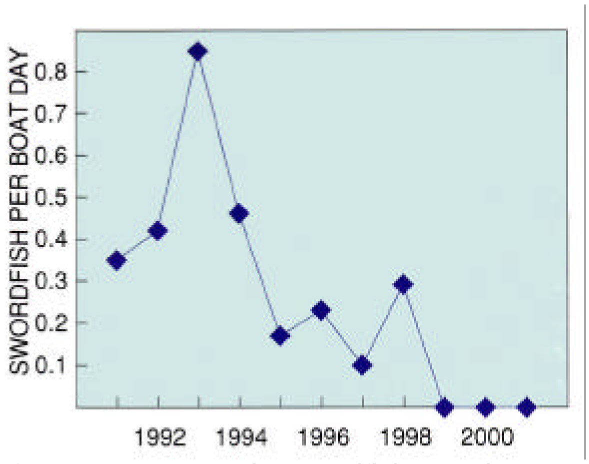


Figure 12. Catch rates of tournament-caught swordfish. Gordons Bay Broadbill Tournament data (after Griffiths, 2002)

Most recreational boats targeting swordfish are launched from harbours at night and, as such, monitoring of this fishery is often poor and there are few catch records. Although recreational landing of swordfish are invariably low, the economic implications of this fishery may be considerable, as was shown in related studies by McGrath *et al.* 1997. This aspect should therefore not be overlooked when planning for the overall management of the swordfishery.

8. MANAGEMENT RECOMMENDATIONS FOR THE SOUTH AFRICAN SWORDFISHERY

The availability of swordfish off South Africa has raised local and international awareness in the harvesting of this resource and unless there is effective management intervention the South African swordfishery may experience the same fate as that of the North Atlantic.

To date, South Africa does not have a defensible commercial swordfish management plan in place. While harvesting is being allowed on an experimental and precautionary basis, it is most urgent to develop a scientifically based plan, referred to as an Operational Management Procedure (OMP), for the sustainable use of this valuable resource. Operational Management Procedure's have been developed for several other South African fisheries e.g. hake, west coast rock lobster and the pilchard and anchovy fisheries.

An operational management plan, as described by Butterworth *et al.* (1997), consists of clearly defined rules. These rules specify exactly how the TAC (or some other regulatory mechanism) is set, what data are collected for this purpose and how these data will be used and analysed. All parties (scientists, managers and industry) agree upon these rules. Once agreed upon, the OMP should be implemented for a number of years (3 to 5), after which it is reviewed and modified.

It is acknowledged that a draft policy document for linefishing is being finalised. This needs to be finalised and strengthened by using the full results of the almost one decade longlining experiment.

Based on the international and local experience, a set of recommendations has been developed that may assist fisheries managers in South Africa during the development of the local swordfishery:

- South Africa must terminate the experimental longlining project, fully analyse the results and implement the new policy, ensuring that long-term rights are issued to capable operators.
- The multi-species nature of this fishery, and especially the complications brought about by the variable bycatch, needs to be better understood and modelled. The level of permitted bycatch of swordfish in tuna longlining operations may need to be re-evaluated and should not be entrenched in long-term rights.
- Assessment of trends in the swordfish industry need to be carefully investigated and understood because of the phenomenon of discards, pricing, currency fluctuations, target switching etc.
- It is generally acknowledged that a developing fishery should implement the precautionary approach[11] (FAO 1995) that limits capitalisation and thus moderates effort. It is well recognised that it is easier to limit effort in a developing fishery than to reduce it in a fully developed one.
- Deriving maximum sustainable benefit from the swordfish resource should be investigated. This includes the development of local technology, associated markets and post-harvest processing, such as the example from the Reunion fishery that lands fewer fish of higher value.
- The potential benefits of swordfish sport-fishing should be recognised and fully developed.

[11] The **precautionary approach** to fisheries recognises that changes to fisheries systems are only slowly reversible, difficult to control, not well understood and subject to changing environmental and human values. It involves the application of prudent foresight, taking account of uncertainties in fisheries systems and the need to take action in the absence of complete knowledge.

- South Africa should actively engage regional fisheries research and management initiatives, including the South West Indian Ocean Fisheries Programme (SWIOFP) and NEPAD related programmes. Cognisance needs to be taken of the possibility that South African stocks may be moderately resident and thus susceptible to local overfishing. The rapid decline in CPUE suggest this may be true.
- As a member of ICCAT, South Africa should strongly participate in discussions within Panel 4. This is probably the most feasible avenue open to South Africa to gain a country-specific quota for swordfish in the future.
- South Africa should become a member of the IOTC and actively contribute to its success. The fact that swordfish caught off South Africa are probably derived from Indian Ocean stock, highlights the importance of regional and international collaboration in management.
- All commercial fishers, both local and foreign, should be obliged as a condition of their permits to provide accurate catch and effort information to the Marine and Coastal Management for swordfish catches made in South Africa's EEZ. Recreational anglers should submit information via the National Marine Linefish System to MCM.
- A monitoring system should be set up to collect biological, fishery and socio-economic information from local and foreign vessels. The onboard and harbour-based observer programme should be fully supported and possibly enhanced to ensure good statistics are collected.
- Tagging of swordfish should be initiated in order top clarify the stock relationships and hence the appropriate management regime.
- Assessing the impact on harmless and vulnerable species must be continued with innovative solutions. For example through the use of gear modifications (such as dyed bait) and restricting fishing to night-time where appropriate.
- Currently, the South African swordfishery is mainly an effort-limited fishery i.e. the number of entrants to the fishery is restricted while catches are limited by the ICCAT quota in the South Atlantic. It would be wiser to combine effort limitation with an annual quota derived from an OMP.
- Consideration should be given to closing specific areas where swordfish aggregate or where juveniles are most abundant (i.e. nursery areas).
- Vessel monitoring systems (VMS) should be mandatory for foreign and local vessels fishing in South African waters (VMS aid in the enforcement of regulations, especially in areas closed to fishing).
- Regulations need to be enforced through effective monitoring and control.

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