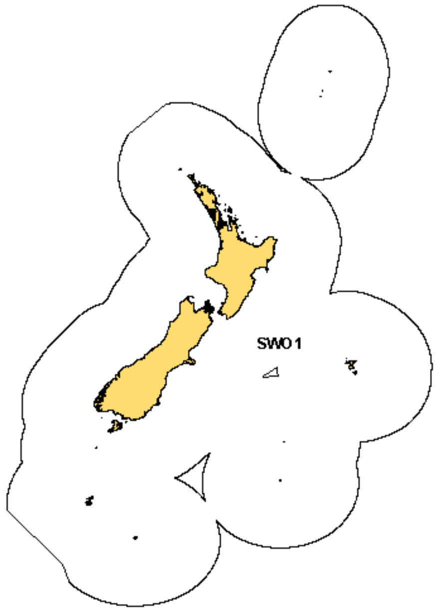
SWORDFISH (SWO)

(*Xiphias gladius*)



1. FISHERY SUMMARY

Swordfish were introduced into the QMS on 1 October 2004 under a single QMA, SWO 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Maori allowances, TACC and TAC for swordfish.

Fishstock	Recreational Allowance	Maori customary Allowance	Other mortality	TACC	TAC
SWO 1	20	10	4	885	919

Swordfish were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because swordfish is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Swordfish were also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any swordfish to the waters from which it was taken from if –
> (a) that swordfish is likely to survive on return; and
> (b) the return takes place as soon as practicable after the swordfish is taken; and
> (c) that swordfish has a lower jaw to fork length of less than 1.25m."

Management of swordfish throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). At its third annual meeting (2006) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of swordfish in the southwest Pacific Ocean (http://www.wcpfc.org/). This measure restricts the number of vessels fishing for swordfish in the convention area south of 20 degrees south.

(a) Commercial fisheries

Annual swordfish catches throughout the Pacific have been increasing with catches averaging 26 385 tonnes in recent years, most of which comes from the northwest, central eastern and southeast Pacific (88%). The swordfish catch from the southwest Pacific has averaged about 12% of the Pacific Ocean total in recent years. In New Zealand, swordfish are caught throughout the year in oceanic waters, primarily by pelagic longlines in areas where the bottom depth exceeds 1000 m.

Swordfish are primarily caught in the tuna longline fishery as a bycatch when targeting bigeye and to a lesser extent when targeting southern bluefin tunas. Swordfish can be caught in most FMAs and adjacent high seas areas although most catches are from waters north of 40ºS. Swordfish catches by domestic vessels increased rapidly from 1994/95 to peak at 1100 t in 2000/01. Since 2000/01 swordfish catches declined in each year coinciding with the decline in effort in the surface longline fishery, until 2005/06 when they increased again (Table 2). This increase is attributed to the development of a target fishery, which is, in part, driven by the recent arrival of several surface longline vessels from Australia. Most of the catch is from FMA 1, FMA 2 and FMA 9.

TLCER and CELR data were analysed to characterise the swordfish catch. Catch in weight was generated from processed weights reported on TLCER forms with a conversion factor of 1.40 applied. Catch in number reported on CELR forms were converted to weight estimates using the average swordfish weight calculated from TLCER data for the domestic and charter longline fleet in a given fishing year. These catch estimates represent nominal catch since they have not been scaled to the LFRR data. LFRR data are provided for comparative purposes in Table 2 for the domestic fleet (NZ owned and operated vessels and chartered longline vessels).

Before the start of the domestic longline fishery in 1990/91, distant water longline fleets were granted foreign license access to fish for southern bluefin and bigeye tuna (Japan) and albacore (Korea). Swordfish catches for the Japanese fleet is given in Table 2 (Japan). Korean catches were only small (0 to 7 t per year) and was mostly (79%) from FMA 9 and FMA 10.

The swordfish bycatch by the Japanese foreign licensed fishery averaged 388 t per year between 1979/80 and 1992/93 with a maximum catch of 761 t in 1980/81. Most of the Japanese swordfish catch (85%) was from FMA 2 and FMA 9.

Table 2: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet and Japanese foreign licensed fleet 1979/80 to 2004/05; with annual totals from LFRR and MHR (from 2001/02) data.

		SWO 1 (all FMAs)			
Year	**JPNFL**	**NZ**	**Total**	**LFRR/MHR**	**NZ ET**
1979/80	386		386		
1980/81	756.1		756.1		
1981/82	734.6		734.6		
1982/83	436.1		436.1		
1983/84	384.8		384.8		
1984/85	316.1		316.1		
1985/86	673.6		673.6		
1986/87	575.5		575.5		
1987/88	286.2		286.2		
1988/89	181.1		181.1		
1989/90	194.3		194.3		
1990/91	211.9	21.9	233.8	41	0.5
1991/92	194.5	33.5	228	32	0.6
1992/93	31.1	46.8	77.9	79	0.6
1993/94		88.2	88.2	102	2.6
1994/95		91.4	91.4	102	0.8
1995/96		148.6	148.6	187	2.5
1996/97		223.3	223.3	283	0.2
1997/98		379.7	379.7	534	2.8
1998/99		679.1	679.1	965	2.9
1999/00		778	778	976	4.6
2000/01		901.4	901.4	1022	25.4
2001/02		783.9	783.9	945	
2002/03		622.0	622.0	673	0.5
2003/04		519.4	519.4	545	0.5
2004/05		305.2	305.2	343	
2005/06				560	

(b) Recreational fisheries

Swordfish are targeted by some recreational big gamefishers with annual recreational catch of 31 fish in the year 2000/01 and an average of 14 swordfish per annum over the last 15 years. Despite variable and low recreational catch there is considerable recreational interest in swordfish and targeting methods have developed significantly in recent years.

(c) Maori customary fisheries

An estimate of the current customary catch is not available, but it is considered to be low.

(d) Illegal catch

Illegal catch, via targeting of swordfish was assumed to occur prior to introduction of this species to the QMS (based on analysis of CPUE data). As most was reported as bycatch landings it did not affect estimates of total annual catch.

(e) Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.44% of the catch. Discard rates are 0.7% on average from observer data of which approximately 60% are discarded dead (usually small fish, or as a result of shark damage). Fish are also lost at the surface in the longline fishery, 0.21% on average from observer data. Approximately 20% of those fish are also dead. Swordfish have occasionally been observed as a bycatch in the skipjack tuna purse seine fishery and in trawl fisheries for jack mackerel and hoki.

2. BIOLOGY

Swordfish (*Xiphias gladius* Linnaeus, 1758) are an epi- and mesopelagic highly migratory species found in all tropical and temperate oceans and large seas. Based on longline catches, swordfish range from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean.

In the New Zealand EEZ swordfish size varies markedly with latitude, with larger swordfish (and hence fewer males) caught south of 40ºS. Average size of both males and females is larger in the southern region compared to the north: 229.3 and 158.3 cm for males, and 231.8 and 174.3 cm for females, respectively. Average length (lower jaw to fork length) of swordfish caught in the EEZ has been relatively stable since 1991, averaging 196.6 cm for the Japanese charter fleet and 163.9 cm for the domestic owned and operated fleet based on limited observer data. The average size over all fleets since 1991 is 178.3 cm however, this will be largely representative of the charter fleet. Males are substantially smaller than females with most males smaller than 189 cm (77%) while most females (51%) are larger than 189 cm for all fleets.

A relationship between lower jaw-fork length and weight has been estimated for swordfish from observer records (n=2835): weight (kg) = (3.8787×10^{-6}) length$^{3.24}$.

Spawning takes place in the tropical waters of the western Pacific Ocean and to a lesser extent the equatorial waters of the central Pacific Ocean.

Swordfish are batch spawners, perhaps as frequently as every few days over several months. Eggs are spawned in the upper layers of the ocean and, like the protracted larval phase, are pelagic. Depending on swordfish size, egg production is estimated to range from 1 to 29 million (68 – 272 kg females respectively).

From 1987 to 2004 the average sex ratio of longline-caught swordfish in the EEZ was 1:3.13 (males:females). This ratio is even higher for the southern region.

Little information on mortality rates is available, but M has been estimated elsewhere in the Pacific to be 0.22 yr^{-1}. This value is consistent with the maximum estimated ages for swordfish in Australia and New Zealand.

Growth rates have been estimated for Pacific Ocean swordfish caught off Taiwan. Estimates of growth rate indicate rapid growth during the first year to about 1 m in lower jaw to fork length, with growth rate progressively slowing with age. The differences in growth parameters between males and females are significant with females growing faster than males. Asymptotic length for males is 213 cm while asymptotic length for females is about 300 cm. The maximum age observed in Taiwanese samples was 10 years for males and 12 years for females. The maximum size reported for a swordfish is 445 cm total length (includes the bill and furthest extension of the tail) and about 540 kg.

Recent studies of swordfish growth rates have been conducted independently in Australia and New Zealand. The results are generally consistent with maximum ages of 18 and 15 years, respectively. It is likely that swordfish attain a maximum age of 20 years. Given the lack of observations of swordfish in New Zealand with ripe or running ripe gonad condition, ages at maturity were defined on the basis of the Australian estimates of lengths at 50% maturity for males and females of 101 and 221 cm, respectively. Using the growth curves estimated for New Zealand swordfish, this corresponds to ages at 50% maturity for males and females of 0.9 and 9.9 years, respectively.

3. STOCKS AND AREAS

Swordfish found in the New Zealand EEZ are part of a much larger stock that spawns in the tropical central to western Pacific Ocean. They are highly migratory and their residence time in the EEZ and adjacent waters is unknown. In the Pacific Ocean swordfish occur from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean. Swordfish are visual predators with a wide temperature tolerance. Extensive diel vertical migrations have been observed for swordfish in the Atlantic and Pacific Oceans from waters deeper than 600 m to the surface and across large temperature gradients (e.g., from 8º to 27ºC) in a few hours. Swordfish are found at their shallowest depth, at or near the surface, at night. Within the EEZ most swordfish are caught in FMA 1, FMA 2, and FMA 9 when sea surface temperatures are 17º to 19ºC.

Stock structure is uncertain and recent genetic studies have indicated that there may be multiple Pacific Ocean stocks. There is limited information on swordfish movement from tagging studies. From a release sample of 113 swordfish tagged in the New Zealand EEZ as part of the New Zealand gamefish tagging programme, to date two have been recaptured. The release locations were 120 nm north of New Zealand and 80 nm north east of East Cape. Both fish were of small size at release and following extended periods at liberty, 8 and 10 years respectively, had grown to sizes consistent with being sexually mature. Despite the long liberty period the recapture positions were not a large distance (<130 nm) from the release locations. Although the apparent net movement is limited, little can be inferred from this information in relation to swordfish stock structure or migration in, and around, New Zealand waters. From a release sample of 672 fish tagged in the Australian EEZ, eight recaptures have been reported. Although some fish tagged in east Australian waters have moved large distances (e.g. 893 nm), none were recaptured outside of the Australian EEZ, or have crossed the Tasman Sea into the New Zealand EEZ. Australian and New Zealand research projects are currently in progress to tag swordfish with satellite archival tags to observe swordfish movement, and perhaps described the stock structure, in the south-west Pacific region.

4. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the western and central Pacific Ocean stock of swordfish will be reviewed by the WCPFC. Unlike the major tuna stocks, in the short term, development of a regional assessment for swordfish is to be undertaken by collaboration among interested members. The first stock assessment for swordfish in the southwest Pacific was a collaborative effort between scientists from Australian and New Zealand. This assessment was reviewed by the Scientific Committee of the WCPFC in August 2006 and the conclusions are briefly described below. Full details of the assessment can be found in Davies et al. (2006) and Kolody et al. (2006a; 2006b).

The swordfish stock assessment covers the southwestern Pacific Ocean (0-50ºS, 140ºE-175ºW) for the period 1952-2004. At this time, it is not possible to conclude that either MFCL or CASAL is preferable tools for conducting the swordfish assessment. CASAL was used to explore the structural assumption for spatial disaggregation with foraging site fidelity. However, the MFCL assessment had the benefit of an extensive exploration of model uncertainty and its results are the principal basis for the stock status summary herein.

The stock assessment assumes a unit stock in the area of the Southwest Pacific Ocean bounded by 0–50ºS latitude and 140ºE–175ºW longitude. There is genetic evidence suggesting that northern and southern populations have limited mixing in the western Pacific Ocean, however, the definition of western and eastern bounds is more arbitrary, and partly reflects a convenient partitioning based on fleet characteristics. In particular, the fisheries to the east of 175ºW are dominated by Korean and Taiwanese fleets, and the data available for catch rate standardization are not as detailed as for the Australian and New Zealand fleets in the southwest Pacific.

The nominal CPUE trends in this south-central region have been increasing in recent years, and this suggests that either the population dynamics in this region are substantially different from the southwest, or catchability might be changing for the south-central fleets.

The status summary represents a synthesis of the Bayesian maximum posterior density (MPD, or best point estimate) results from a subset of 10 models (the most plausible ensemble), selected from several hundred results (Figure 1). In the following conclusions, the estimates represent the median (and range) of the MPD results from the plausible model ensemble, such that if one of the models at the extreme end of the range were actually a perfect unbiased estimator, there would be a 50% chance of the true value being more extreme than the uncertainty bound indicates:

1) Relative total stock biomass (TSB) estimates for recent years are the most reliable reference points because they are the most closely linked to the highest quality data, and are reasonably robust to the alternative model assumptions explored. The MPD results from the plausible model ensemble indicate:

- TSB(2004)/TSB(1995) median = 0.70, range = (0.56–0.74)

2) All of the Spawning Stock Biomass (SSB – roughly corresponding to age 10+ fish) reference points are much more uncertain than TSB because SSB represents a small portion of the catch, and may be badly biased by natural mortality assumptions, and the model aggregation of sex-specific characteristics of growth, mortality and migration. Furthermore, the southern range of the stock seems to consist predominantly of mature females, but this region is poorly sampled by the fishery and it is difficult to relate abundance in this southern part of the population to the core population.

- SSB(2004)/SSB(1995) = 0.75 (0.51–0.86)

3) The ratio of current biomass over the estimated biomass that would have been observed in the absence of fishing (NF) provides a measure of the fishery impact on the population that might be more meaningful than the biomass ratio at two points in time if the population experiences non-stationary production dynamics (which these assessments tend to suggest).

- TSB(2004)/TSBNF(2004) = 0.59 (0.31–0.69)
- SSB(2004)/SSBNF(2004) = 0.49 (0.15–0.65)

4) The data are not sufficient to estimate a stock recruitment relationship reliably, and most or all models explored suggest some form of non-stationary (or at least highly variable) recruitment dynamics. This seriously undermines the usefulness of the MSY-related reference points. However, in so far as these reference points have been calculated, the majority of MPD estimates from the plausible model ensemble suggest that biomass (total and spawning) are probably above levels that would sustain MSY and fishing mortality is probably below $F_{(MSY)}$.

- TSB(2004)/TSB(MSY) = 1.7 (0.87–3.0)
- SSB(2004)/SSB(MSY) = 3.4 (0.75–6.4)
- F(2004)/F(MSY) = 0.70 (0.33–2.2)

5) The apparent optimism of the MSY-related reference points is countered by the stock projections (assuming constant future recruitment according to the estimated stock recruitment relationships, and constant effort at 2004 levels), which suggest biomass declines over the short term (Figure 2):

- TSB(2009)/TSB(2004) = 0.88 (0.78–1.00)
- SSB(2009)/SSB(2004) = 0.84 (0.71–0.86)

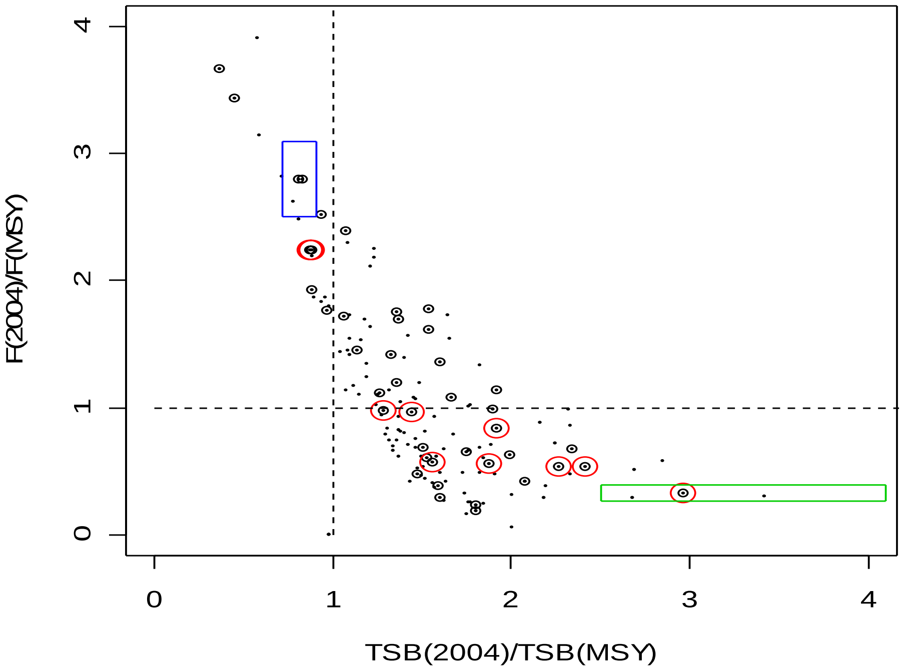


Figure 1: Stock status summary plot. Points indicate the estimates corresponding to the MFCL models examined. Large circles indicate the most plausible model ensemble used for stock status determination. Example model 1 (top left corner) and 2 (lower left corner) are indicated by the large rectangles which encompass the two-dimensional 95% confidence limits (without the correlation).

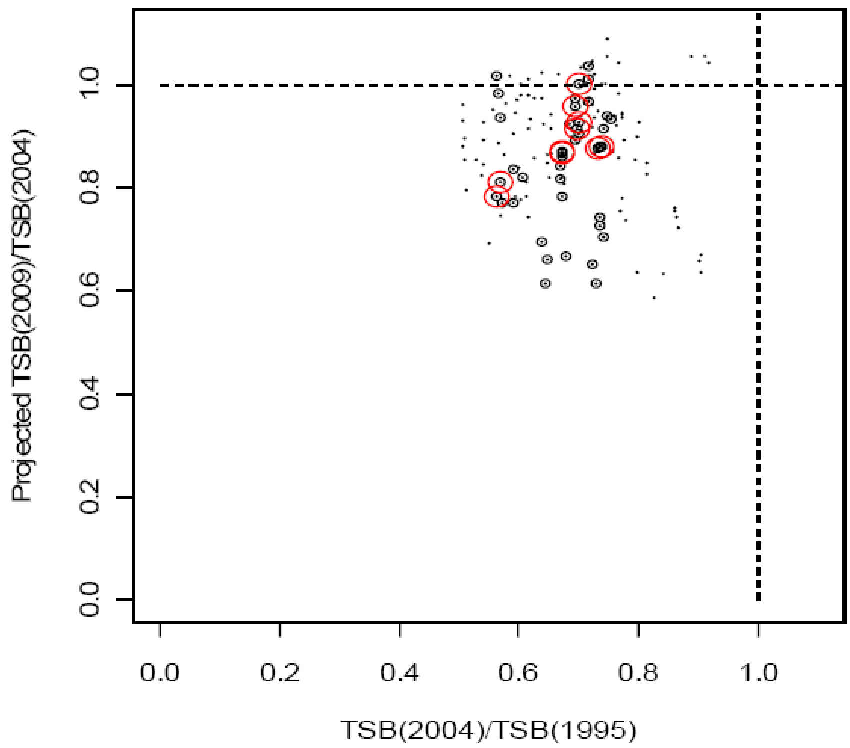


Figure 2: Summary of recent biomass trends and short term deterministic projections (with 2004 effort) in relation to model uncertainty. Points indicate the estimates corresponding to MFCL models examined. Large circles indicate the most plausible model ensemble used for stock status determination.

(a) Catch per unit effort indices (CPUE)

The following section describes the New Zealand abundance indices used in the regional assessment.

Nominal and standardised CPUE indices for the longline fishery have been calculated with fishing operational variables and environmental effects examined as potentially significant factors in explaining the variance in CPUE models. Catch and effort data collected using the detailed TLCER forms for the tuna longline fishery from 1993 to 2004 has been groomed. A total of 51 004 data records were available with detailed effort information for individual fishing operations. This data has been linked to a range of environmental variables including remotely sensed observations for sea surface temperature (SST) and ocean colour (chlorophyll) at a spatial resolution closely related to individual operations. These variables have been expressed in relation to oceanic fronts, climatology and oceanographic indices of meso-scale dynamics on both a seasonal and monthly temporal scale. Other potential explanatory variables include moon brightness (phase), day length, fraction of longline set during night hours, depth and depth variation.

The significant factors affecting NZ swordfish CPUE were year and quarter; and important predictors were location (particularly longitude); depth, and depth variation (especially areas of high bathymetric gradient, e.g. continental slope and over local seamounts); local fishing effort; night fraction; moon phase (CPUE was highest during the hours of darkness and increased around the time of the full moon); mean SST (positively correlated); and, SST anomaly (negatively correlated with CPUE). Although light sticks and bait type have been identified as significantly affecting swordfish catch rates, this predictor was excluded from the standardised CPUE analysis because of the lack of available data before 2003.

A strong seasonal (quarter) factor in both nominal and standardised CPUE was estimated. This is potentially of high utility for the development of a regional stock assessment model in that seasonality in catch rates may be indicative of annual cycles in fish abundance caused by movements between NZ waters and, most likely, the tropics or north-east Australia where swordfish are believed to spawn.

The nominal and standardised annual CPUE indices from 1993 to 2004 are broadly similar with an increasing trend in catch rates from 1995 to 1998, followed by a stable phase, and then a decrease to 2003, followed by a slight increase in 2004 (Figure 3). The substantial increase by around 200% from 1995 to 1998 requires careful consideration before this time series is of utility for a stock assessment model. It has been suggested that a number of fishing operational factors have most likely contributed to the increase in catch rates. These include: increased targeting for swordfish in the domestic longline fishery; changes in operations such as the time of setting, setting on or near full moon, number of hooks set, and the increased use of light sticks. The latter has been identified as the most significant factor affecting catch rates. It is therefore highly unlikely that the time series through this period is an accurate index of relative abundance. For this part of the time series to be of utility in to the regional stock assessment, a process that produces a trend in catchability must be defined and estimated.

The CPUE decline from 2000 to 2004 in NZ is consistent with a corresponding decline observed for the east Australian swordfish fishery, where in central parts of the fishery catch rates declined from over 6 fish per 1000 hooks in 2000 to around 3 fish per 1000 hooks in 2003.

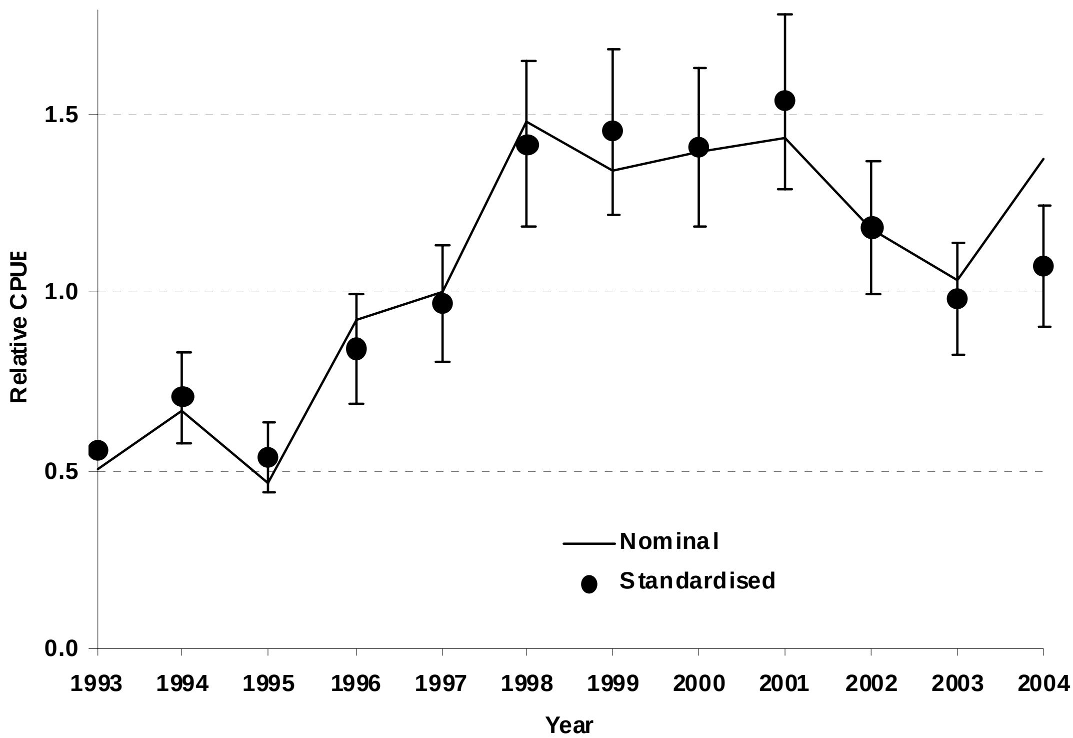


Figure 3: Nominal and standardised annual swordfish CPUE indices (normalised about the geometric mean for each time series) for the longline fishery, 1993-2004. Vertical bars indicate two standard errors.

(b) Other factors

Other fleets also fish the stock fished in the New Zealand EEZ and the impact of current regional catches on the stock are unknown. It is often assumed that swordfish, particularly large swordfish, may have long residence times which may make them vulnerable to over fishing. Recent Australian research suggests that swordfish CPUE has declined in areas that have been fished the longest and that vessels have maintained high catch rates by travelling further each season, suggesting that serial depletion may be occurring.

5. STATUS OF THE STOCKS

Swordfish taken in New Zealand are part of a larger regional stock.

In 2006 the WCPFC Scientific Committee reviewed the first regional assessment undertaken for swordfish in the southwestern Pacific region. Although the estimates of stock status relative to standard biological reference points (e.g. B_{MSY}) could not identify whether the stock was presently overfished or not, this assessment has indicated consistent declines in stock abundance in recent years, and most model projections predict further declines at current levels of fishing mortality.

Until estimates of stock status are more certain, the Scientific Committee recommended as a precautionary measure that there be no increases in fishing mortality on this stock, as this is likely to move the stock towards an overfished state.

This recommendation applies particularly to the area encompassing the western component of the southwest Pacific as these fisheries account for most of the swordfish catch in the southwest Pacific.

It is not currently possible to estimate a long-term sustainable yield for swordfish, or to determine if recent catch levels will allow the stock(s) to move towards a size that would support a MSY.

6. FOR FURTHER INFORMATION

Bigelow, K.A.; C.H. Boggs and X. He. (1999). Environmental effects on swordfish and blue shark catch rates in the US North Pacific longline fishery. *Fishery Oceanography* 8: 178–198.

Campbell, R.A. and N.A. Taylor. (2000). Data and biological parameter specifications for a spatially structured operating model for broadbill swordfish and bigeye tuna in the south-west Pacific. FRDC 99/107 Milestone Report.

Carey, F.G. and B.H. Robison. (1981). Daily patterns in the activities of swordfish, *Xiphias gladius*, observed by acoustic telemetry. *Fishery Bulletin* 79: 277–292.

Carocci, F. and J. Majkowski. (1996). Pacific tunas and billfishes, atlas of commercial catches. FAO, Rome, 9 p, 28 maps.

Davies, N.M.; Griggs, L.; Unwin, M. (2005). Information available for developing a stock assessment for New Zealand swordfish (*Xiphias gladius*). *Final Research Report for New Zealand Ministry of Fisheries project SWO2003/0*1, Specific Objective 4. 26 p.

Davies, N., R. Campbell, and D. Kolody.(2006). CASAL Stock Assessment for South-West Pacific Broadbill Swordfish 1952-2004. WCPFC-SC 2; ME WP-4.

Griggs, L. (2005). Historical and biological data summaries for swordfish (*Xiphias gladius*). *Final Research Report for New Zealand Ministry of Fisheries project SWO2003/01*, Specific Objectives 1 and 2. 27 p.

Griggs, L.; Francis, M.; Ó Maolagáin, C. (2005). Growth rate, age at maturity, longevity and natural mortality rate of swordfish (*Xiphias gladius*). *New Zealand Fisheries Assessment Report* 2005/56. 29 p.

Holdsworth, J. and P. Saul. 2001. New Zealand billfish and gamefish tagging, 2000-01. Draft Annual Report to Ministry of Fisheries.

Kolody, D., R. Campbell, and N. Davies. (2006a). Multifan-CL Stock Assessment for South-West Pacific Broadbill Swordfish 1952-2004. WCPFC-SC2; ME WP-3.

Kolody, D., N. Davies, and R. Campbell. (2006b). SW Pacific Swordfish Stock Status Summary from multiple assessment models. WCPFC-SC2; SA WP-7.

Nakamura, I. (1985). Billfishes of the world, an annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fisheries Synopsis 125(5) iv + 65 p.

Nishikawa, Y.; M. Honma; S. Ueyanagi and S. Kikawa. Average distributions of larvae of oceanic species of scomboid fishes, 1956–1981. Far Seas Fisheries Research Laboratory S series 12, 99 p.

Punt, A.E.; R.A. Campbell and A.D.M. Smith. (2001). Evaluating empirical indicators and reference points for fisheries management: application to the broadbill swordfish fishery off eastern Australia. *Marine and Freshwater Research* 52: 819–832.

Stone, H.H. and L.K. Dixon. (2001). A comparison of catches of swordfish, *Xiphias gladius*, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. *Fishery Bulletin* 99: 210–216.

Sun, C-L; S-P Wang and S-Z Yeh. (2002). Age and growth of the swordfish (*Xiphias gladius* L.) in the waters around Taiwan determined from anal-fin rays. *Fishery Bulletin* 100: 822–835.

Unwin, M.; Richardson, K.; Uddstrom, M.; Griggs, L. (2005). Standardised CPUE indices for swordfish (*Xiphias gladius*) from the tuna longline fishery 1992–93 to 2003–04 using environmental variables. F*inal Research Report for New Zealand Ministry of Fisheries project SWO2003/01*, specific Objective 3. 26 p.

Ward, P. and S. Elscot. (2000). Broadbill swordfish, status of world fisheries. Bureau of Rural Sciences, Canberra, 208 p.

Yabe, H.; S. Ueyanagi; S. Kikawa and H. Watanabe. 1959. Study of the life history of the sword-fish, *Xiphias gladius* Linneaeus. N*ankai Regional Fisheries Research Laboratory Report* 10: 107–150.