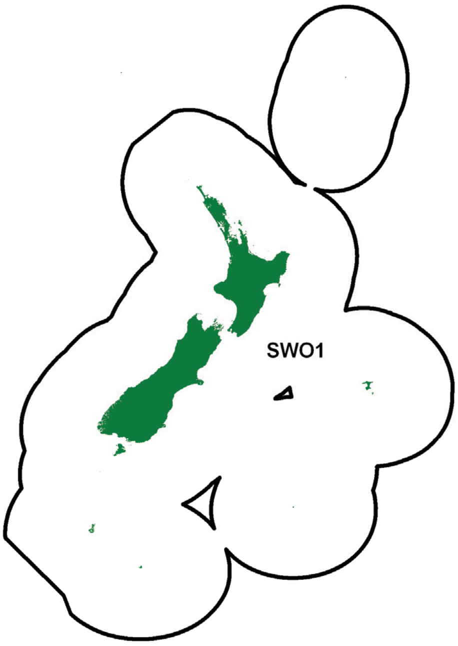
SWORDFISH (SWO)

(*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 Customary non-commercial allowances, TACC and TAC for swordfish.

Fishstock	Recreational Allowance	Customary non-commercial 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.int/). This measure restricts the number of vessels fishing for swordfish in the convention area south of 20 degrees south.

1.1 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. Figure 1 shows historical landings and TACCs and longline effort for SWO stocks.

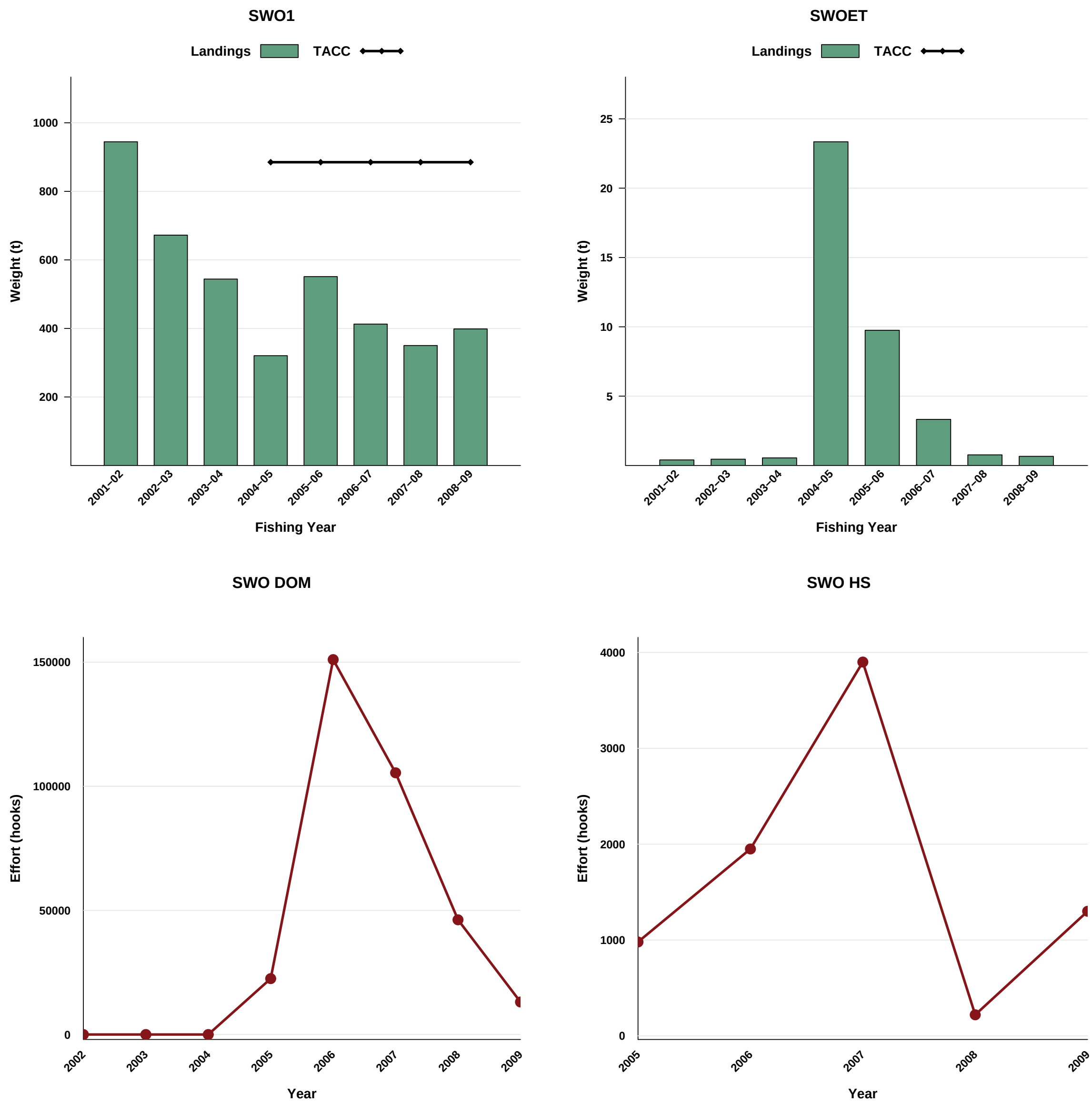


Figure 1: [Top] Swordfish catch from 2001-02 to 2008-09 within NZ waters (SWO1) and on the high seas (SWOET). [Bottom] Fishing effort (number of hooks set) for all domestic and high seas surface longline vessels targeting swordfish with less than 11 hooks per basket or float, from 2002 to 2009 and 2005 to 2009, respectively.

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 2008/09; with annual totals from LFRR and MHR (from 2001/02) data.

	SWO 1 (all FMAs)				
Year	JPNFL	NZ/MHR	Total	LFRR	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	1 022	25.4
2001/02		945	783.9	958.8	
2002/03		673	622.0	670.0	0.5
2003/04		545	519.4	555.2	0.5
2004/05		344	320.7	344.7	22.7
2005/06		560.9	548.3	558.9	9.7
2006/07		416.0	402.3	425.8	3.3
2007/08		350.9	350.9	351.4	0.7
2008/09		399.1	399.1	393.9	0.6

1.2 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.

1.3 Customary non-commercial fisheries
An estimate of the current customary catch is not available, but it is considered to be low.

1.4 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.

1.5 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.

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.

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: 228 and 158.4 cm for males, and 231.9 and 175 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. Overall 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%) and 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 spawning 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 2005 the average sex ratio of longline-caught swordfish in the EEZ was 1:3.15 (males:females).

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.

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 conventional tagging studies. From a release sample of 124 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. Nineteen pop-off satellite archival tags have been deployed on swordfish in New Zealand with the aim of tracking fish over the spring spawning period. The eight longer term tracks (4 to 8 months) show fish moving into sub-tropical waters in spring and returning to the New Zealand EEZ or adjacent waters in summer. Data from satellite tagged swordfish in New Zealand and Australia was used in the stock assessment model and will help describe 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. All SWP models were age-structured (ages 0-19+), sex-aggregated, iterated on a quarterly timestep (1952-2007), spatially-disaggregated into two roughly equal longitudinal units, with 11 fisheries and 4 informative effort series. The varying model assumptions in the uncertainty 'grid' were explored in a balanced factorial design with:

- 2 stock recruitment curve steepness priors (0.65, 0.9)
- 2 diffusive mixing assumptions (0.05, 0.1 per quarter)
- 8 growth rate / maturity / mortality options
- 2 recruitment deviation options (SD of log-normal deviates = 0.1, 0.5)
- 2 sample size down-weighting options for catch-at-size likelihoods (1/5, 1/20)
- 3 relative weighting options for CPUE indices (fleets weighted differently)
- 2 selectivity constraint options

The Maximum Posterior Density results from the plausible model ensemble indicate:
• TSB(2007)/TSB(1997): median = 0.69, range = (0.55 – 0.83).
• SSB(2007)/SSB(1997) = 0.58 (0.42 – 0.71).

The assessment was updated the conclusions are briefly described below. Full details of the assessment can be found in Davies *et al.* (2006, 2008), and Kolody *et al*. (2006a; 2006b, 2008).
"Stock assessments were undertaken for two areas: the south-west Pacific (SWP, 140°Ẽ-175°W) and the south-central Pacific (SCP, 175°W̃-130°W), both separately and combined.

The subset of models represents the most extreme (highest and lowest) of the models in terms of a set of reference points. The 2008 estimates appear to be much more certain than 2006, and near the centre of the distribution of estimates provided in 2006. This reduction in uncertainty is what might have been predicted given that the recent reduction in fishing effort seems to have been sufficient to break the "one-way-trip" nature of the fishery that was observed up to 2003-2004, and hence appears to now provide informative contrast with which to improve the estimation of stock productivity. The model predicts that following a period of continued decline the southwest Pacific swordfish biomass has recently increased.

The key conclusions of the models presented indicate that in the southwest Pacific overfishing is not occurring and the stock is not in an overfished state (Figure 2). Reference point levels estimated in the 2008 assessment where more optimistic than the 2006 assessment, $F_{current}/\tilde{F}_{MSY}$ was 0.44 compared to 0.71 in 2006, although $B_{current}/\tilde{B}_{MSY}$ was 1.57 compared to 1.70 in 2006 and the range estimated in the 2006 assessment included more pessimistic estimates.
The stock assessment attempted for swordfish in the south-central Pacific was unable to determine the current stock status. It was also noted that the available data do not indicate evidence of significant fishery impacts in the South Central Pacific, but catches have increased in recent years to levels exceeding those in the South West Pacific."

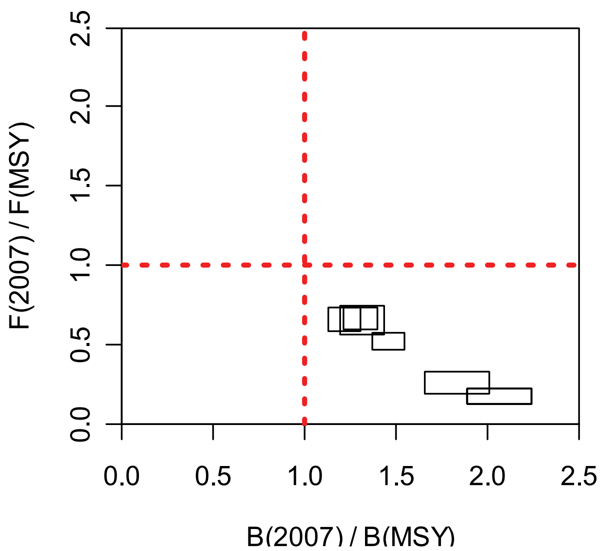


Figure 2: Summary plot comparing South-West Pacific fishing mortality, F(2007)/F(MSY), and total stock biomass, TSB(2007)/TSB(MSY), for Southwest Pacific swordfish from a subset of plausible MULTIFAN-CL models. Boxes indicate the upper and lower 95% confidence limits (but not the covariance) for each individual model.

4.1 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.

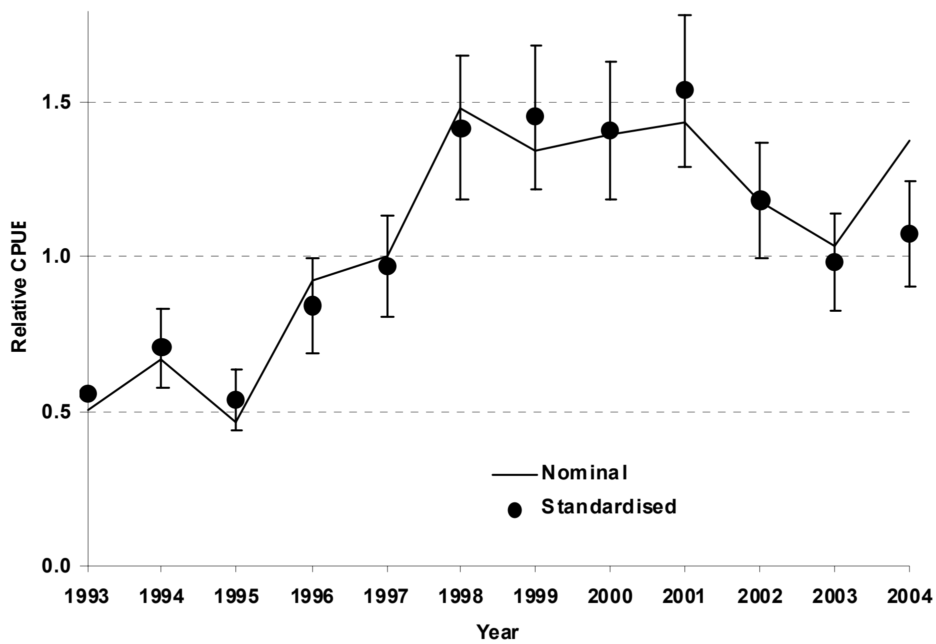


Figure 3: Nominal and standardised annual swordfish CPUE indices (normalised about the geometric mean for each time series) for the longline fishery, 1993-2004. Vertical bars indicate two standard errors.

4.2 Other factors

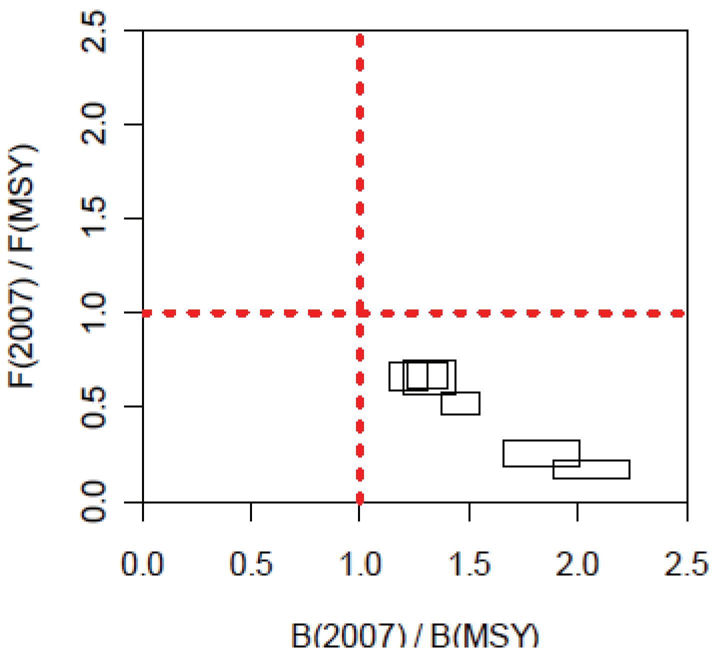
Other fleets also fish the stock fished in the New Zealand EEZ and the impact of current regional catches on the stock are unknown. It is often assumed that swordfish, particularly large swordfish, may have long residence times which may make them vulnerable to over fishing. Recent Australian research 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

Stock structure assumptions

Swordfish taken in New Zealand are part of a larger regional stock the evaluation below refers to the assessment of the southwest portion of that stock.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2008.
Reference Points	Target: $B>B_{MSY}$ and $F<F_{MSY}$ Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20%SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10%SB_0.
Status in relation to Target	Very Likely that $B>B_{MSY}$ and $F<F_{MSY}$
Status in relation to Limits	Soft Limit: Very Unlikely to be below Hard Limit: Very Unlikely to be below
Historical Stock Status Trajectory and Current Status	



Summary plot comparing southwest Pacific fishing mortality, F(2007)/F(MSY), and total stock biomass, B(2007)/B(MSY), for southwest Pacific swordfish from a subset of plausible MULTIFAN-CL models. Boxes indicate the upper and lower 95% confidence limits (but not the covariance) for each individual model.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Following a period of continued decline, the southwest Pacific swordfish biomass has recently increased.
Recent Trend in Fishing Mortality or Proxy	

Other Abundance Indices	Annual CPUE trends for the SWP shown that the Australian and New Zealand fleets show a decline from 1997-2003, and increases from 2003-2007. In contrast, the Japanese fleets show a continuous (though noisy) decline from 1997-2006. It is not clear which of the trends is closer to actual abundance.
Trends in Other Relevant Indicator or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	Projections predict further increases in stock size at current fishing mortality levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely Hard Limit: Very unlikely

Assessment Methodology		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. A parallel assessment in CASAL was also undertaken, but is not reported on here.	
Main data inputs	Commercial catch, CPUE, catch-at-age	
Period of Assessment	Latest assessment: 2008	Next assessment: ?
Changes to Model Structure and Assumptions	Major changes from the 2006 assessment include: • Two-three years of additional data, which includes informative contrast in catch levels and CPUE in the SWP • Simplification of the spatial structure within the SWP • Quantification of swordfish mixing rates on the basis of recent Pop-up Satellite Archival Tags (PSAT) and conventional tagging studies • Correction of catch data from NZ (~25% of landings were omitted in 2006) • Additional size composition data (NZ port sampling from 2006-7, Spanish observer data from 2004) • Exploration of alternative growth curves and maturity schedules, in light of evidence of methodological variability among laboratories • Exploration of models that include the SCP population	
Major Sources of Uncertainty	Conflicts between Japanese and the Australian and New Zealand CPUE data.	

Qualifying Comments
Limiting data and lack of an abundance index from the South Central portion of the stock resulted in no reliable assessment results for that portion of the stock.

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 30°S. Seabird bycatch mitigation measures are required in the New Zealand, Australian EEZ's and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to some extent through Conservation and Management Measure (CMM2008-06).

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