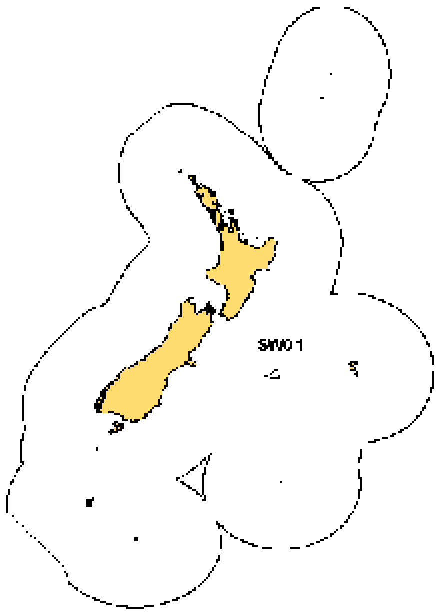
# SWORDFISH (SWO)

(*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 as follows:

| 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) will be the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand will be responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission. However, it is not expected that WCPFC will attempt to actively manage swordfish in the first years of the Commission.

### (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 40º S. Swordfish catches by domestic vessels increased rapidly from 1994/95 to peak at 1100 t in 2000/01. Catches in the last six years have averaged 865 t per year. Most of the catch is from FMA 1, FMA 2 and FMA 9. Total swordfish landings for New Zealand are given in Table 1.

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 1 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 1 (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 1: 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 data.**

| | | SWO 1 (all FMAs) | | | |
|---|---|---|---|---|---|
| **Year** | **JPNFL** | **NZ** | **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 | 1022 | 25.4 |
| 2001/02 | | 783.9 | 783.9 | 956 | |
| 2002/03 | | 622.0 | 622.0 | 683 | 0.5 |
| 2003/04 | | 519.4 | 519.4 | 551 | 0.5 |
| 2004/05 | | 305.2 | 305.2 | 349 | |

**Table 2: Estimated catches (t) of *X. gladius* by fishing year (using proportion caught from TLCER data and annual LFRR totasl) for each fishery management area (FMA) in the New Zealand EEZ from 1993–94 to 2004–05.**

| Fishing year | | | | | | | Fisheries Management Area (FMA) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | Total |
| 1993/94 | 65.2 | 21.7 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 11.2 | 1.9 | 102 |
| 1994/95 | 61.2 | 22.9 | 0.0 | 0.0 | 0.1 | 0.0 | 13.5 | 2.4 | 1.9 | 102 |
| 1995/96 | 89.9 | 81.4 | 0.0 | 0.0 | 0.3 | 0.0 | 10.2 | 2.9 | 2.3 | 187 |
| 1996/97 | 136.0 | 127.7 | 0.0 | 0.0 | 1.8 | 0.0 | 8.2 | 9.1 | 0.2 | 283 |
| 1997/98 | 217.0 | 220.8 | 0.0 | 0.0 | 2.0 | 0.0 | 24.6 | 69.7 | 0.0 | 534 |
| 1998/99 | 419.0 | 392.9 | 0.0 | 0.0 | 37.0 | 0.0 | 50.1 | 39.7 | 26.3 | 965 |
| 1999/00 | 299.7 | 517.6 | 0.1 | 0.0 | 6.6 | 0.1 | 41.7 | 99.8 | 10.5 | 976 |
| 2000/01 | 353.6 | 496.4 | 0.2 | 0.0 | 27.4 | 0.0 | 13.1 | 93.7 | 37.6 | 1022 |
| 2001/02 | 322.9 | 460.3 | 0.0 | 0.0 | 7.7 | 0.0 | 42.6 | 111.2 | 11.3 | 956 |
| 2002/03 | 150.7 | 422.4 | 0.0 | 0.1 | 8.2 | 0.0 | 15.7 | 69.6 | 16.2 | 683 |
| 2003/04 | 110.3 | 339.4 | 0.0 | 0.0 | 3.9 | 0.0 | 42.7 | 50.1 | 4.7 | 551 |
| 2004/05 | 95.8 | 140.9 | 0.0 | 0.0 | 0.9 | 0.0 | 35.1 | 71.7 | 4.5 | 349 |

### (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 50º N to 45º S in the western Pacific Ocean and from 45º N to 35º S 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 40º S. 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) = $(3.8787 \times 10^{-6})$ 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 and the results are generally consistent with maximum ages of 18 and 15 years were recorded 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 50º N to 45º S in the western Pacific Ocean and from 45º N to 35º S 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 27º C) 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 FMA1, FMA2, and FMA9 when sea surface temperatures are 17º to 19º C.

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, future 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. Australian and New Zealand researchers are currently developing a regional assessment for review by the Scientific Committee of the WCPFC in August 2006.

To date there has been no regional stock assessment of swordfish, although Australian researchers developed a population operating model to perform Monte Carlo simulations to evaluate what management indicators may be most practical for managing swordfish according to specific fisheries reference points. Under the collaborative project in progress, this operating model has been modified and updated during 2005–06 with all available fisheries and biological information from Australia and New Zealand. It will be used to evaluate alternative swordfish regional assessment models with the aim of recommending a regional assessment for swordfish in 2006.

The operating model makes the assumption that there is a discrete south-west Pacific stock. This seems reasonable given that genetic studies indicate the worldwide population of swordfish is genetically structured not only between the major oceans, but also within each ocean, and that gene flow is restricted despite the absence of geographic barriers. Within this region, the model is spatially disaggregated into 5 areas, with the NZ waters being separated into the north and south areas. Candidate assessment models will most likely replicate the spatial stratification of the operating model in fitting to simulation data. Operating model simulations scenarios will examine the importance of seasonal migrations, current stock depletion level, sex disaggregation, with the facility for including or excluding tag-recapture data. The performance of the candidate assessment models will be compared relative to a set of biological and fishery indicators.

Where the operating model simulations aims to address fundamental questions regarding the performance of alternative regional swordfish assessment models, these models will also be applied to a regional south-west Pacific stock assessment. The range of models being considered include MULTIFAN-CL, CASAL, a stock depletion estimator, and a spatially-disaggregated Pella-Tomlinson surplus production estimator. The preliminary results of the MULTIFAN-CL assessment was presented to the Scientific Committee of the WCPFC in 2005 with a number of conclusions. The assessment was sensitive to uncertainty in estimates of movement, and the assumptions made relating to movement parameters, e.g. length-specific movement rates, homogeneous mixing between areas, or foraging site fidelity. In the absence of tag-recapture information, movement must be inferred from temporal-spatial patterns in swordfish CPUE, catch length frequency, and sex ratios. Within the annual cycle of a model, seasonal variation in length frequency may indicate length-specific movement between areas. This highlights the importance of length frequency information for a swordfish stock assessment.

The spatial structure assumed in the stock assessment models offer a framework for assessing swordfish in NZ waters, i.e. that component of the annual dynamics and abundance existing within the spatial strata consistent with the NZ EEZ.

**(a) Catch per unit effort indices (CPUE)**

Relative abundance indices are an essential input to stock assessment models and are typically derived from a standardised CPUE series where the species of interest is the intended target. The target fisheries for swordfish operating in the southwestern Pacific Ocean, include the Australian longline fleet, and more recently, the New Zealand longline fishery that primarily is a bigeye tuna target fishery. The largest of the New Zealand tuna fisheries operates in the eastern part of the EEZ, with nearly 60% of its operations targeting bigeye.

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. 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.

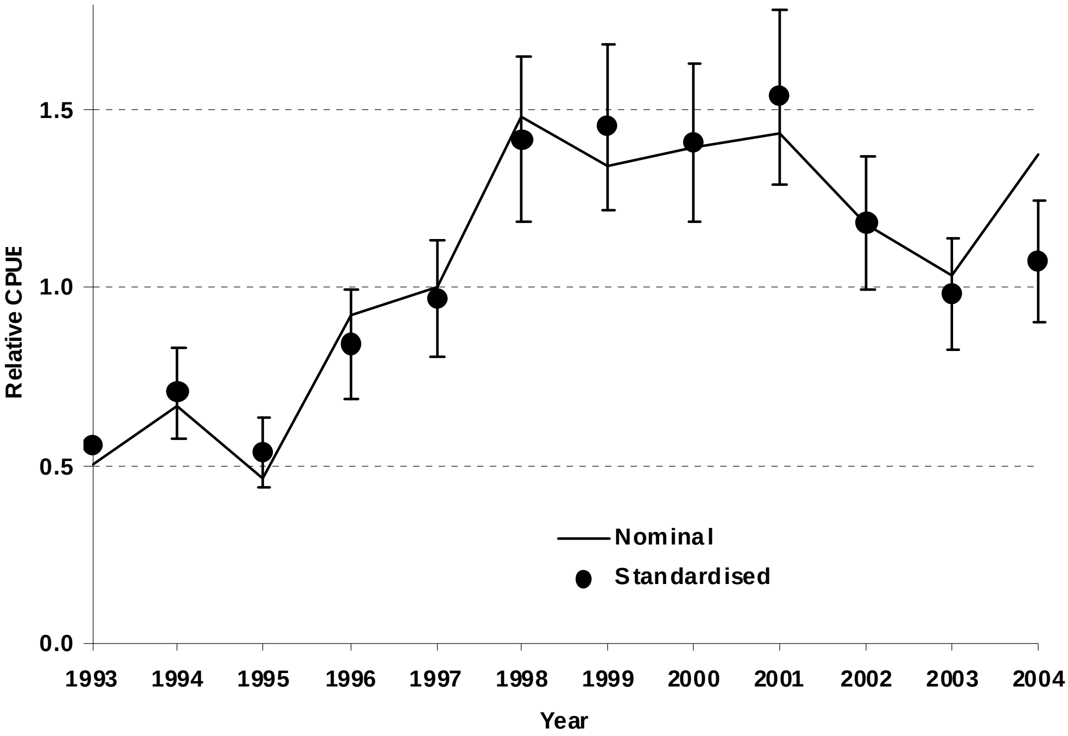



**Figure 1: Nominal and standardised annual swordfish CPUE indices (normalised about the geometric mean for each time series) for the longline fishery, 1993-2004. Vertical bars indicate two standard errors.**

**(b) Biomass estimates**

No estimates of biomass ($B_o$, $B_{msy}$, or $B_{current}$) are available.

**(c) Estimation of Maximum Constant Yield (MCY)**

There has been no sufficiently stable period of the longline fishery with which to estimate MCY using the $cY_{av}$ method.

**(d) Estimation of Current Annual Yield (CAY)**

Current biomass cannot be estimated, so CAY cannot be determined.

**(e) Other yield estimates and stock assessment results**

No information is available.

**(f) 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

Thus far, there is no evidence of a decline in average fish size within the EEZ that suggests that swordfish population age or size composition has been impacted by fishing mortality. However, the CPUE standardisation analysis indicates declines in relative abundance in recent years that is consistent with observed catch rates in other parts of the south-west Pacific region. No estimates of current biomass are available.

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.

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