Reproductive dynamics of broadbill swordfish (*Xiphias gladius*) in the domestic longline fishery off eastern Australia

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1. NON-TECHNICAL SUMMARY

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Objectives:

1. To provide information on the size-at-maturity and spawning dynamics of swordfish occurring in the eastern AFZ.
2. Determine whether the aggregations of swordfish off eastern Australia are the result of a spawning migration into Australian waters or some other factor.
3. Determine impact of fishing on the spawning biomass of swordfish by determining the proportion of the catch consisting of adult fish.
4. Determine linkages in seasonal changes in catch per unit effort of swordfish with seasonal changes in the oceanic environment.

Outcomes achieved:

This study provided the first description of reproductive activity in swordfish within the Australian region. The reproductive parameters we determined have already been used in the development of an operational model for the fishery, which previously relied on information from the northern hemisphere that , as it turned out, was significantly different from that found for the Australian population. In addressing the objectives of the study we now have a significantly better understanding of swordfish biology in eastern Australian waters (including their relationship to the complex oceanography of the region), that will support sustainable management of the fishery. This work has been presented at a number of forums, both academic and to the fishery, to increase awareness of the limits within which sustainable development of the fishery can occur. Finally, this work set the groundwork for a study of the age and growth of swordfish in Australian waters (also funded by FRDC and AFMA) and provided a significant input into sample collection.

Non technical summary:

The reproductive ecology of broadbill swordfish (*X. gladius*) (referred to as swordfish) was examined from fish caught by the domestic longline fishery off eastern Australia between May 1999 and March 2001, mainly between latitudes 20 and 30 ºS and out to longitude 165 ºE. The project was largely funded by the FRDC although additional funding was obtained from AFMA. The project was actively supported by the east coast longline fishery, for which we are grateful. The overall objective to understand the reproductive dynamics of the species in eastern Australian

waters was achieved although further study, expanded on in this report, would help to quantify more accurately some of the conclusions drawn.

Female swordfish outnumbered males by approximately 2.5 to 1 and were significantly larger than male swordfish. The proportion of males to females, although low, was relatively constant up to 170 cm orbital fork length (OFL) thereafter decreasing to zero for fish greater than 230 cm OFL. Relatively fewer males were caught in the fishery in winter and spring when the water was at its coldest. This fact, together with earlier sampling in more northern waters showing a more even sex ratio, indicates that male swordfish may move northward at this time.

A female spawning (gonadosomatic) index indicated a spawning period covering the months of September through to May. This pattern was supported by mean oocyte (egg) size and histology although hydrated oocytes, reflecting imminent spawning, were concentrated between December and March. Oocyte development was asynchronous and the presence of hydrated oocytes and post-ovulatory follicles in the same ovaries of a number of females indicated multiple spawning. Male reproductive activity extended from October through to April mirroring that of the females. Batch fecundity was linearly related to fish size with a range in the number of eggs from 1.2 and 2.5 million hydrated oocytes in fish ranging in size from 173 to 235 cm OFL. We estimated that mature swordfish spawned every 2.5 days or 90 times during the spawning season. However, as we don't know whether spawning fish remain in the area continuously this estimate can only be considered a maximum value. During the spawning period the proportion of spawning to inactive mature females was significantly higher in waters west of Longitude 158° E than in waters to the east. Further to the east, samples taken from the New Zealand fishery showed no actively spawning fish during the main spawning period. Spawning activity was restricted to waters with a sea surface temperature greater than 24 °C. Our data indicated that female swordfish may migrate from the east into the warmer waters of the East Australia Current to spawn although spawning fish may cover a wider geographic range in years when warm surface waters >24 °C extend further out to sea (Objective 2). We found no evidence to indicate that swordfish movements could be related to enhanced feeding conditions either in inshore or offshore waters.

Size at maturity (Objective 1) was determined for the swordfish catch taken off eastern Australia during the study period. Gompertz and Logistic models were used to estimate the proportion of immature to mature fish for both sexes. The length at which 50% of females reached maturity (L_{50}) was estimated at 193.6 (±0.51 SE) cm OFL using the Gompertz model and 199.8 (±0.51 SE) cm OFL using the logistic model. The male L_{50} was 85.8 cm using the Gompertz model or 102.3 cm OFL using a constrained version of the same. However, considering the relatively small data set for the male swordfish, considerable uncertainty surrounds these estimates. The size/weight frequencies were similar for both the sampled and total catch by the fishery between July 1999 and April 2001. We estimated that females comprised 70.7% of the total catch and males 29.3% of the total (Objective 3). We determined that 77.0% of the females caught were immature. In contrast, only 27.0% of the males caught were immature. This is because the males reach maturity at a much smaller size. It is not possible to say whether such a significant catch of immature fish will have an impact on the stock in future years. However, given the history of other swordfish fisheries that take a large proportion of immature fish, and where stock declines have been observed, the size of the catch will need to be monitored carefully in the future.

Ideally, the last objective (Objective 4) - to determine the linkages in seasonal changes in catch per unit effort with seasonal changes in the oceanic environment - will require a full analysis of the catch by the fleet in relation to the physical and biological oceanography of the region. However, we had the opportunity to examine fine scale relationships of the swordfish with the environment, enabled by an underway sampler we had installed on a longliner on this and an earlier study in the same region. The sampler measured sea surface temperature, salinity and fluorescence in relation to time and position, and for this study we were able to examine 4 years of continuously collected data. Stomach samples of swordfish were sampled opportunistically throughout this period. The contribution of environmental variables to variations in the catch per unit effort showed that month, year, fluorescence and moon phase were significant factors in swordfish distribution. Directly comparing the probability of catching swordfish to these factors indicated that swordfish were more concentrated in waters of higher temperature and lower fluorescence.

In summary, we found that swordfish spawned over the Australian summer in waters greater than 24 ºC. Although spawning females were captured across the latitudinal range of the fishery, significantly more females in spawning condition were found inshore than offshore, apparently associated with warm Coral Sea water and its southward extension, the East Australia Current. That mature-sized non-spawning fish were found in colder waters off New Zealand during the spawning period supports this conclusion. Female swordfish reached maturity progressively from 150 cm OFL onwards with half the female population mature by 195 cm OFL. Males matured at a significantly smaller size – half of the male population reaching maturity at a size of 85 cm OFL. The ratio of females to males in the fishery was approximately 2.5 to 1 varying with respect to season and length of fish. We estimated that approximately 70% of the females captured by the fishery were immature. Whether the take of these immature fish will impact on the spawning biomass is unclear as we are yet to determine whether the fishery covers the range of the parental stock. However, as similarly high catches of immature fish reported in the Atlantic fishery were thought to be impacting on the spawning biomass, continued monitoring is advised.

Swordfish ate mainly squid (72.5% by weight), fish (27.4% by weight) and occasionally crustacea (<0.1% by weight). The proportion of squid in the diet increased with size whereas the proportion of fish and crustacea decreased. Prey mass (an indication of feeding success) increased with predator size and decreased with increasing fluorescence although the reverse was true for prey number. We found that the swordfish were more commonly found in clearer waters where they apparently have more success in catching larger prey species. The higher numbers of smaller prey (specifically crustacea) taken in the more turbid waters suggest they feed also in the fronts on smaller, more numerous species. We found no evidence to support an alternative hypothesis that swordfish distribution was related to feeding. Rather, different feeding strategies were used depending on the oceanographic environment in which the fish were found.

Key words: swordfish, reproductive biology, feeding ecology, east coast longline fishery, fisheries oceanography, East Australian Current

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3. BACKGROUND

Development of the fishery

Over the past five years the domestic longline fishery for swordfish off eastern Australia has grown from a catch of less than 50 tonnes to its present rate of ~2500 tonnes per annum (AFMA data base). As the fishery is so young it is as yet not clear whether there is a seasonal difference in catch rates, although there does appear to be increased catches between August and December (AFMA data base). The rapid increase in catches of swordfish and the entry of new fishers into the fishery has raised concerns that sustainable catch levels will be passed before informed management is in place. To determine what level of fishing of swordfish is sustainable, information on basic population parameters such as longevity, age at maturity and stock structure is urgently required.

In response to the need for a better understanding of swordfish stock structure and population biology, ECTUNAMAC assigned high priority to these areas in their recent evaluation of research priorities for the east coast tuna and billfish fishery.

One aspect of the population biology of swordfish about which we know virtually nothing in our region is their reproductive biology and dynamics. In particular, is there a specific spawning area for swordfish in the SW Pacific? If so, is the Mooloolaba fishery targeting the stock as they aggregate to spawn? These are vital issues in developing a harvest strategy for our fishery. However, before we can answer such questions we need information on size-at-maturity and spawning dynamics, egg production and the sex ratio of catches. As yet there is no information on any of these in our region.

Reproductive dynamics of swordfish

Although nothing is known of the reproductive biology of swordfish in Australian waters, studies in the northern hemisphere indicate that the size of many of the fish being taken in the Australian fishery were under the size at which swordfish attain maturity (e.g. Taylor and Murphy 1992). That study and others in the northern hemisphere have also shown seasonal and spatial differences in spawning. For example, swordfish in the northern Atlantic Ocean spawn from December to June overlapping the northern hemisphere spring, whereas closer to the equator swordfish spawn year-round (Grall et al. 1983, Taylor and Murphy 1992, DeMartini 1997, Arocha and Lee 1998). There are also longitudinal differences - mature swordfish from similar latitudes in the Pacific Ocean have been found in spawning condition in the west but not in the east (Kume and Joseph 1969). These studies also found localised spawning areas relatively close to the coast in a number of areas. As yet we do not know any of these details for our stock but if they are part of a spawning migration, increased fishing pressure may impact on their long-term viability.

Mature female swordfish are significantly larger than males and although sex ratios in total do not depart from a 1: 1 ratio, there are latitudinal and longitudinal differences. In the northern hemisphere mature males appear to concentrate closer to the equator whereas females are more common away from the equator (DeMartini 1997). Such information, also necessary for accurate stock assessment, and like spawning data, is not available for the Australasian region.

Physical environment

The east coast longline fishery extends from 20 to 40 ° S and seaward to ~ 165 ° E, covering an approximate area of 750,000 square miles. The fishery therefore potentially covers a wide range of habitats, both in terms of the physical oceanography of the region and the seabed topography. The main area of the fishery is located over a deep basin through which a chain of seamounts, the Tasmantid Guyots, extend along Longitude 156 ºE. Deeper water continues out to approximately 158 ºE where another series of seamounts are found. Further east the seabed shallows to approximately 1000 m to a plateau known as the Lord Howe Rise. Little is known of the biology and ecology of these seamounts and plateaus although a recent study of the benthic fauna showed a high degree of endemism of their biota (De Forges et al. 2000). Whether this endemism extends to the midwater fauna preyed on by the swordfish associated with these seamounts is unknown.

The oceanography of this region is governed by the interaction of eastward-flowing subantarctic waters reaching the Tasman Sea from the south and westward-flowing tropical waters via the South Equatorial Current from the north. The extent and intensity of these currents is dependant on the time of year and the intensity of interannual cycles such as the El nino southern oscillation. In spring the South Equatorial Current feeds the East Australia Current which fills down the coast of eastern Australia through spring and summer retreating northward again in autumn. In some years there are dramatic differences in the volume and extent of the southward flow which has been linked to various indicators of the El Nino southern Oscillation. The eastern AFZ is considered to be low in biological productivity due to an absence of permanent nutrient-rich upwellings and currents (Ward and Elscot, 2000 p137). However, the development of this and other fisheries in recent years, and the increasing awareness of the links between inshore and offshore processes indicate this is likely to be too simplistic a view. The concentration of swordfish captures around seamounts and the Lord Howe Rise suggests that subsurface factors (e.g. Taylor columns) may also play a role in enhancing prey levels in the area.

Alternate hypotheses

The work proposed here will concentrate on the reproductive dynamics of the species. However, we will incorporate our growing knowledge of the oceanography of the area and an analysis of swordfish feeding habits to determine whether seasonal increases in swordfish catch rates are linked to factors other than reproductive activity. For example, there is a spring increase in plankton production generally along the east coast of Australia which may provide increased prey levels that could attract the swordfish. We will therefore aim to continue our analysis of the regional oceanography that has resulted from our evaluation of ocean colour satellite imagery and longline catches off eastern Australia over the past two years (CSIRO1993).

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4. NEED

The swordfish fishery has risen in the space of five years from an annual catch of less than 50 tonnes to ~2500 tonnes presently. A number of fishers with dormant licenses in the east coast longline fishery are now changing their boats over to take advantage of this new fishery. Others that have been in the fishery since its start are now upgrading their boats or buying new ones to improve their catches. At present there are ~ 100 licenses in operation with a further 100 still to become operational. However, there is as yet no idea of the size of the stock on which this fishery is based. Without a concerted effort to establish basic population parameters upon which suitable management advice can be given the swordfish fishery is in danger of reaching unsustainable levels of fishing. In the northern hemisphere, swordfish fisheries are already managed under strict quotas. Recently, there have been moves off Florida, USA to halt fishing of swordfish for up to three months to allow juveniles to grow through to maturity (Anon. 1998). There is a pressing need, therefore, to supply basic population parameters upon which effective management can be given.

The need for such information has been recognised by the Eastern Tuna MAC. They provided a list of 11 priority issues for the east coast tuna industry many of which related to the lack of understanding of the population parameters of swordfish. They concluded that research was needed for swordfish on stock structure (priority 1), determination of age and biological characteristics (priority 5), spatial and temporal dynamics of their distribution (priority 7) and seasonal movement and migration patterns (priority 9). All of these priorities cannot be fully addressed without an understanding of the reproductive dynamics of this species.

References

Anonymous (1998) Florida asks U.S. to halt commercial swordfishing. National Fisherman"

5. OBJECTIVES

5. To provide information on the size-at-maturity and spawning dynamics of swordfish occurring in the eastern AFZ.
6. Determine whether the aggregations of swordfish off eastern Australia are the result of a spawning migration into Australian waters or some other factor.
7. Determine impact of fishing on the spawning biomass of swordfish by determining the proportion of the catch consisting of adult fish.
8. Determine linkages in seasonal changes in catch per unit effort of swordfish with seasonal changes in the oceanic environment.

6. PROJECT RESULTS

6.1 Reproductive dynamics of broadbill swordfish, *Xiphias gladius*, in the domestic longline fishery off eastern Australia

Jock Young, Anita Drake, Jessica Farley, Thor Carter and Michael Brickhill

Abstract

The reproductive ecology of broadbill swordfish, *Xiphias gladius*, was examined from 1437 fish (size range 50–300 cm orbital fork length [OFL]) caught in the domestic longline fisheries off eastern Australia and New Zealand between May 1999 and March 2001. Reproductive activity was assessed using histology, gonadosomatic index and maximum oocyte size. Males were significantly smaller than females and represented less than one third (29.3%) of the sampled fish. Sex ratio differed significantly with respect to fish size and time of year. Females began maturing at 150 cm OFL and spawned from September to March with the greatest activity from December to February. Males began maturing at 90 cm OFL; ripe males were found from January to March but also in May and October suggesting an extended reproductive period. During the spawning period the proportion of spawning to inactive mature-sized females was significantly higher in waters west of Longitude 158°E than in waters to the east. Further to the east, samples taken from the New Zealand fishery showed no actively spawning fish during the main spawning period. Females were increasingly reproductively active as water temperature increased beyond 24°C and sea surface chlorophyll a decreased below 0.2 ug/l. Batch fecundity was linearly related to fish size with a mean batch fecundity of 1.66 million oocytes in females ranging in size from 173 to 232 cm OFL. The presence of hydrated oocytes and post-ovulatory follicles in the same ovaries indicated multiple spawning, and depending on the time taken for the follicles to degrade, may have been daily at the height of the spawning season.

Introduction

Broadbill swordfish (*Xiphias gladius*) (referred to as swordfish) have a broad distribution in all the major oceans to 50º south and north, limited only by the 13ºC sea surface isotherm (Palko et al.1981). They are typically associated with boundary currents as well as seamounts and plateaux where they may form resident populations (Carey and Robinson 1981, Sedberry and Loeffer 2001). Off eastern Australia, where such conditions prevail, swordfish have been fished commercially, firstly by Japanese longliners and more recently by the Australian longline fishery (Campbell et al. 1998, Caton et al. 1998, Ward and Elscot 2000). Australian landings of swordfish have increased from less than 100 tonnes in 1995 to their present catch of ~2500 tonnes (Ward and Elscot, 2000). Studies from the northern hemisphere (e.g. Taylor and Murphy 1992) indicate that the size of many of the fish being taken in Australia is under the size at which swordfish attain sexual maturity, which along with the increased fishing pressure has raised concern that populations may be over-exploited before adequate controls are in place. Despite the growing importance of swordfish to the domestic fishery, little is known about the life history of the species in Australian waters, particularly their reproductive biology. To determine a sustainable level of fishing for swordfish, information on basic population parameters, particularly those concerning the reproductive dynamics of the species in the Australian region, is required.

In the northern hemisphere the reproductive biology of swordfish is well known although there is a great deal of variation in the reproductive parameters reported for the species. Female swordfish usually outnumber males although this relationship is affected by fish size as well as spatial and temporal factors (Arocha 1997, De Martini et al 2000). For example, mature males appear to concentrate closer to the equator whereas females, particularly larger individuals, are more common in temperate latitudes (DeMartini 1999). Similarly, spawning in swordfish can vary both seasonally and spatially. Swordfish in the northern Atlantic Ocean spawn from December to June, whereas closer to the equator they spawn year-round (Grall et al. 1983, Taylor and Murphy 1992, DeMartini 1999, Arocha and Lee 1998). Kume and Joseph (1969) found that mature swordfish from similar latitudes in the Pacific Ocean were in spawning condition in the west but not in the east. Swordfish are also known to spawn in localized areas relatively close to the coast and in relation to physical variables, particularly sea-surface temperature (Arocha 1997). Given the varying life history scenarios of this species worldwide it is unclear which of the above apply to the stock in the Australian region.

In this section we examine aspects of the reproductive dynamics of swordfish off eastern Australia and New Zealand. Specifically, we determine sex ratio, spawning patterns in relation to season, area and oceanographic factors, and fecundity. Size-at-maturity is dealt with in detail separately in this report. We also examine alternative methods for determining the seasonal and spatial extent of spawning in swordfish.

Methods

Oceanographic sampling

Underway sea surface temperature, salinity and fluorescence were collected on the longliner "Sniper" as part of a study of ocean colour satellite imagery, and where a full description of the equipment can be found (Young et al. 2000). Satellite sea surface temperature images from the AVHR NOAA satellite were archived during the study for later comparisons with the distribution of swordfish of known reproductive status. Sea surface chlorophyll data was obtained from the CSIRO Marine Research remote sensing group for the same purpose, and was courtesy of the NASA SeaWiFS Project and Orbimage.

Biological sampling

Swordfish were sampled from three fisheries: the Australian east coast longline fishery based out of Mooloolaba in southern Queensland, the domestic longline fishery around New Caledonia and the domestic longline fishery off the North Island of New Zealand (Fig. 1).

Swordfish were sampled from the Australian fishery between August 1998 and March 2001. Fish were captured by longlines set at night (between 2100 h and 0600h) and fished to a depth of approximately 60 m. Gonads were collected predominantly between 20°S and 35°S from the coast to approximately 165°E (Fig. 1). However, most came from between 25°S and 30°S and were distributed between the inshore seamounts and offshore as far as the northward extension of the Lord Howe Rise in waters with a depth range from 1000 to 4000m (Fig. 1). Samples were collected either by CSIRO observers from longliners or by longline crews during fishing operations at sea. Data were collected on the length and sex of 1437 fish, and of these gonads were sampled from 1016 females and 421 males. Fish ranged in size from 55 to 300 cm OFL (posterior edge of orbit to the fork of the tail) for females and 50 to 220 cm OFL for males (Table 1, Fig. 1a). There was no significant difference in the size of swordfish caught inshore and offshore for either females or males over the study period (Komolgorov Smirnov Test, P>0.1).

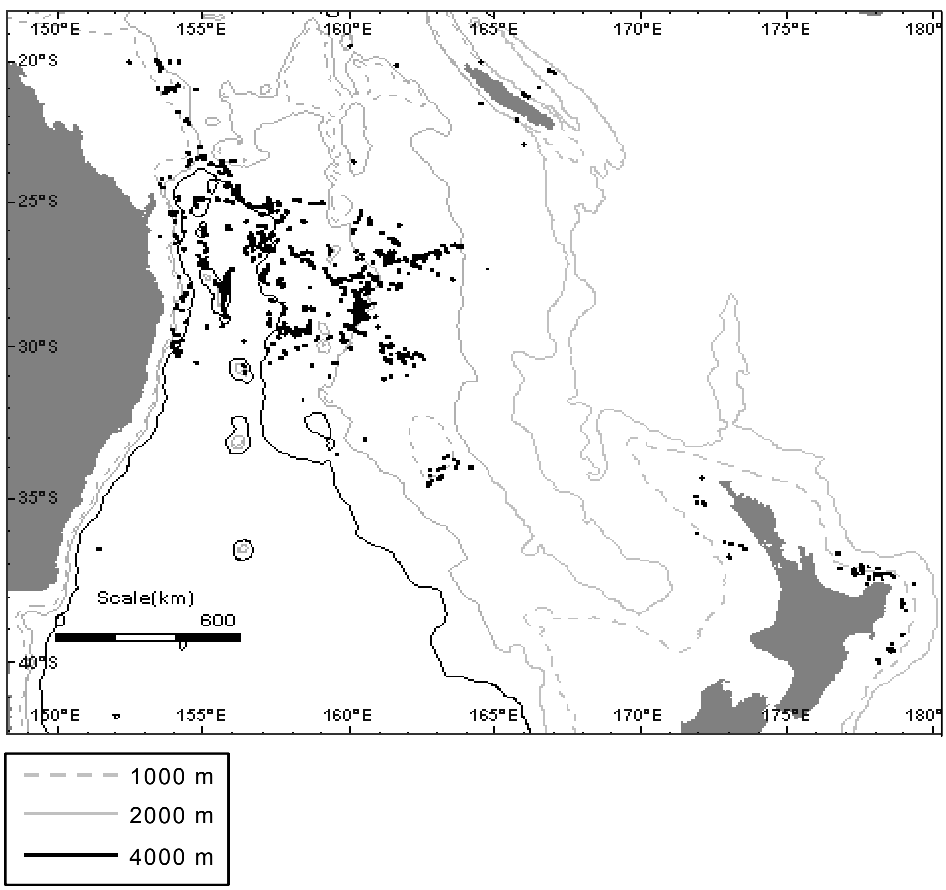


Figure 1: Study area showing capture positions of broadbill swordfish (*X. gladius*) from which gonads were collected and depth contours of the area.

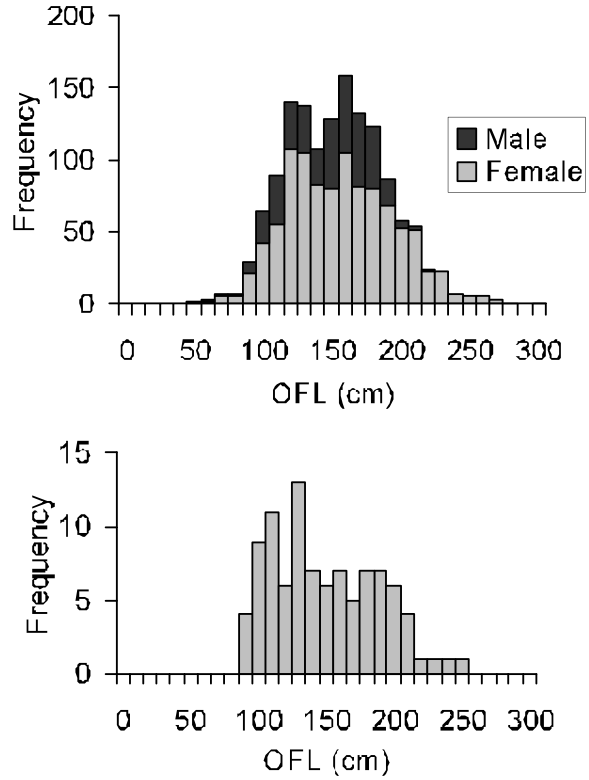


Figure 1a: **Size distribution of broadbill swordfish (*X. gladius*) sampled from the eastern Australia fishery (top) and the New Zealand fishery* below (males, filled histograms; females, open histograms,* males not collected).**

Table 1: Number and size range of broadbill swordfish, *Xiphias gladius*, from which reproductive data were extracted between 1998 and 2001 (OFL; orbital fork length in cm).

Year	Season	Female			Male			Total n
		n	OFL range	Mean OFL (SE)	n	OFL range	Mean OFL (SE)	
1998	Win	9	112 - 187	147.3 (± 9.5)	6	136 - 176	157.7 (± 6.4)	15
1998	Spr	7	122 - 173	143.1 (± 6.8)	0			7
1998/99	Sum	0			0			0
1999	Aut	6	143 - 217	180.3 (± 10.9)	2	110 - 152	130.8 (± 20.8)	8
1999	Win	139	55 - 260	158 (± 3.2)	42	50 - 215	158.8 (± 5.6)	181
1999	Spr	131	155 - 250	160.7 (± 3.1)	45	99 - 198	150.3 (± 3.7)	176
1999/00	Sum	163	97 - 280	168.9 (± 3.3)	60	100 - 220	147.6 (± 4.0)	223
2000	Aut	167	80 - 300	158.9 (± 3.0)	95	92 - 208	150.3 (± 2.9)	262
2000	Win	123	60 - 275	162.6 (± 3.5)	40	97 - 190	146.3 (± 4.0)	163
2000	Spr	240	70 - 270	153.6 (± 2.3)	66	95 - 195	150.3 (± 3.6)	306
2000/01	Sum	66	73 - 232	151.4 (± 5.0)	43	67 - 183	141.2 (± 5.1)	109
2001	Aut	37	99 - 216	163.2 (± 6.3)	29	78 - 191	156.2 (± 5.5)	66
Total		1088			428			1516

Seventeen females ranging in size from 97 to 248 cm OFL were sampled from the longline fishery around New Caledonia between October 1999 and February 2001. A further 95 females ranging in size from 93 to 252 cm OFL were sampled from the New Zealand fishery between January and February 2001.

For each swordfish the orbital fork length was measured to the nearest centimetre. The gonads were then removed, labeled with the sex, length of the donor fish, position and date of capture and frozen. A sample was taken from 27 ovaries prior to freezing and fixed in 10% buffered formalin to compare the histology of frozen and unfrozen specimens.

Sex ratio

A generalized linear regression was used to determine the factors affecting sex ratio for fish sampled in the Australian fishery. Forward stepwise regressions determined which of the factors – fish length, time of year, year, area (inshore [west of 158ºE] or offshore [east of 158ºE) - significantly affected sex ratio.

Laboratory processing

In the laboratory, gonads were thawed, trimmed of fat and the sex confirmed. The paired gonads were individually weighed (±1 g) and a sample from 951 ovaries and 233 testes pairs were preserved in 10% buffered formalin for oocyte measurements and/or histology.

Ovaries were assessed for reproductive activity using three different methods – histology, largest oocyte size and by gonadosomatic index (GSI). Histology is considered the most precise measure to determine the reproductive status of individual fish (Hunter and Macewicz 1985). Therefore, we used histology as our primary method for determining reproductive activity. To prepare histological sections, a portion of preserved ovary sample was embedded in paraffin, sectioned to 6µm and stained with Harris's haematoxylin and eosin counter stain. After initial analysis of histological material sampled from Australia, only ovaries from New Zealand or New Caledonia that contained either advanced staged oocytes (or greater) or were from females ≥ 150 cm (OFL) were sectioned. Histological sections were examined using criteria developed for the northern anchovy, Engraulis mordax (Hunter and Macewicz 1985a, 1985b), and swordfish (Arocha 1997). Each ovary was staged according to the most advanced group of oocyte present in the sample; unyolked, early yolked, advanced yolked, migratory nucleus or hydrated. Postovulatory follicles (POFs) were identified as either new (no signs of degradation) or older (signs of degradation). Atresia (resorption of oocytes) of advanced yolked oocytes was recorded to aid in the determination of the reproductive status of individual swordfish. The rate of atresia was recorded for each sample and graded on a level from 0 to 3.

0. No advanced yolked oocytes are in the alpha stage of atresia.
1. <50% of advanced yolked oocytes are in the alpha stage of atresia.
2. >50% of advanced yolked oocytes are in the alpha stage of atresia.
3. 100% of advanced yolked oocytes are atretic or beta atresia present. Only unyolked and early yolked oocytes remain viable.

A comparison of histological sections prepared from 27 ovaries that were subsampled both prior to and after freezing showed no difference in the observation or classification of oocyte stage, atresia or postovulatory follicles.

As histology is a time consuming and expensive process, we also examined the use and suitability of the two other techniques as indicators of reproductive activity. To estimate the largest oocyte size present in the ovary, a small amount of tissue was teased out under a stereo microscope and the diameter of the five most advanced oocytes was measured (on a random axis) to the nearest 0.01 mm. Measurements were carried out with a Leitz stereo microscope fitted with a Phillips CCD camera in conjunction with the NIH Image 1.5.4 computer software program. The camera was calibrated by an eyepiece micrometer with an accuracy of ±0.01 mm.

A gonadosomatic index (GSI) was determined for individual females using the formula GSI = Ln (GW) / Ln (OFL) where GW = gonad weight (g) and OFL (cm) = orbital fork length (following Hinton et al. 1997) after linear regression showed no significant interaction of gonad stage with the relationship between Ln (GW) and LN (OFL) (P=0.96).

Linear regression analysis was run on slopes of ln(GW) versus ln(OFL) equations for males at different stages of testicular development. These slopes were then statistically compared using an analysis of covariance (ANCOVA) homogeneity of slopes test. The same statistical procedures were applied to non-logged data (GW vs. OFL).

Male reproductive activity was assessed by histology and GSI. Male gonads were classified into one of six developmental stages based upon histological criteria developed by Grier (1981) and De

Sylva and Breder (1997). One difficulty associated with staging swordfish testes is that the histology of individuals that have not spawned (small stage 2 fish) may sometimes resemble that of recovering post-spawning individuals (large stage 6 fish), particularly in cases where residual spermatozoa are reabsorbed after spawning (Billard and Takashima 1983). To distinguish these individuals (without knowing their age or body size beforehand) we assessed the degree of lobule development in the absence of spermatogenesis (De Martini et al. 2000). Male swordfish were considered mature if their gonad development stage was stage 4, 5 or 6. Maturity was indicated in stage 4 and 5 individuals by the presence of spermatozoa in the duct.

Fecundity and spawning frequency

To determine the type of oocyte development in swordfish, the distribution of oocyte sizes was measured for three ovarian samples, at varying stages of maturity. A subsample was taken from each ovary and teased apart. The diameter of ~1000 randomly chosen oocytes > 0.10 mm was then measured on a random axis to the nearest 0.01 mm.

Batch fecundity estimates were made on ovarian samples that contained unovulated hydrated oocytes with not more than 50% atresia and with no new postovulatory follicles (Schaefer, 1996). Batch fecundity was determined using the gravimetric method (Hunter et al. 1985) where counts were made of hydrated oocytes present in ovarian subsamples of known weight. Frozen gonad samples were thawed and weighed to the nearest gram. Six subsamples (range 1 - 4 g) were taken from each ovary. The subsamples were weighed to an accuracy of ±0.005 g and stored in 10% buffered formalin. Subsamples were teased apart to release the oocytes from the connective tissue, and then washed through two sieves (mesh size 0.5 mm and 1.0 mm) to separate out the hydrated oocytes. The number of hydrated oocytes was then counted under a stereomicroscope for each of the twelve subsamples and multiplied up to the total weight of both ovaries to determine the total batch fecundity. The mean of the twelve batch fecundity estimates was used as the final batch fecundity for the fish.

Two methods are commonly used to estimate the average spawning frequency of a population - the “postovulatory follicle method” and the “hydrated oocyte method” (Hunter and Macewicz, 1985b). Since the length of time postovulatory follicles remain visible in the ovary is unknown in swordfish, we used the “hydrated oocyte method” for fish caught in Australian and New Caledonian waters. To use this method, females must be sampled just prior to spawning so that all fish that were going to spawn could be identified. Since all fish were sampled by longlines set at dusk and hauled at dawn, and spawning in swordfish is presumed to occur during the night (Palko et al. 1981), we believe our sampling fulfils the requirements of this method. We calculated the number of fish with hydrated or migratory nucleus oocytes present (since both indicate imminent spawning) as a proportion of the total number of mature females. Our estimate, however, is likely to overestimate the spawning frequency of swordfish if fish are caught before the onset of the migratory nucleus stage.

Geographic patterns in spawning

Samples were examined in relation to their geographic position and time of year to determine whether there were spatial and temporal differences in gonad maturity. Samples from the Australian region were assessed based on two geographical areas: inshore (west of 158ºE), and offshore (east of 158ºE). Stage of maturity of individual females was further compared at point of capture with sea surface temperature and chlorophyll a concentration.

Results

Physical environment

In winter 1999, satellite imagery of sea-surface temperatures off eastern Australia showed the 22°C isotherm extending south to ~ latitude 33°S along the eastern Australian coastline where an anticyclonic warm-core eddy was beginning to form (Fig. 2). Surface waters within the 22°C isotherm extended seaward to the northeast beyond 165°E. By December 1999, a narrow filament of warmer (>24°C) East Australia Current (EAC) water had extended south along the coastline to 34°S. In June 2000 there was a similar distribution of 22°C water. In December 2000, however, surface waters were generally warmer throughout the study area. On the main fishing grounds (see Fig. 1) off eastern Australia, sea-surface temperatures ranged between means of ~20°C in late winter and early spring to between 25°C in the 1999-2000 summer and 27°C in the 2000-2001 summer, the latter peak corresponding to a flush of warm water down the coast during the 2000-2001 summer (Fig. 2). The variation in underway sea surface temperature values in the two years of the study highlighted the interannual variability in oceanographic conditions of the waters off eastern Australia.

Underway sea surface salinity ranged between ~34.9 and 36 parts per thousand of seawater. Seasonal patterns in salinity were less clear than found for temperature from the underway sampling. There was an indication of higher values in summer and autumn although there was substantial interannual variation (Fig. 2). Modeled sea surface salinity for the region showed an area of higher salinity water between Noumea and New Zealand than in waters to the south and north, presumably related to the influx of South Equatorial Current water at this latitude (Fig. 2a). The region of high salinity was sustained year round although was more extensive in late autumn than at other times of the year. Sea surface fluorescence ranged from <0.1 ug l^{-1} in late summer up to 0.3 ug l^{-1} in late winter with little variation between years. Fluorescence essentially followed a reverse path to that of the sea surface temperature reflecting the oligotrophic (nutrient poor) nature of the regions' water masses during the Australian summer.

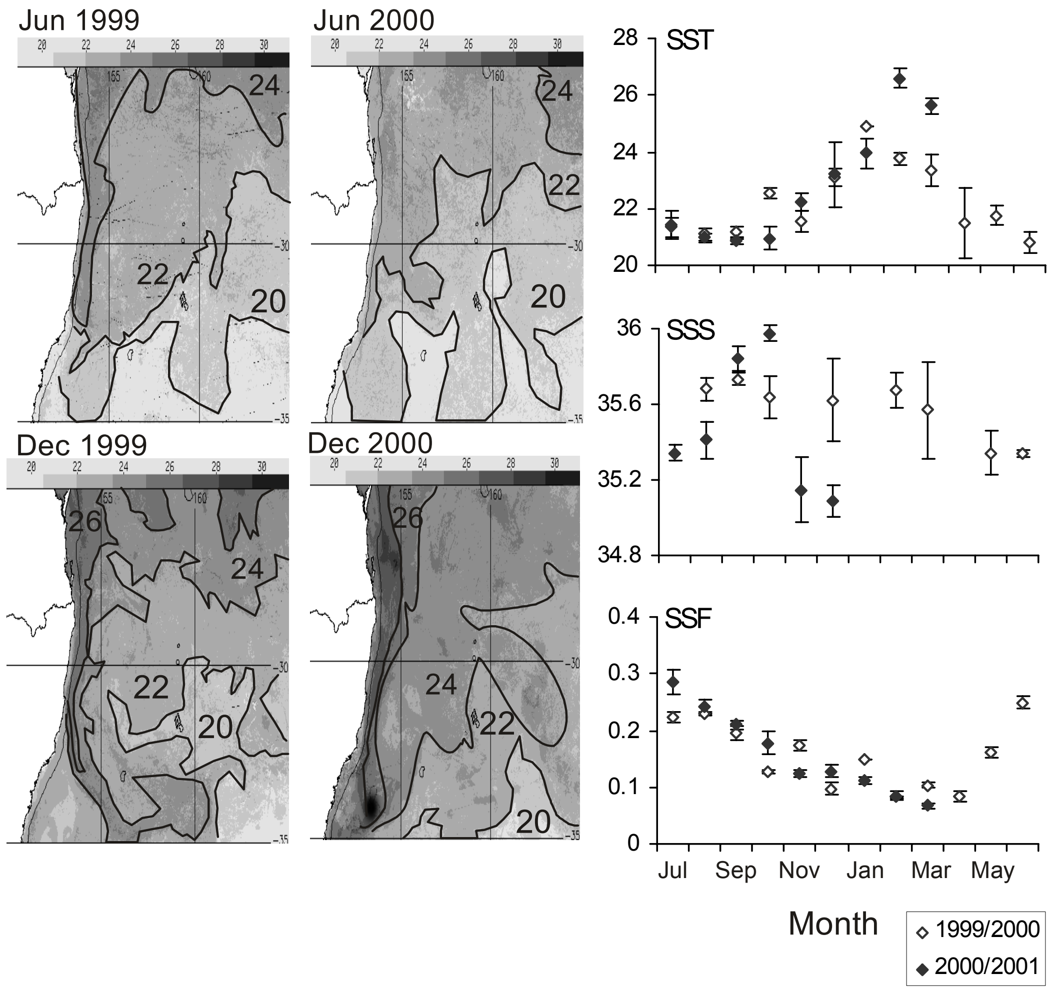


Figure 2: Grey-scale satellite images of June and December sea-surface temperature (SSTºC) in 1999 and 2000, and mean monthly plots of underway sampler-derived SST, sea surface salinity (SSS, ppt) and sea surface fluorescence (SSF, µg l^{-1}) in relation to time of year for the main fishing area.

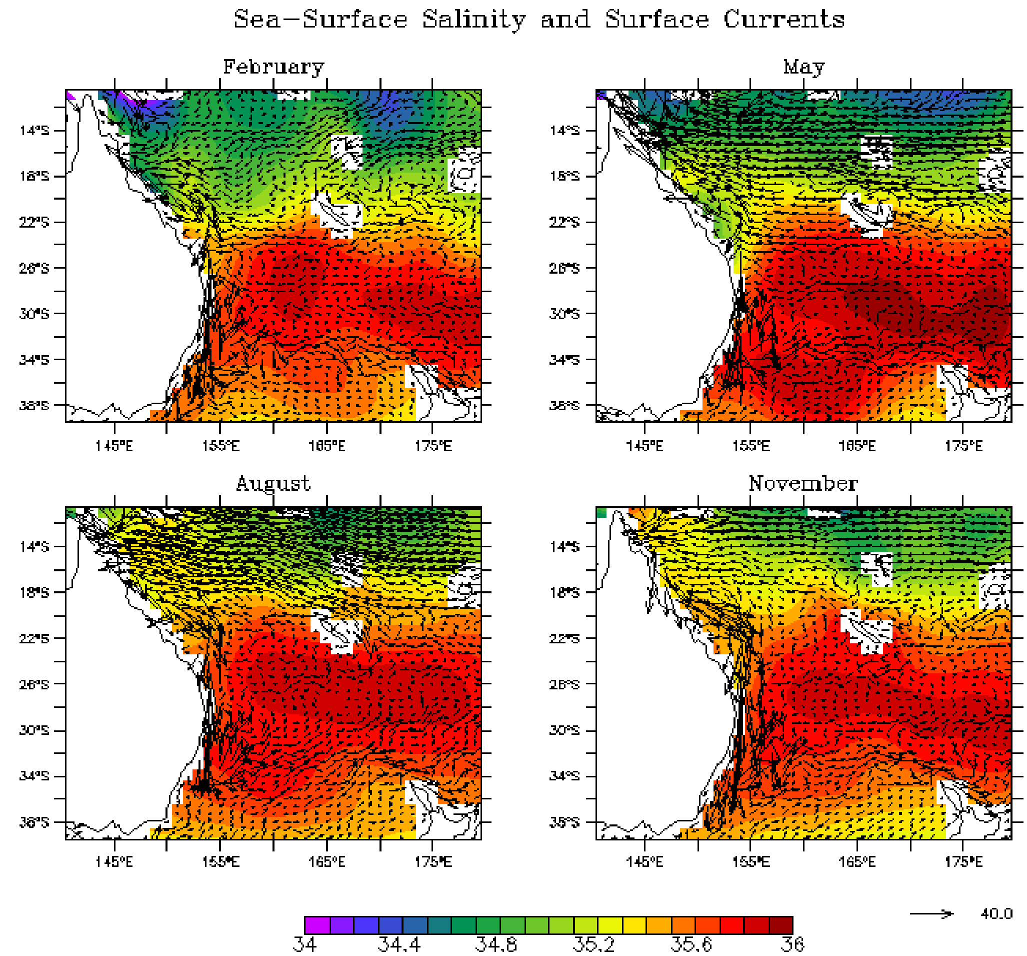


Figure 2a: **Modeled sea-surface salinity (ppt) and surface currents in summer (February), autumn (May), winter (August) and spring (November) off eastern Australia (source: Levitus, S., R. Burgett and T.P. Boyer: NOAA Atlas (NESDIS). World Ocean Atlas 1994. Volume 3: Salinity. U.S. Department of Commerce. National Oceanic and Atmospheric Administration. courtesy of Andreas Schiller, CSIRO Marine Research).**

Sex ratio

Overall, males made up 29.3 % of the total sample of 1437 swordfish examined for reproductive activity. The ratio of males to females was significantly related to the size of the fish and to season (Table 2). The relationship between sex ratio (y) and length (x) could be best described by the polynomial function: y = 3E-09X5 – 2E-06X4 + .009X3 – 0.1513X2 + 11.378X – 238.43 (r^2 = 0.82) (Fig. 3). Other functions, in particular the logistic function, failed to describe the variability in sex ratio in smaller fish. Although there was significant variation in sex ratio below 150 cm OFL there was a rapid increase in the proportion of females to total fish caught after fish reached 180 cm and by 220 cm all fish caught were females (Fig. 3). The proportion of males to females was significantly higher in summer and autumn suggesting that males may migrate out of the area in winter and spring, possibly to the north, during the colder months (Fig.4). Although area had no affect on sex ratio there was an interaction between area and season indicating there may have been an affect of different movement patterns by the fishers.

Table 2: Results from a generalized linear regression of the model: sex ~ length + area + season + season*area (family binomial).

	Df	F value	P
Length	1	20.55	< 0.001
Season	3	7.27	< 0.001
Area	3	1.32	ns
Season:area	9	1.97	0.04

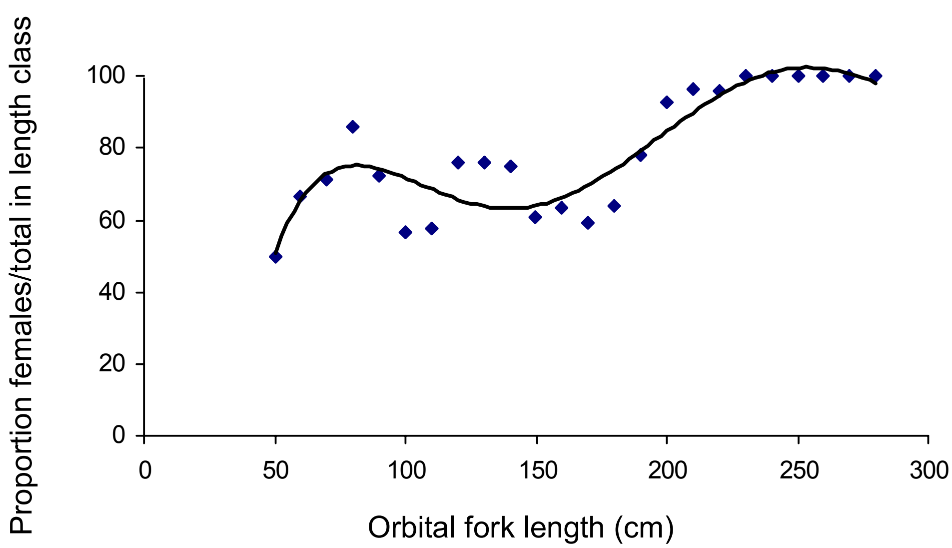


Figure 3: Proportion of females to total number of broadbill swordfish (*X. gladius*) sampled in relation to orbital fork length (Australian fishery only).

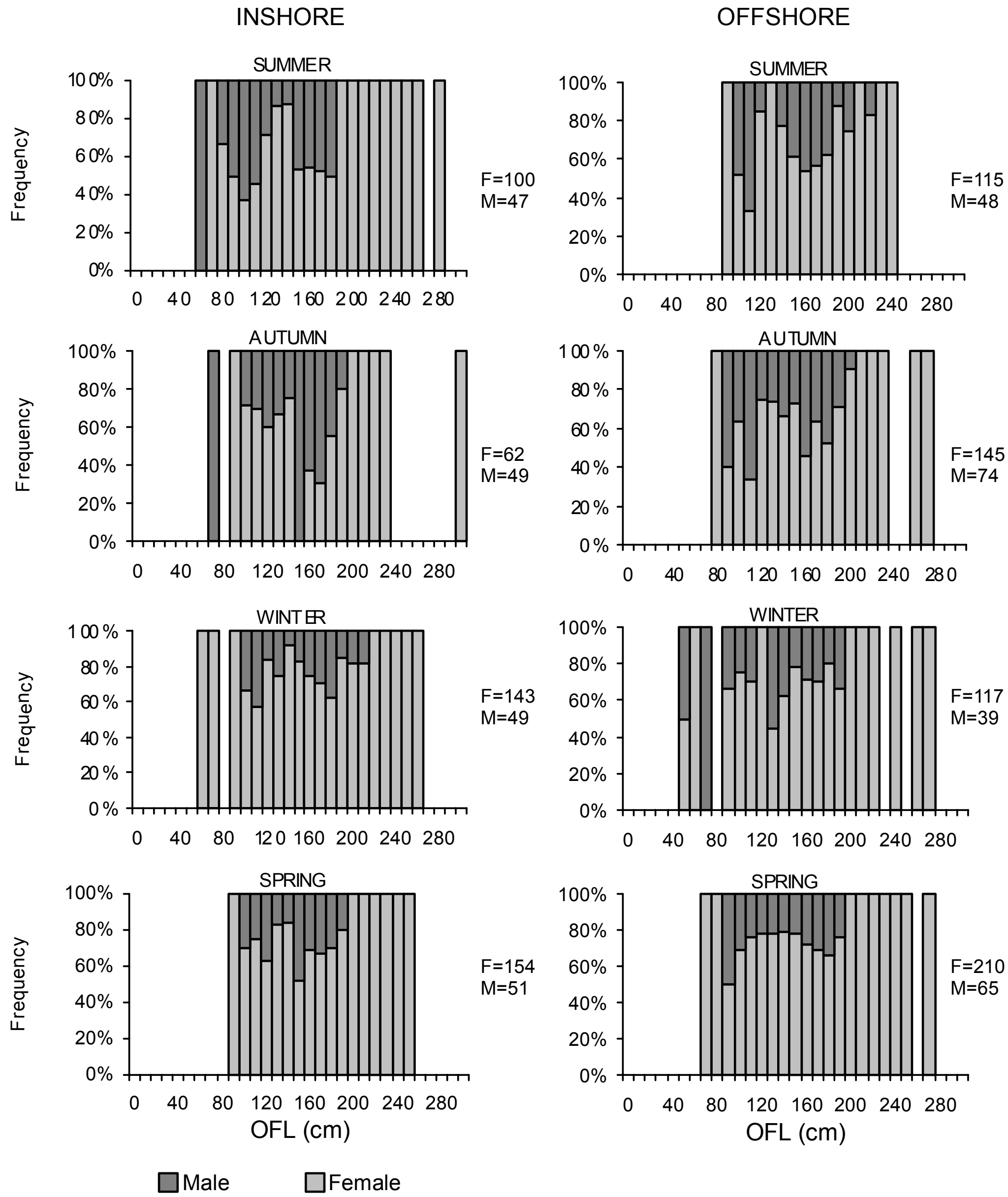


Figure 4: **Proportion of female (light shading) to male (dark shading) broadbill swordfish (*X. gladius*) by 10 cm length classes in relation to season and area (Inshore, <158ºE; Offshore, >158ºE) (Australian fishery only).**

Female classification and reproductive activity

Swordfish ovaries are circular in cross section, bilobed and asymmetrical. The right ovary (RO) was larger than the left (LO), the relationship between them described by the equation LO = 1.3138(RO) + 61.08 (n=1362, $r^2 = 0.88$). Ovaries had a well-developed mass of connective tissue and smooth muscle with a very thick ovary wall. Immature ovaries were generally small and firm weighing less than 500 g, whereas mature ovaries weighed up to 18 kg with hydrated oocytes clearly visible in cross section (Fig. 5). Individual oocytes ranged in size from <0.2 mm for immature oocytes to 1.65 mm for fully developed (hydrated) oocytes (Fig. 6).

Using microscopic characteristics, we developed a classification scheme for female swordfish (Table 3, Fig.8). We classified females as mature (actively spawning) if their ovaries contained advanced yolked oocytes, and there was evidence of recent or imminent spawning activity (migratory nucleus, hydrated oocytes or postovulatory follicles). Those with 100% of yolked oocytes in the alpha or beta stages of resorption were classed as post-spawning. It is likely that females classed as "post-spawning" will regress at some stage to a "resting" state during the year. These females were histologically identical to immature females. Table 3 shows the number of females in each reproductive class.

Figure 5: Female broadbill swordfish (*X. gladius*) carcass from which ripe gonads (pictured in foreground) were dissected (scale on carcass 150 cm; scale next to gonads 100 cm).

The smallest mature female sampled, based on histological criteria, was 120 cm OFL, and the smallest female in spawning condition was 154 cm. The majority of females less than 150 cm OFL showed little development based on oocyte size (Fig. 7), or gonad index. The smallest female with a GI>1.375, used by Hinton et al. (1997) to classify swordfish as reproductively active, was 154 cm.

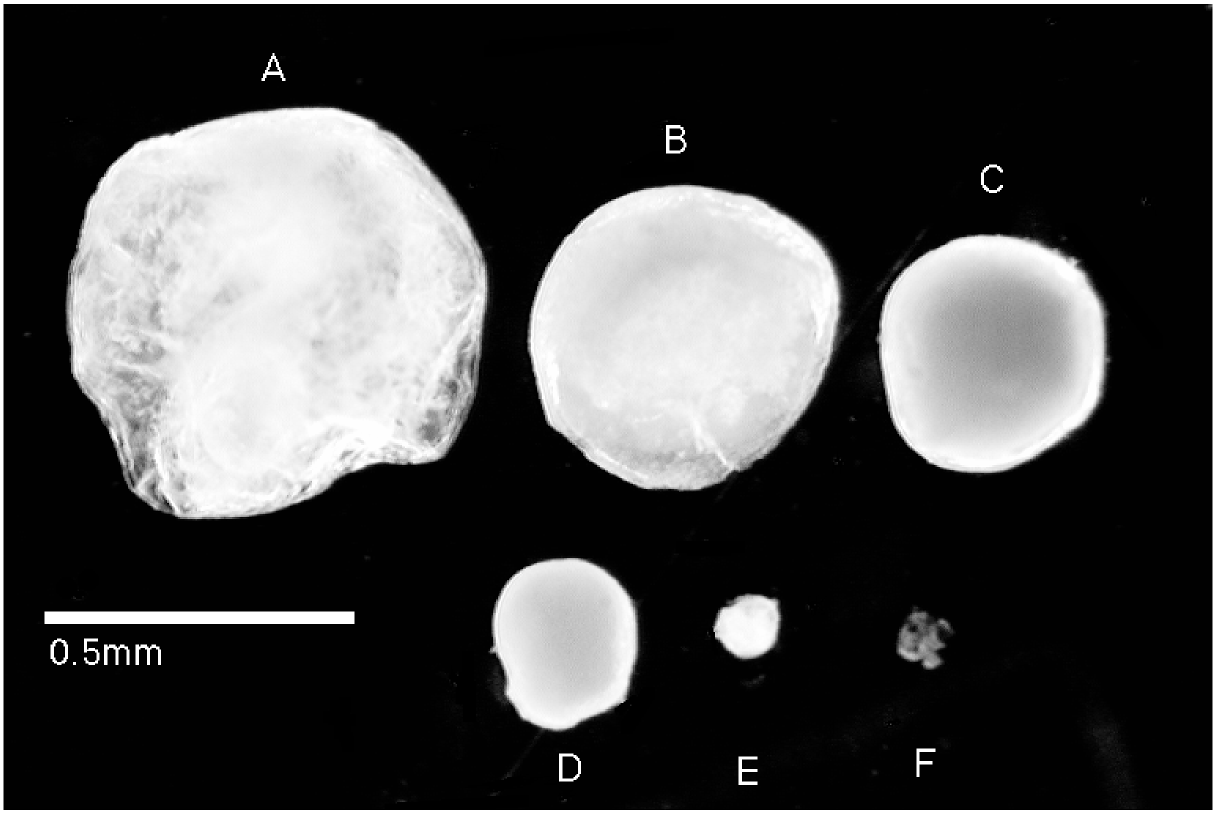


Figure 6. **Size range of developing and fully developed (hydrated) oocytes from a female broadbill swordfish (*X. gladius*) taken off eastern Australia (scale on figures).**

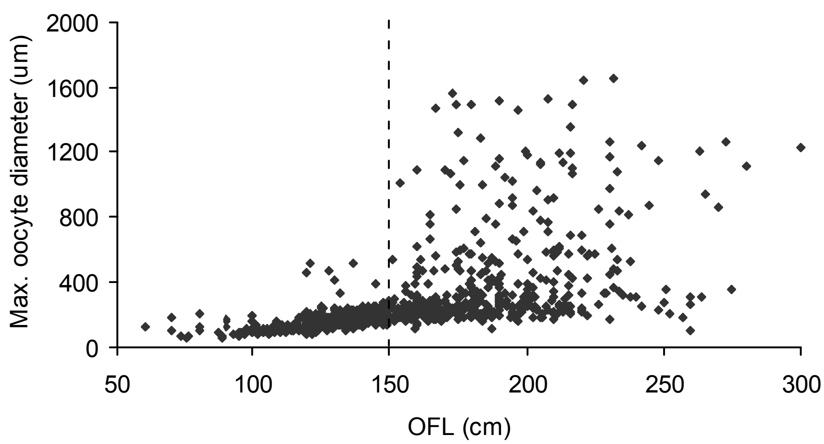
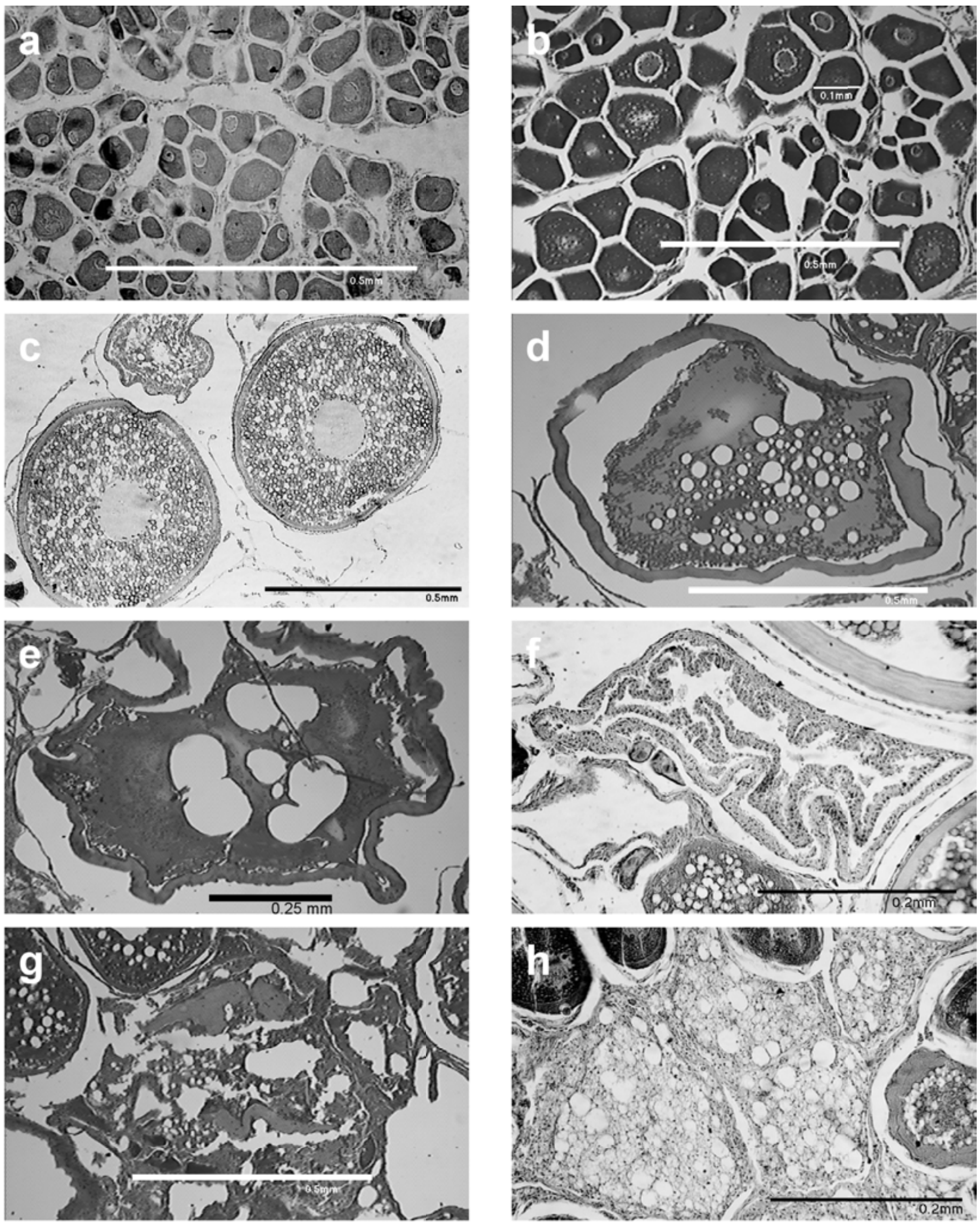


Figure 7: **Maximum oocyte size in relation to orbital fork length (OFL) in female broadbill swordfish (*X. gladius*) off eastern Australia. The dotted line represents the size at which the swordfish begin to spawn as determined by histology.**

Table 3: Maturity classification of female broadbill swordfish (*X. gladius*) gonads from samples collected from the Eastern Australian, New Zealand and New Caledonian fisheries. Samples from the latter two fisheries were only collected during the spawning season.

Maturity stage	Histological criteria	Samples from Australian waters	Samples from New Caledonia	Samples from New Zealand
Immature or resting females (Stages 1 & 2)	Ovaries contain unyolked (Stage 1) or early yolked oocytes (Stage 2) that are often densely packed. No advanced yolked oocytes present. No advanced yolked oocytes in the alpha stage of atresia. No postovulatory follicles present	578 (81.0%)	3 (25.0%)	39 (92.9%)
Mature: not actively spawning (Stage 3)	Ovary contains unyolked, early yolked and advanced yolked oocytes Less than 100% of advanced yolked oocytes are in the alpha stage of atresia. No postovulatory follicles present	51 (7.1%)	0	0
Mature: actively spawning (Stages 4 to 5)	Ovary contains fully yolked oocytes, and either migratory nucleus oocytes, hydrated oocytes or postovulatory follicles are present. Less than 100% of advanced yolked oocytes are in the alpha stage of atresia.	47(6.6%)	8(66.7%)	0

Figure 8: Transverse section of ovaries from immature to spawning female swordfish (*X. gladius*)(a, stage 1 – only immature oocytes present; b, stage 2 – early yolked oocytes present; c, stage 3 – advanced yolked oocytes present; d, stage 4 – migratory nucleus oocytes present; e, stage 5 – hydrated oocytes present; f, post ovulatory follicles denotes immediate past spawning, if present with advanced yolked oocytes reflects past spawning and also classified as spawning; g, stage 2 – late alpha atresia and if present with unyolked oocytes indicates resting mature or post-spawning; h, beta atresia).



Male classification and reproductive activity

Male swordfish testes were generally thin and straplike and only fully mature fish had enlarged gonads. As in the females there was a small (ST) and large testis (LT), the relationship between them described by the equation LT = 1.6635(ST)– 4.6436 ($n = 52$, $r^2 = 0.92$).

Male swordfish gonads were divided by histology into six categories (Table 4, Fig. 9). These divisions were based largely on the relative proportions of spermatogonia and their transition through spermatocytes and spermatids to spermatozoa. As mentioned previously, there was difficulty in distinguishing stage 2 fish from mature post-spawn fish (stage 6).

Table 4. Developmental stages in the male gonad of broadbill swordfish (*X. gladius*) (modified from Grier 1981, DeSylva & Breder 1997).

Maturity stage	Description of gonad
Immature (Stage 1)	Testicular lobules lined with epithelium in which spermatogonia are dominant. This stage is characteristic of the immature gonad and a gonad after spawning. The latter gonad is larger and has more lobules and connective tissue. Spermatogonia have prominent nucleoli.
Early spermatogenesis (immature) Stage 2	Spermatogonia and spermatocytes present. Spermatogonia mitotically divide in nests. Chromatin condensed. Nucleoli invisible. Primary spermatocytes are larger than the secondary spermatocytes, which form by meiosis.
Mid spermatogenesis Stage 3	All stages of sperm development seen (spermatogonia – spermatocytes – spermatids – spermatozoa). Meiosis observed at all stages in cysts, which line the lobules. Ripe sperm becoming abundant in cysts and lobule lumen but not in ducts, which are largely collapsed.
Spermatogenesis completed (mature) Stage 4	Gonad packed with ripe sperm in lobules and ducts, with little/no spermatogenesis occurring in the lobule lining. Cysts are rarely seen and spermatogonia are rare.
Functional Maturity Stage 5	Gonad full of sperm. Cysts still present but are declining in number.
Post-spawning Stage 6	Few ripe sperm left inside lobules.

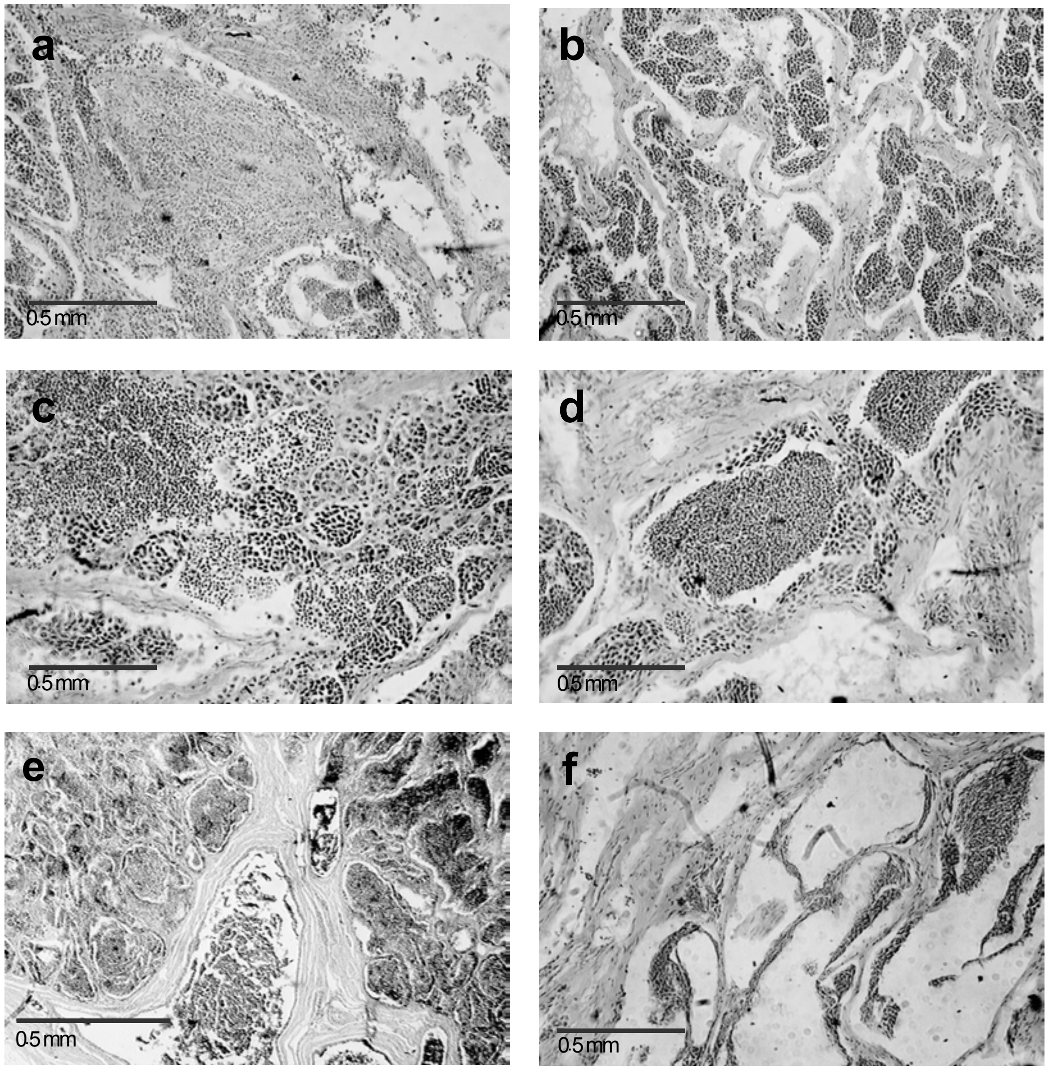


Figure 9: Transverse section of male swordfish (*X. gladius*) testes at various stages of development. Stage 1, spermatogonia; b, stage 2, early spermatogenesis; c, stage 3, mid spermatogenesis; d, stage 4, late spermatogenesis; stage 5, functional maturity; f, stage 6, post spawning.

Hinton et al.'s (1997) formula for female swordfish GSI was tried and rejected for male swordfish. Although ln(GW) was correlated with ln(OFL) in four of the five stages (determined by histology) the slopes of the regression equations from males in different stages were significantly different ($p=0.021$). When the same procedure was repeated for non-logged data, GW was correlated with OFL in stages 2, 3 and 4 but not in stages 5 and 6. However, as the slopes of the regression equations were statistically similar ($p=0.23$), and because the breakdown in the GW:OFL relationship in stages 5 and 6 was probably due to low sample sizes (only 6 in each stage) we used GSI = GW/OFL as the index. However, the relationship between the index and actual gonad stage was not significant and so could not be used independently to determine seasonal and spatial patterns.

Spawning season

Gonad indices, calculated from samples collected continuously from July 1999 to March 2001, revealed that spawning in swordfish lasted from September through to March (Fig. 10). We noted, however, that the timing and relative number of spawners differed between the two spawning periods sampled. Relatively fewer spawning females were sampled in 2000 than in 2001. This may be related to the warmer sea surface temperatures recorded in the latter year (see Fig. 2).

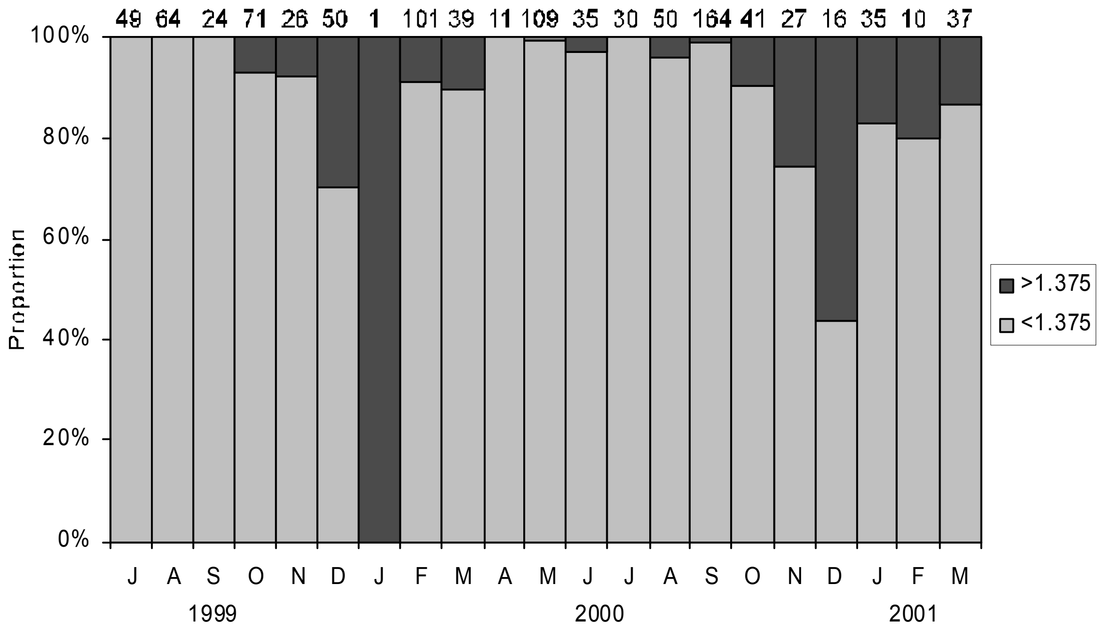


Figure 10. Proportion of mature to immature female swordfish (*X. gladius*) >150 cm OFL from August 1998 to March 2001 based on gonadosomatic index (According to Hinton et al.'s (1997) formula an index greater than 1.375 is considered mature; numbers of fish examined are given above each month) .

Based on histology, the majority of females caught during the winter months (May to September) were either immature or resting (stages 1 or 2) (Fig. 11). In October and November there was an increase in the incidence of females that were mature but inactive (stage 3). A few actively spawning females (stage 5) were also caught during these months, but their relative abundance did not increase substantially until December through to February. At the same time, the number of stage 2 females decreased. Post-spawning females were most abundant from March onwards. This transformation of females from immature/resting to mature but inactive in spring, then to actively spawning over summer suggests that spawning in swordfish may be synchronous to some degree, and that peak spawning occurs during a short three month period (December to February). Although sample sizes were small, a similar pattern of development was found in both the 1999/2000 and 2000/01 spawning seasons.

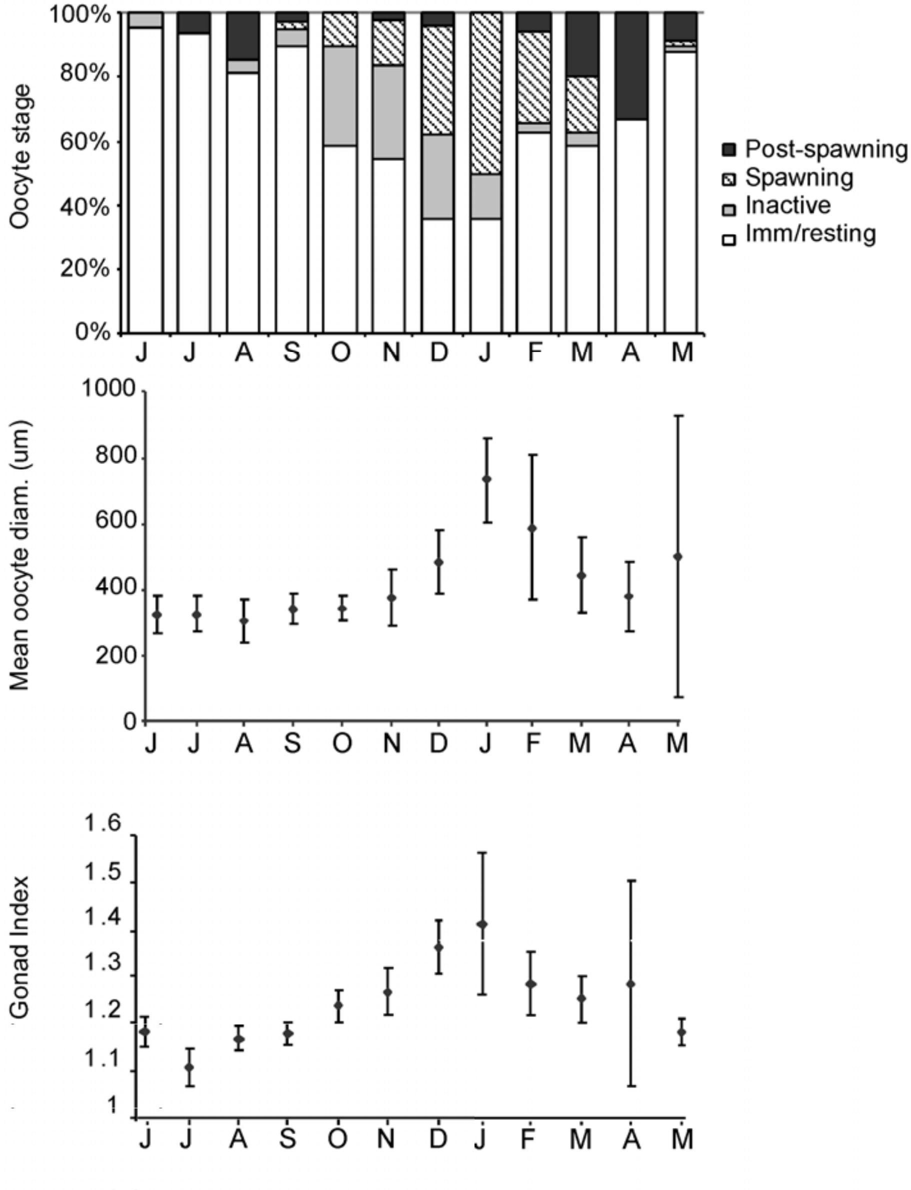


Figure 11: **Maturity classification of female swordfish (*X. gladius*) from histology (a), gonad index (b) and maximum oocyte diameter (c) in relation to time of year for fish greater than 150 cm OFL (Australia and New Caledonia).**

Inter-comparisons between oocyte stage, maximum oocyte size and GSI showed that all three indices could be considered proxies for the other although oocyte size had a closer relationship to oocyte stage than did GSI (Table 5). Maximum oocyte size differed significantly with respect to month for fish that were large enough to spawn (Kruskal-Wallis $\chi 2$ =42.05, df =11, p=0, Fig.11). Maximum oocyte diameter was higher in January and February than at other times of the year reflecting the pattern established by histology. A similar pattern was also found for GSI in relation to time of year (Kruskal-Wallis $\chi 2$ = 59.0, df =11, p=0, Fig.11).

Table 5. Comparison of relationships between mean maximum oocyte diameter (MOD), oocyte stage and gonad index(GSI).

	Relationship	r^2	P
MOD v oocyte stage	$y = 281.74x - 161.16$	0.98	<0.01
MOD v GSI	$y= 11.121e^{2.7577x}$	0.78	<0.01
Oocyte stage v GSI	$y= 0.1561x + 0.8784$	0.96	<0.01

Mature-staged male swordfish (≥ stage 4) were found in all months of the year (Fig. 12). Males in spawning condition were found only in five months – in May and September and then from January through to March (Fig. 12). However, spent males were found continuously from September to March mirroring the female spawning season. There was no significant difference between male GSI and time of year (ANOVA, F=2.64, P=0.10), although mean values increased in the summer months and declined through winter (Fig. 12).

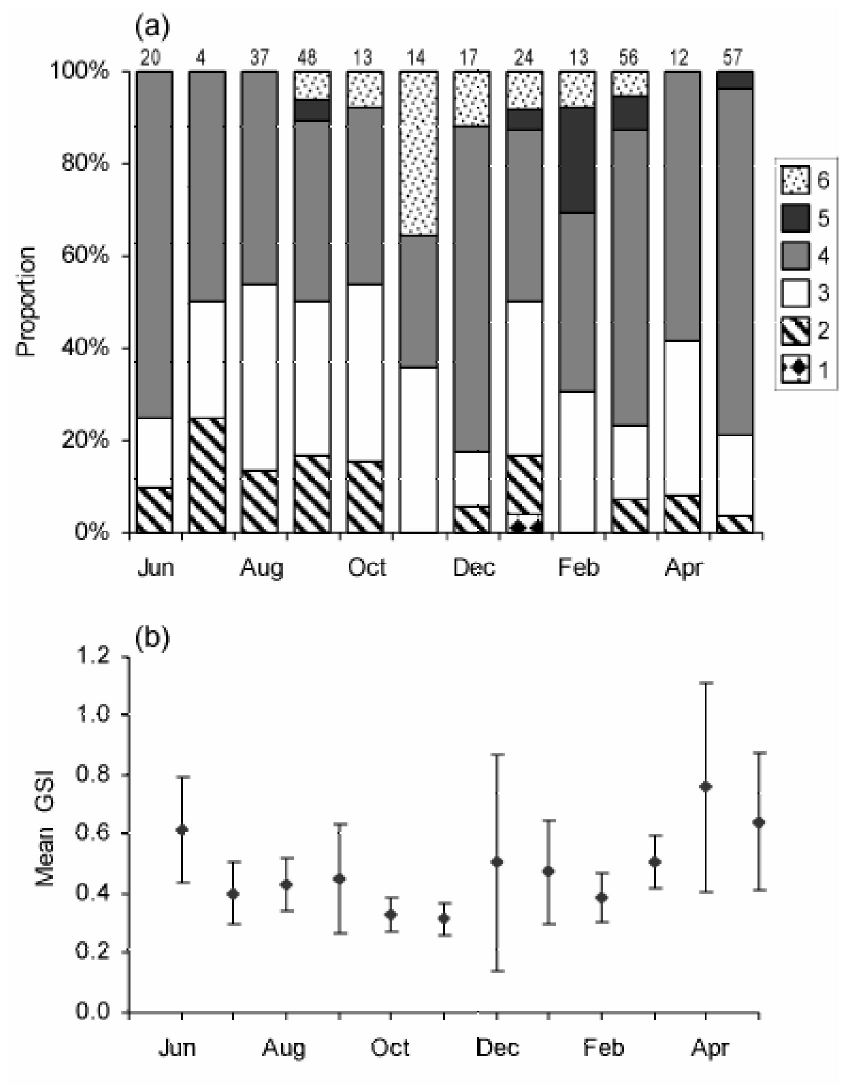


Figure 12: Maturity classification of male swordfish (*X. gladius*) from histology (a), gonadosomatic index (b)

in relation to time of year for all fish.

Spawning location

In winter, there were very few mature females in either inshore (west of 158ºE) or offshore (east of 158ºE) waters (Table 6). The proportion of mature females in inshore waters increased progressively over spring and reached a peak there in summer declining again in autumn (Fig 13). Offshore, there were relatively fewer mature females in all seasons except autumn (Table 6). Although the proportion of mature to inactive fish was consistent between years, there was a significantly lower proportion of mature females offshore in the 2000/2001 spawning season than in the previous one (Table 7). The decline in mature fish offshore continued to the east with collections off northern New Zealand showing no mature fish during the 2001 spawning period. A comparison of GSI values of fish caught at the same time off eastern Australia of similarly mature size showed that the New Zealand fish had values significantly below those from Australian waters (Fig. 14).

An overlay of position of capture of females ≥150 cm from summer 2001 showed spawning fish in warm (>25 ° C) water close to the Australian coast with progressively less active fish to the south east and no active fish from New Zealand waters (Fig.15). To determine whether these differences were related to the oceanography we examined the relationship between reproductive stage and two oceanographic variables – SST and Chl a. These comparisons showed a positive relationship between spawning fish and sea-surface temperatures above 24 °C and chlorophyll a less than 0.2 ug/l (Fig.16). Spawning activity reached a maximum in waters with a sea-surface temperature of 27°C and <0.1 Chlorophyll a.

Table 6: Proportion of mature (including mature, mature (spawning) and spawned (atretic)) fish to inactive (M:I) mature sized female and male swordfish (X. gladius) from inshore (<158°E) and offshore (>158°E) waters off eastern Australia, in relation to season. (n, number of fish).

	Females				Males			
	Inshore		Offshore		Inshore		Offshore	
	M:I	n	M:I	n	M:I	n	M:I	n
Winter	0.02 : 0.98	63	0.05 : 0.95	59	0.46 : 0.54	26	0.6 : 0.4	25
Spring	0.4 : 0.6	35	0.14 : 0.86	108	0.38 : 0.62	13	0.58 : 0.42	38
Summer	0.6 : 0.4	57	0.4 : 0.6	35	0.78 : 0.22	32	0.75 : 0.25	4
Autumn	0.43 : 0.57	21	0.6 : 0.4	86	0.74 : 0.26	35	0.8 : 0.2	55

Table 7: Proportion of mature to inactive (M:I) mature-sized female and male swordfish (*X. gladius*) from inshore (<158°E) and offshore (>158°E) waters off eastern Australia in relation to spawning season (September – March). (n, number of fish).

	Females				Males			
	Inshore		Offshore		Inshore		Offshore	
	M:I	n	M:I	n	M:I	n	M:I	n
1999/2000	0.59 : 0.41	46	0.39 : 0.61	71	0.5 : 0.5	4	0.75 : 0.25	4
2000/2001	0.55 : 0.45	53	0.14 : 0.86	110	0.6 : 0.4	50	0.48 : 0.52	56

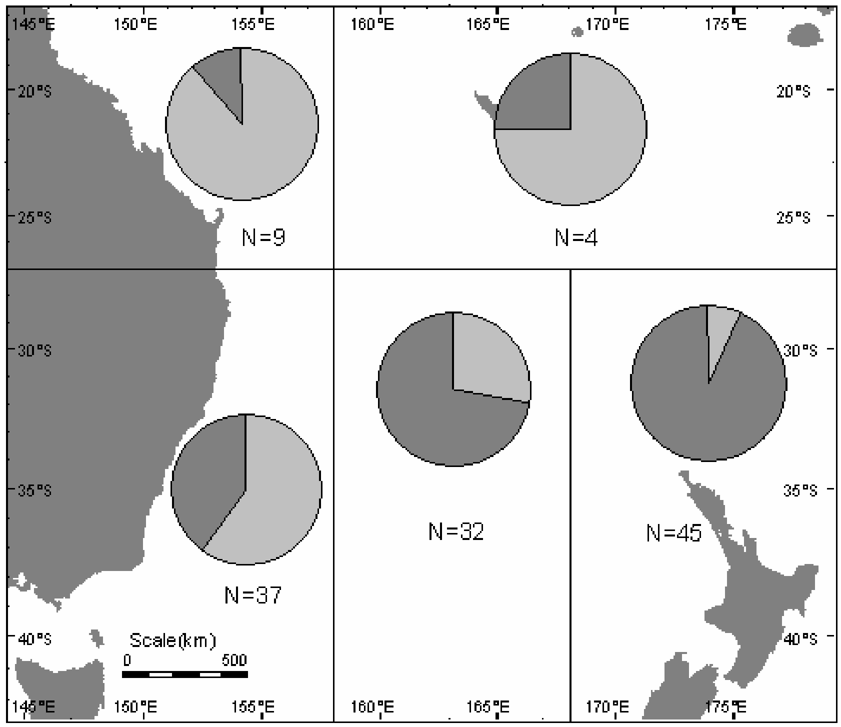


Figure 13: Proportion of inactive (darker shading) to mature (lighter shading) female swordfish (*X. gladius*) over the spawning season in five different areas of the fishery.

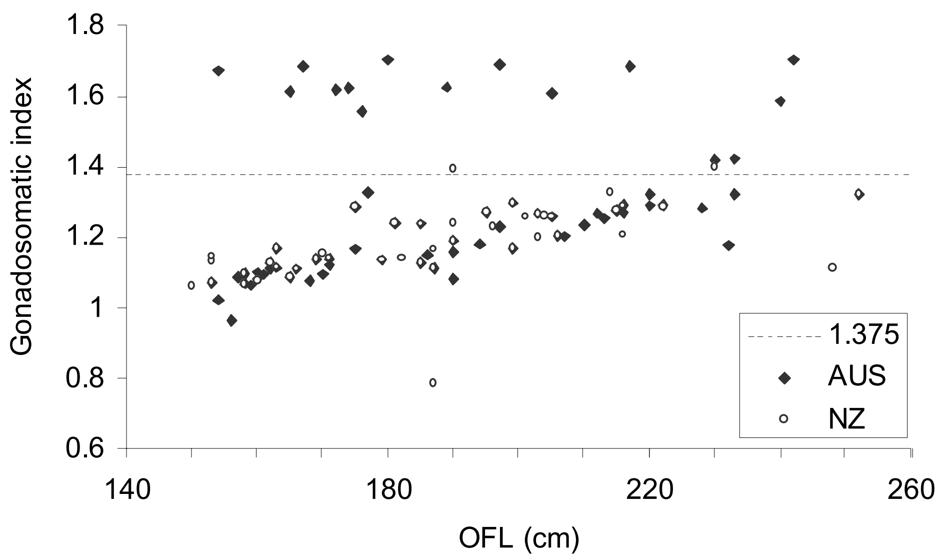


Figure 14: Comparison of gonadosomatic indices for female swordfish (*X. gladius*) (OFL > 150 cm) caught in the Australian and New Zealand fisheries in January and February 2001 (1.375 is the index above which females are mature [Hinton et al.1997]).

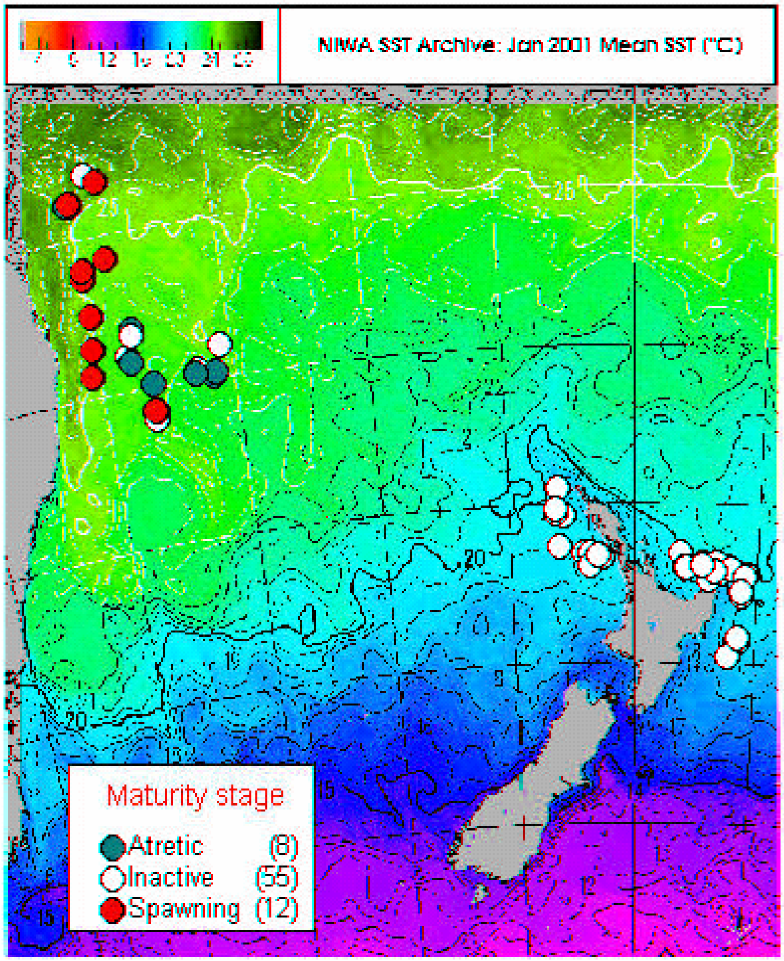


Figure 15: **Position of capture of atretic, inactive and spawning female swordfish (*X. gladius*) (>150 cm OFL) in the south-west Pacific Ocean in January and February 2001.**

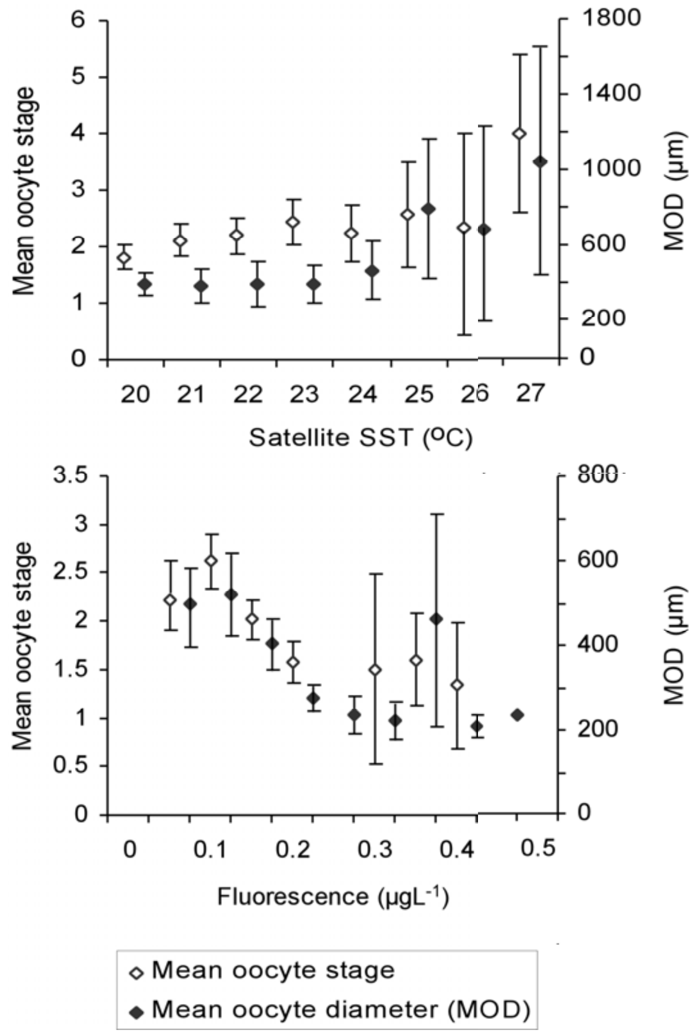


Figure 16: Relationship between maturity stage of mature-sized female swordfish (*X. gladius*) and sea surface variables off eastern Australia during the spawning season.

The significant relationships between oocyte maturity and SST indicated some movement by female swordfish into warmer waters to spawn. Spawning fish were mostly separated geographically from inactive or atretic fish, both of which were in relatively cooler waters outside the warmer waters in which the swordfish spawned. We compared the cumulative frequency distributions of inactive, atretic and spawning female swordfish in relation to temperature. The distributions showed that both inactive (Komolgorov-Smirnov test [KS], Dmax = 34.31, N1=39, N2=170, P<0.01) and atretic (KS, Dmax = 30.77, N1, N2=39, P=0.05) females were found in significantly cooler water than spawning swordfish.

Batch fecundity

The distribution of oocytes in the gonads of mature females was continuous with a small mode of

>1200um oocytes in fish with hydrated oocytes (Fig. 17). This pattern of oocyte distribution indicates that yolked oocytes are continually maturing from unyolked oocytes during the spawning season and are spawned in batches, a characteristic of fish that have indeterminate annual fecundity (Hunter et al. 1985). Batch fecundity was estimated for nine swordfish with unovulated, hydrated oocytes (Table 8). From these data we determined that batch fecundity (BF) was best described by the linear equation:

BF = hydrated oocytes (20,173 * Length) – 2,272,924 ($F=29.06$, $df=1,7$, $P=0.001$, $r^2 = 0.8059$). On average, relative batch fecundity was 11.4 oocytes per gram body weight.

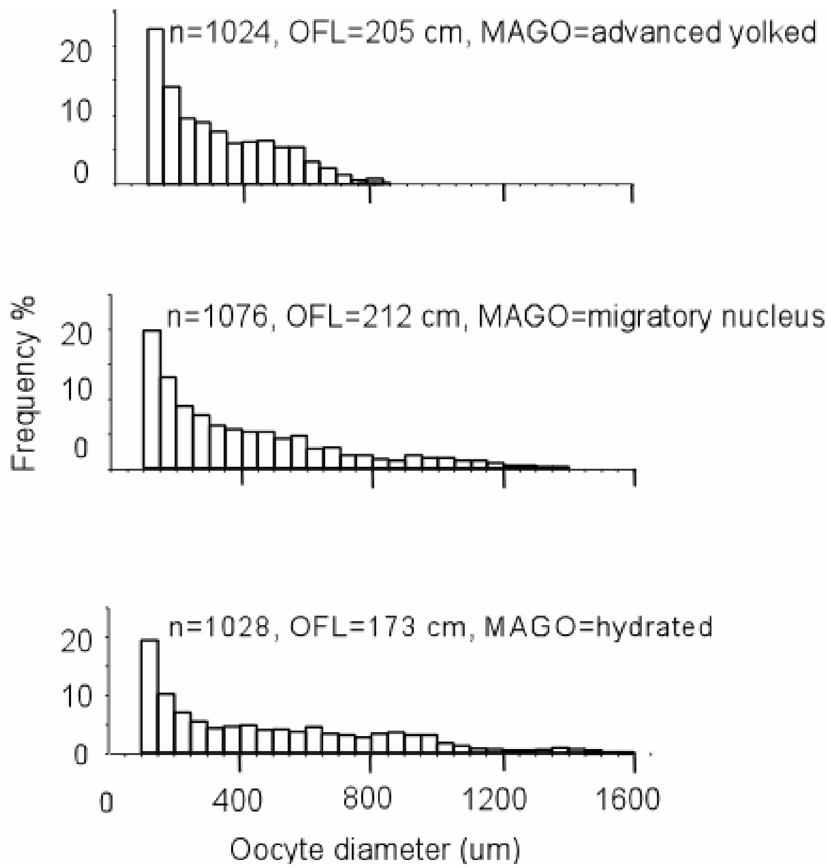


Figure 17: Size frequency distribution of oocytes randomly sampled from ovaries of three female swordfish (*X. gladius*) (MAGO = most advanced group of oocytes).

Table 8: Batch fecundity estimates for nine ripe female swordfish (*X. gladius*) (total fish weight calculated from the equation RW=1.299x10-5 x OFL3.074; De Martini et al. 2000, - no data).

Orbital fork length (cm)		Fish weight (kg)	Gonad weight (g)	Batch fecundity estimate	Mean diam. of hydrated oocytes (µg)	95% CI (µg)	Oocytes/g
	173	98.48	4553	1176236	1566	86.0	11.9
	174	100.24	4361	1167348	1496	93.2	11.6
	180	111.25	6941	1185016	1502	65.4	10.7
	185	121.03	5128	1358855	-	-	11.2
	190	131.37	9680	1742745	1524	62.4	13.3
	190	131.37	15074	1822072	-	-	13.9
	208	173.51	12095	1838075	1536	102.7	10.6
	221	209.06	11577	2503822	1646	57.6	12.0
	232	242.73	12032	2112169	1652	165.4	8.7
Mean	194.8	146.56	9049	1656260			11.5

Spawning frequency

The ovaries of 48 (33.1%) females classed as mature from Australia and New Caledonia contained migratory nucleus or hydrated oocytes, giving a mean spawning interval of ~3 days. If the analysis is restricted to mature females sampled during the peak spawning season (December to February), the spawning interval is reduced to 1.78 days suggesting that either a greater proportion of mature females are spawning during these months, or individuals are spawning more often. Sixteen females contained evidence of two spawning events (postovulatory follicles with either migratory nucleus or hydrated oocytes). If we assume swordfish are capable of resorbing postovulatory follicles in 24 hours, and hydration of oocytes occurs just prior to spawning, the presence of these two spawning events suggests that swordfish are capable of spawning daily. Ten of these females were sampled in December and January - the peak of the spawning season.

Potential annual fecundity

Annual fecundity is defined as BF x (length of spawning season/spawning frequency). Thus, a 200 cm (OFL) female would shed a total of 21 to 42 million oocytes between December and February. However, it is unclear if a female would spawn for this length of time. The presence of post-spawning fish as early as November and December would suggest that individuals have a relatively short spawning season, and that there may be a turnover of fish on the spawning ground.

Discussion

Sex ratio

The main factors affecting the sex ratio of swordfish off eastern Australia were size of fish and season. We found that although females always outnumbered males (overall ratio of males to females was 1:2.25) there was a slight increase in the proportion of males in fish at ~ 170cm OFL, the same result as that found in swordfish sampled from the western Indian Ocean (Poisson 2001). The variability we, and others (e.g. De Martini et al.2000), found in the sex ratio below this size may be due to loose, but sex specific, aggregations of small fish commented on by fishers within the Australian fishery. As fish length increased beyond 170 cm, the proportion of males declined sharply, and no males > 220 cm were caught. Our results agree with earlier observations of sex ratios in the eastern Australian region (Caton et al. 1998). Elsewhere, there is a range of results. In the eastern Pacific Ocean the proportion of females to males was approximately equal in fish with lengths between 130 and 170 cm (Kume and Joseph 1969). Above this size the proportion of females became progressively higher. Off Hawaii sex ratios were an increasing power function between 100 and 220 cm and nearly all fish >220cm EFL were females. Most (0.55) of the swordfish <140 cm were male, most (0.64) swordfish >150 cm were female (DeMartini et al. 2000).

The ratio of males to females, although remaining less than half, increased significantly during summer and autumn off eastern Australia. This pattern was similar to that found in a recently completed study off Reunion Island in the southwestern Indian Ocean (Poisson, 2001). In that study, the proportion of males was also highest in autumn; the proportion of females was highest in winter. Seasonal differences in sex ratios are commonly reported for swordfish (Palko et al. 1981, Grall et al. 1983, Taylor and Murphy 1992, DeMartini 1999, Erhardt 1999). However, in most of those studies there was a latitudinal component that we did not find. That is, males dominated toward the equator and females were increasingly dominant away from the equator. That we did not find any difference in this regard may be because most samples were collected south of 25°S. In an earlier study of the area that extended from 10° to 50°S collections north of 20°S showed male numbers approaching that of females (Caton et al. 1998). In the northern hemisphere, females also dominate further away from the equator with males increasing toward the equator (De Martini 1999). The relatively lower numbers of males during winter and spring in the main area of the fishery may be because the males move equator-ward to avoid the increasing influence of subantarctic waters at those times.

Techniques for determining gonad maturity

Histological preparations are the most precise way of determining the maturity status of individual fish (West 1990). Histology can detect postovulatory follicles that can be used to determine the number of spawning events through a season. Also, postspawning ovaries can be distinguished from immature/resting and spawning ovaries (Hunter and Macewicz, 1985). However, histology is expensive and, with respect to determining the spatio-temporal limits of swordfish spawning patterns,may give little further information than could be obtained from techniques such as GSI (eg. Kume and Joseph 1969) or direct measurement of largest oocyte size (Taylor and Murphy 1992).

We found that for females all three techniques could be used as proxies for each other although GSI can be affected by a number of factors, particularly by the size of the fish and “may not yield a totally accurate indication of gonadal activity” (De Vlaming et al 1982, Cayre and Laloe 1986).

Generally, maximum oocyte diameter, calibrated by histology, is a more accurate indicator of the temporal and geographical extent of spawning in scombrids (Schaefer 2001), and could be used in any ongoing monitoring of swordfish stocks in the Australian region.

GSI was the only alternative technique to histology tested for males. Validation of a GSI formula for male swordfish is difficult because the magnitude of changes in testicular weight during development is much less than those that occur in ovarian weight (Arocha 1997). Hinton et al.'s (1997) GSI formula was deemed to be valid for females because it fulfilled some basic assumptions. One of these assumptions was that the relationship between gonad weight and body size remained constant at different stages of development (DeVlaming et al.1982). However, male testes packed with several types of germ cells (e.g. stage 4) may have a very similar weight as spent/redeveloping testes containing a lot of connective tissue (e.g. stage 1 and 2) thus any differences in GSI may be masked by individual variations in weight with length and was likely to be the reason we were unable to detect a significant relationship between male GSI and time of year.

Temporal and spatial variations in spawning activity

We found an extended spawning season between September and March with the main activity from December to February. This is typical of temperate populations of swordfish (Yabe et al. 1959, Nishikawa et al. 1978, Grall et al.1983). A similar although slightly longer spawning period was noted recently in the south western Indian Ocean (Poisson 2001). Off Hawaii, reproductively active females were caught primarily in spring at similar latitudes to our study (De Martini et al. 2000). Closer to the equator the reproductive season for swordfish is protracted in both the Pacific and Atlantic Oceans (Nishikawa and Euyanagi 1974, Grall et al.1983, Taylor and Murphy 1992, Megalofonou et al. 1995). Earlier studies of larval swordfish in the eastern Australian Fishing Zone between 10ºS and 20ºS found larvae from July to September indicating that the spawning season is also protracted in Australian waters towards the equator (Nishikawa et al. 1985). It appears though that, even in areas where the spawning period is extended, the numbers of spawning fish increase from spring to midsummer (Taylor and Murphy 1992).

Our study supports earlier work that indicated the extent and duration of spawning is linked closely to sea surface temperature (Palko et al. 1981, Arocha 1997). We found that spawning activity was associated with surface water temperatures greater than 24ºC, mirroring that found for spawning swordfish in the Atlantic Ocean (Arocha 1997) and the Mediterranean Sea (Sanzo 1922 cited in Arocha 1997). The relationship between spawning and a suitable sea surface temperature is underlined by the southward extension of spawning activity in swordfish associated with the warm East Australian Current. In a comparison of fish caught at the height of the southern hemisphere spawning season between waters off eastern Australia and colder waters off New Zealand, mature-sized fish from the latter were either immature/resting or post-spawning, whereas the fish caught in the Australian zone were actively spawning. The regional oceanography at that time showed a wedge of warm tropical origin water extending down the Australian coast whereas off New Zealand the extension of the east Australia Current – the Tasman front – is ~200 n. miles north of the area where the New Zealand fish were caught. Whether it is temperature per se that is responsible for the distribution of spawning fish or some associated factor — low chlorophylls were also correlated with increased spawning — is difficult to distinguish. However, indirect evidence suggests that temperature is the most likely reason. Firstly, swordfish eggs and larvae are found in or near the surface where temperatures are at a maximum (Govoni et al. 2000). Warmer temperatures along with food availability are usually associated with faster growth in fish larvae, enabling the larvae to grow through predation windows (Methot and Kramer 1979).

Although we have no data on food availability to the larvae, the waters in which they are spawned is tropical in origin and is considered oligotrophic whereas directly to the south are the nutrient rich waters of the Tasman Sea (Jitts 1965). Thus food is unlikely to be the main reason why the larvae are spawned in the warmer waters of the EAC and the Coral Sea. Although there have been no experiments to determine the favoured temperature for larval swordfish, in general fish eggs and larvae, particularly those of scombroid fishes, do better in warmer waters (Bakun 1996, Harrison and Parsons 2000). This may be because the increase in temperature accelerates growth rates thereby decreasing the time spent during the high-mortality larval stages (Hunter 1981, Houde 1989).

Swordfish larvae are found in surface waters (Govoni et al.2000). However, little is known of where in the water column swordfish spawn. Indirect evidence indicates that swordfish may also spawn close to the surface. We know that swordfish are caught by longline in the upper 50 m of the water column at night, the time at which many scombroid fishes are known to spawn (Schaefer 1996). The majority of spawning fish in this study contained migratory nucleus and hydrated oocytes but relatively few contained POFs (16.6% of mature females). The presence of advanced staged oocytes suggests that females were about to spawn. The relative lack of POFs in the females captured, however, indicates that they move away from the surface and thus from capture, once spawning is completed.

Fecundity and spawning frequency

Unlike the present study, Arocha (1997) reported an exponential relationship between fecundity and length, with an inflection point at ~200 cm lower jaw to fork length (~180 cm OFL). Also, our estimates of swordfish fecundity were lower than Arocha’s (1997) Atlantic Ocean study (up to 9 million oocytes per spawn) and lower than those reported for the Pacific Ocean (3 to 6 million oocytes, Uchiyama and Shomura 1974) and the Mediterranean (De la Serna et al. 1996, Hazin et al.2001). Although our sample size was low and thus should be viewed with caution (see Schaeffer 2001), we found a linear relationship between fish size and batch fecundity and our estimate of batch fecundity reached a maximum of only 2.5 million oocytes. Hazin et al. (2001) also reported a linear relationship for Mediterranean swordfish although they reported average batch fecundities of ~5 million oocytes. The difference between the batch fecundities reported here and estimates elsewhere may be methodological. Arocha (1997) reported that he and other studies based their estimates on counts of oocytes greater than 650-750µm (effectively advanced yolked oocytes and above) whereas we only counted hydrated oocytes, and these varied in mean size between 1496 and 1652 µm (Table 8). In counting only the hydrated oocytes we followed Hunter et al. (1985) who concluded that this method is best in that it avoids the difficulty of partitioning the most advanced oocytes from smaller ones.

Swordfish are indeterminate multiple spawners, continually maturing new oocyte batches throughout a typically protracted spawning season (Arocha 1997, DeMartini et al. 2000). Swordfish are batch spawners with asynchronous oocyte development (oocytes in many stages of development occurring simultaneously in reproductively active ovaries, sensu Hunter et al. 1985, Arocha 2002). Oocyte maturation in swordfish is not group-synchronous as reported previously by Taylor and Murphy (1992).

By comparing the proportion of mature females with unovulated hydrated oocytes to those without, Arocha (1997) determined that swordfish spawn approximately every 3 days or ~81 times per season. However, we have no way of knowing how long individual fish spent in the spawning grounds; fish may move out of the spawning area to gain condition in the potentially more productive cooler waters outside the spawning area as has been suggested for tuna species (Sharp 2001). The high proportion of inactive or atretic fish collected off New Zealand supports this suggestion. We also have no way in which to tell the length of time spawning ceased in fish where atretic oocytes were found.

Conclusions

Swordfish have an extended spawning period during the Austral summer although spawning was most intense between December and February. Swordfish spawned in the Coral Sea and East Australia Current where sea surface temperature was greater than 24°C. The presence of significantly greater proportions of mature-sized females with either inactive or post-spawning gonads during the height of the spawning season in colder waters off New Zealand underline the link between spawning and oceanographic conditions in swordfish. There was a positive linear relationship between batch fecundity and fish size with an average fecundity of 1.66 million eggs in females ranging in size from 173 to 232 cm OFL. The presence of post-ovulatory follicles and hydrated oocytes in the same fish indicated multiple spawning, the number of which we were unable to determine.

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6.2 Size-at-maturity of broadbill swordfish, *Xiphias gladius*, in relation to catch in the eastern Australian Fishing Zone

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Abstract

Size at maturity was determined for the broadbill swordfish (*Xiphias gladius*) catch taken off eastern Australia between July 1999 and April 2001. Maturity stage was determined histologically from 128 male and 410 female swordfish. Gompertz and Logistic models were used to estimate the length at which 50% maturity (L_{50}) occurred for both sexes. Confidence intervals on the estimates were constructed using bootstrap methods. We found that the parametric models were appropriate for the female data set but were sensitive to the relatively small sample size in the male data set. The L_{50} for females was estimated at 193.6 (±0.51 SE) cm orbital fork length (OFL) using the Gompertz model and 199.78 (±0.51 SE) using the logistic model, which gave the best fit to the data. A further L_{50} was calculated at 219.3 cm gonadosomatic data from 1030 female swordfish taken over the spawning period. However, if only data corresponding to the peak spawning period are analyzed (December to February) this value was reduced to 201.9 cm, underlining the effect of mature, spent fish (small gonad size) on such calculations. The inclusion of the latter will generally overestimate maturity size and thus should be avoided. The male L_{50} was 85.8 cm using a Gompertz model. The size/weight frequencies were similar for both the sampled and total catch by the fishery sampled between July 1999 and April 2001. We estimated that females comprised 70.7% of the total catch and males 29.3% of the total. Of those caught, we estimated that 77% of the females and only 27% of the males were immature. These results are discussed in relation to effort by the fishery.

Introduction

With the recognition that the sustainability of broadbill swordfish, *Xiphias gladius*, (referred to as swordfish) stocks is dependent on preserving parental biomass, most studies of swordfish stocks include some estimate of the size at which the fish attain sexual maturity; that is, the size at which they are ready to spawn. The usual reference point, the length at which 50% of a population's gender reaches maturity (L_{50}) has been determined for most swordfish stocks that are presently being fished, although most of these studies have been carried out in the northern hemisphere (reviewed in Ward and Elscot 2000). The various studies completed have revealed significant variation in maturity estimates in relation to sex, geographical area, local conditions and stock. For example, female swordfish caught in Hawaiian waters reached 50% maturity at 144 ± 2.8 cm OFL (102 ± 2.5cm OFL for males) (DeMartini et al. 2000), whereas females caught in the Northwest Atlantic reached 50% maturity at 159 cm OFL (113 cm EFL for males) (Arocha and Lee, 1996). Poisson et al. (2001) reported an estimate of 170 cm OFL for females from the western Indian Ocean. There has been no attempt as yet to determine a value for the stocks being fished in Australian and New Zealand waters. A recently developed operational model for the swordfish fishery off eastern Australian assumed a knife edged L_{50} of 170 cm OFL based on data from regions elsewhere (Punt et al. 1999). Thus determination of an accurate L_{50} for the Australian zone is a priority since the ratio of mature to immature fish in the fishery has implications for the population's sustainability.

The various size-at-maturity studies completed so far have also used various methodologies to determine L_{50}, in particular, definitions of what constituted a mature fish has varied. For example, DeMartini et al. (2000) used histological staging, whereas Poisson et al. (2001) used the validated gonadosomatic index of Hinton et al. (1997). Statistical methods for determining L_{50} have also varied between studies and may be responsible for some of the variations reported between studies (DeMartini et al. 2000, Poisson et al. 2001).

In this study we aim to determine size-at-maturity relationships for male and female swordfish from maturity defined from histological staging, and for females using a gonadosomatic index. We will then apply these size-at-maturity relationships to estimate the proportion of mature male and female swordfish in the catch by the domestic fishery during the study period.

Methods

Determination of gonad maturity by histology

The reproductive state of female and male swordfish was determined according to the methods outlined in Chapter 6.1. Five oocyte stages were identified in female gonads and six stages of gonad development were identified in males. Following De Martini et al. (2000), females were classified as being mature if they contained stage III (advanced) oocytes and above. Stage II fish that showed signs of alpha and/or beta atresia were also considered mature. Males classified as Stage IV and above were considered mature.

Determination of gonadosomatic index

A gonadosomatic index (GSI) was determined for individual females using the formula GSI = Ln (GW) / Ln (OFL) where GW = gonad weight (g) and OFL (cm) = orbital fork length (following Hinton et al. 1997). This index was valid since linear regression showed no significant interaction of gonad stage with the relationship between Ln (GW) and LN (OFL) ($p = 0.96$) (see Young et al, Chapter 6.1).

Calculation of confidence intervals

The proportion of mature to immature males and females was determined for each 10-cm length class for fish caught in the spawning season (September to March). The data was assumed to be binomially distributed Asymmetric 95% confidence intervals about the estimates of maturity at length (fig. 1) were calculated from the inverse beta distribution (Abramowitz and Stegun, 1965, p 945)

$$\sum_{n=a}^{N} \binom{N}{n} p^n (1-p)^{N-n} = I_p(a, n-a+1)$$

where N is the sample size and n is the number of successes in a Bernoulli trial, p is the probability of a success (i.e. the fish is mature), $I_p(.)$ is the inverse Beta distribution Asymmetric confidence intervals are then calculated by the formulae:

$$CI_{\text{Upper}} = I_p(p, n\text{-}p+1), \;\; CI_{\text{Lower}} = 1 - I_p(p+1, n\text{-}p)$$

Parameter Estimation

Two separate models were fitted to data of the proportion of mature individuals at length ; the Gompertz model and a logistic model. The Gompertz model $g(l)$, is given by:

$$g(l) = L_\infty e^{-e^{-k(l-L_0)}} \qquad (1)$$

where $g(l)$ is the estimated proportion of mature individuals in length class l, L_∞ is the asymptotic maturity level , k is a parameter specifying the steepness of the curve and L_0 is the estimate of the length at which the maturity is zero. This function is asymmetric about its inflection point (Deriso & Quinn, 1999), allowing for greater flexibility in its ability to fit the data. A logistic model $p(l)$, of proportional maturity at length, was also applied to the data, given by:

$$p(l) = \frac{1}{1 + e^{a+bl}} \qquad (2)$$

where a and b are empirically estimated parameters specifying the shape of the ogive. Both models were fitted separately to data from both sexes. Unlike the Gompertz model the logistic equation is symmetric about its inflection point. The data was fit to both models using maximum likelihood estimation assuming a binomial error distribution (Deriso and Quinn, 1999). The negative log-likelihood functions for the two models are:

Gompertz:

$$-\ln(\mathcal{L}) \;\; = \sum_{l=1}^{N} \left(\ln\binom{n_l}{\hat{Y}_l} - \hat{Y}_l e^{-g(L-L_0)} (n_l - \hat{Y}_l) \ln\left(1 - e^{-e^{-g(L-L_0)}}\right) \right)$$

Logistic:

$$-\ln(\mathcal{L}) \;\; = \sum_{l=1}^{N} \left(\ln\binom{n_l}{\hat{Y}_l} + \hat{Y}(1 + e^{a+bL}) + (n_l - \hat{Y}_l) \ln\left(1 - e^{a+bL}\right) \right)$$

where N is the number of length classes, n is the number of samples in the lth length class, $\hat{Y}_l$ is the observed number of mature individuals in l.

The best fit to the data was obtained using Quasi-Newton minimization (Venables and Ripley, 1999) of the negative log-likelihood function in the statistical computer package, R using the function nlm and constrained minimization methods using the S-Plus 2000 function nlminb. Final model selection was based on a comparison of the Akaike Information Criterion (AIC) from the two models (Hilborn and Mangel, 1999). The AIC is calculated by the formula AIC = $-2\ln(\mathcal{L})-2p$ (Venables & Ripley, 1999) where $\mathcal{L}$ is the maximized log-likelihood and p is the number of parameters in the model. The model with the lowest AIC value is considered preferable (Hilborn & Mangel, 1999).

Bootstrap estimates of L_{50} confidence intervals

While the model fitting routines can provide estimates of the standard error about the parameters of the models, there is no simple way to obtain estimates of the standard error about the actual L_{50} estimate (Roa et al, 1999). Therefore, to obtain approximate 95% confidence intervals around the length at 50% maturity (L_{50}) a nonparametric approach using a bootstrap method was used. Data from within a length class were randomly sampled with replacement, and the curve was re-fitted. This process was repeated 5000 times and 95% confidence intervals about the L_{50} estimate from both the Gompertz and the logistic model were calculated from these bootstrapped estimates.

Estimating the proportion of mature fish taken by the fishery

Monthly catch data (specifically weights and numbers of fish caught) for the period of the reproductive sampling were analysed to determine the proportion of mature fish in the catch. Since the maturity models estimate maturity at length, weights W were converted to length using the formula length $l = \alpha W^{\beta}$ where α and β are empirically estimated parameters. Since no parameterisation of this curve was available for the Australian zone, the estimates of α and β from De Martini, et al. (1999) were used ($\alpha = 1.3\times10^{-5}$ and $\beta = 3.074$). Sampling sex ratio and maturity curves were used to determine the mature proportion of the catch for each sex. To estimate the mature proportion of the catch, $\hat{C}_l^{(S)}$, in length class l of either sex s ($s = m$ for males, $s = f$ for females) we used the formula

$$\hat{C}_l^{(s)} = \begin{cases} \sum_{l=\min(l)}^{\max(l)} \left(\hat{q}_l C_{l,t} \hat{\phi}_l^{(f)} \hat{p}_l^{(f)}\right) & s = f \\ \sum_{l=\min(l)}^{\max(l)} \left((1-\hat{q}_l) C_{l,t} \hat{\phi}_l^{(m)} \hat{p}_l^{(m)}\right) & s = m \end{cases} \qquad (3)$$

where $\hat{q}_l$ is the proportion of the catch in length class l, estimated as female from the maturity sampling data, $\hat{q} = \hat{N}_l^{(f)} / \left(\hat{N}_l^{(f)} + \hat{N}_l^{(m)}\right)$ and $\hat{N}_l^{(f)}$ and $\hat{N}_l^{(m)}$ are the numbers of female and male fish respectively, in the lth length class in the maturity sampling data. The proportion of animals at length l for either sex, $\hat{p}_l^{(s)}$, was calculated using the empirical distributions of the samples collected i.e. - $\hat{p}_l^{(s)} = \dfrac{\hat{p}_i^{(s)}}{\sum_{l=i} \hat{p}_i^{(s)}}$.

The term $\hat{\phi}_l^{(s)}$ in equation (3) refers to the expected proportion of animals mature at length within the catch of a particular sex. This was calculated from the models with the lowest AIC value, for each sex. For example this may be expressed as

$$\hat{\phi}_l^{(s)} = \begin{cases} p(l) & s = f \\ g(l) & s = m \end{cases} \qquad (4)$$

for the case where a logistic model $p(l)$ is chosen for females and a Gompertz model $g(l)$.

Results

Size at first maturity

The first indication of oocyte development was found in fish within the 100 cm OFL size class where early yolked eggs were found. However, they were not consistently found until fish reached 120 cm (Fig. 1). Advanced yolked eggs (mature) were not found continuously until fish had reached 150 cm, with two exceptions within the 120 cm size class. Hydrated oocytes reflecting imminent spawning were found from fish in the 160 cm size grouping (minimum 160 cm OFL) onwards.A comparison of ovary stage with fish length showed the wide spread of mature fish in relation to length but confirmed that mature females were not present consistently until fish reached 154 cm OFL. The smallest actively spawning fish (migratory nucleus oocytes, hydrated oocytes or post ovulatory follicles) was observed at 154cm.

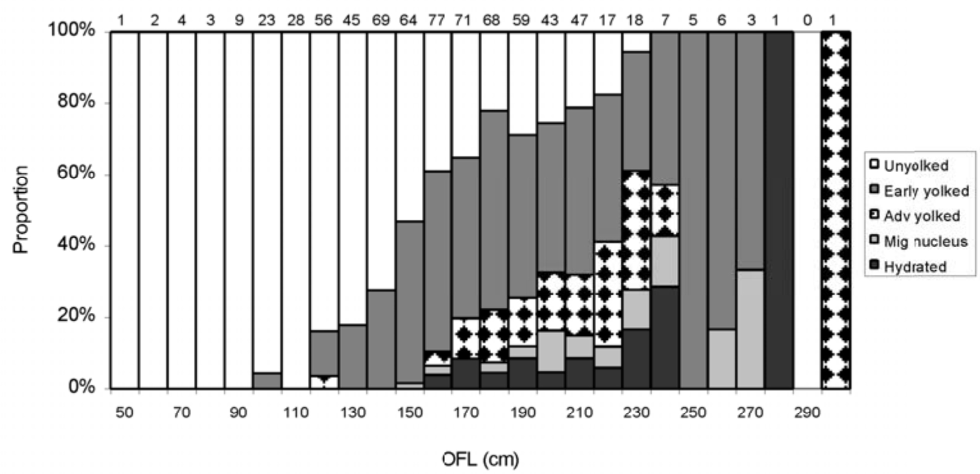
Mature gonads were first observed in male swordfish within the 90 to 100 cm size class with ripe and post spawning fish from the 110 cm size class upwards (Fig. 1). Stage II fish were found almost through the entire size range of samples. However, their presence, particularly in fish greater than 110 cm, was likely an indication of our inability to distinguish between immature fish and mature fish that were not actively spawning.

Size at 50% maturity

Maturity curves and associated confidence intervals were determined for each sex from logistic and Gompertz curves fitted to the proportion of mature to immature swordfish (Figs. 2 and 3). Both models gave similar estimates of L_{50} for the female population at 199.8 cm OFL and 193.6 cm OFL respectively (Table 1). The model fits for the male population differed widely – 85.9 cm for the Gompertz and 102.2 cm OFL for a constrained Gompertz (Table 1). The model fits were hampered by small sample size when fitted to the male maturity data. Neither model adequately represented the male data, although the Gompertz model yielded the most plausible fit. The logistic model, being constrained to always reach unity, placed too much emphasis on points at either end of the length scale and did not estimate a sigmoidal relationship between OFL and maturity from the male data set. The logistic model (not shown) failed either to fit the male data or produce a plausible estimate of L_{50} (Table 1), while the unconstrained Gompertz model failed to predict 100% maturity at any length. Both of these results are due to the effect of small sample size at the tails of the data. The logistic model was not considered workable for the males and so was not used. The constrained Gompertz model did not fit the data as well as the unconstrained version and had a higher AIC (Table 1). For this reason the unconstrained Gompertz model was chosen as the final model, despite the fact that it predicts that there will never be 100% maturity in the male population.

The small sample size for the male data set made calculation of the standard errors about the L_{50} estimate impractical. The female data set, on the other hand, did not suffer from similar problems. Based on these analyses, we concluded that the best estimate of L_{50} was given by the logistic model for the females and the Gompertz model for the males. Therefore to calculate the mature and immature proportion of the catch (equation 4), we used the logistic model for female catch, and the Gompertz for the male catch.

(a)



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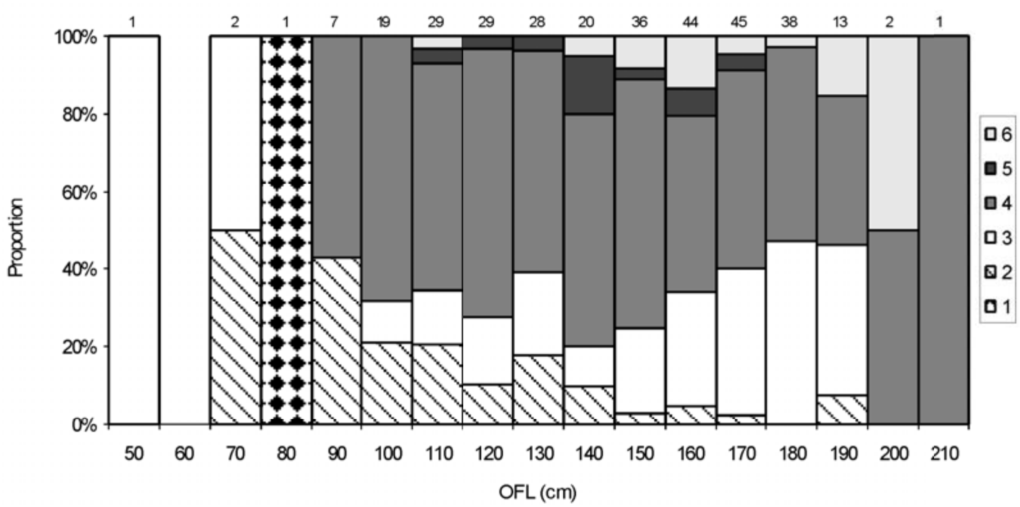


Figure 1. (a) Oocyte development per 10 cm size class for female swordfish (*X. gladius*) (Legend refers to reproductive stages) (b) Gonad development per 10 cm size class for male swordfish (Legend refers to male reproductive stages).

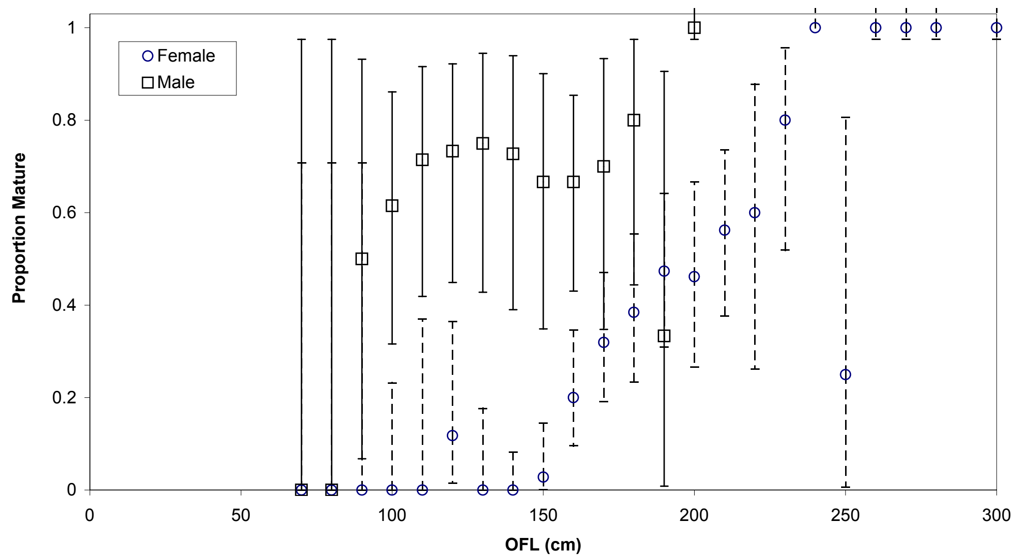
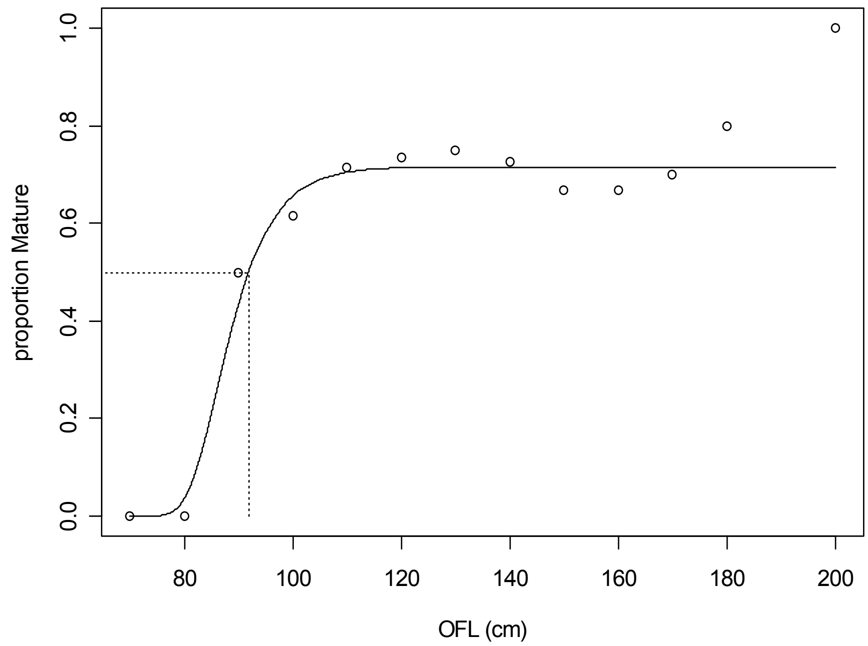


Figure 2. Binomial confidence intervals about the proportion of mature male and female *X. gladius*. The male data shows evidence of smaller individuals being mature but also greater uncertainty in the data. Both sexes show higher variability about the tails of the size distribution, due to the smaller sample sizes. The data point at 250cm OFL was removed from the analysis due to the small sample size as was the male data point at 190cm OFL

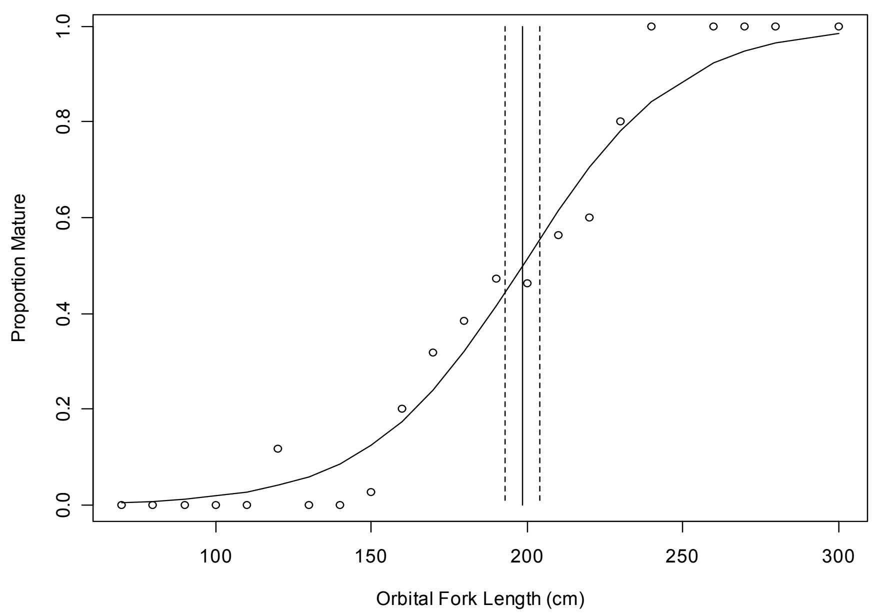
In addition we computed the L_{50} of female swordfish using gonadosomatic data at 201.9 cm OFL using data from the peak spawning period (December to February) and 219.3 cm from the entire spawning period (September to March) (Fig. 4). These data were not used in the subsequent analyses however, as this method has no way of discerning spent mature females from immature females and would thus overestimate the size at which the L_{50} was reached.

Size at maturity of *Xiphias gladius* in relation to the catch by the fishery

Between July 1999 and March 2001 a total of 2214.3 tonnes of swordfish were caught by the fishery (Australian Fisheries Management Authority catch records). The greatest biomass of fish was taken in May 2000 when ~190 tonnes (~3,700 fish) of swordfish were landed (Fig. 5). Overall, males made up 41.2 % of the total sample of 1437 swordfish examined for reproductive activity (Young et al., Chapter 6.1). However, the sex ratio varied over the range of fish measured such that few males were taken that weighed more than 150 kg (Fig. 6). Therefore, when we computed the sex ratio for each size class over the size (weight) range of fish caught by the fishery only 29.32% by weight of the catch was male (70.68% were female by weight) (Table 3). According to the conversion of length to weight by De Martini et al (1999) the L_{50} for female swordfish equates to a fish weight of ~150 kg. As such, the catch was dominated by females less than the size (weight) of maturity (Fig. 8, Table 3). Of the 1565.1 tonnes of females caught by the fishery during the study period only 361.2 tonnes (22.98% of the females caught) were mature (Table 3). In contrast, the male component of the catch was dominated by mature fish (73% of the males caught) (Table 3).



a)



(b)

Figure 3. Fitted maturity curves for (a) male and (b) female *X. gladius*. The plot of the male fits shows the unconstrained and constrained Gompertz models. The selected maturity curve fits were the constrained Gompertz curve (where Y∞ was set to unity- see text for explanation) for the males and the logistic for the females. In the upper panel the two vertical lines are the estimates of L50 for each model with the larger estimate from the unconstrained fit. In the lower panel (females), the solid vertical line shows the estimate of the 50% maturity level for males (102.2 cm) and females (199.78 cm). Dashed lines show the bootstrapped 95% confidence intervals around the 50% maturity point for the females.

Table 1. Parameter estimates with standard errors from the two maturity models fitted to data from both sexes of *X. gladius.*

Parameter	Males		Females	
Gompertz Model			Gompertz Model	
AIC = 33.35			AIC =59.45	
	Estimate	± SE	Estimate	± SE
L_{50}	85.85	-	193.59	0.512
G_∞	0.704	0.046	0.961	0.199
g	0.197	0.214	0.025	0.006
L_0	86.072	5.500	181.01	10.977
Constrained Gompertz			Logistic Model	
AIC = 39.91			AIC = 63.33	
	Estimate	± SE	Estimate	± SE
L_{50}	102.22	-	199.7825	0.1727
g	0.0165	0.0043	8.129	0.854
L_0	80.006	13.89	-0.041	0.005

Table 2. Estimates of 50% maturity (L_{50}) and the parameters of logistic models fitted to female gonadosomatic index (GSI) data from spawning and non-spawning seasons. Also presented are 95% confidence limits around the parameter estimates.

	December - February			September - March		
	Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL
L_{50}	201.9	-	-	219.3	-	-
α	8.943	6.975	11.165	8.253	5.681	11.357
β	-0.041	-0.030	-0.052	-0.041	-0.027	-0.057

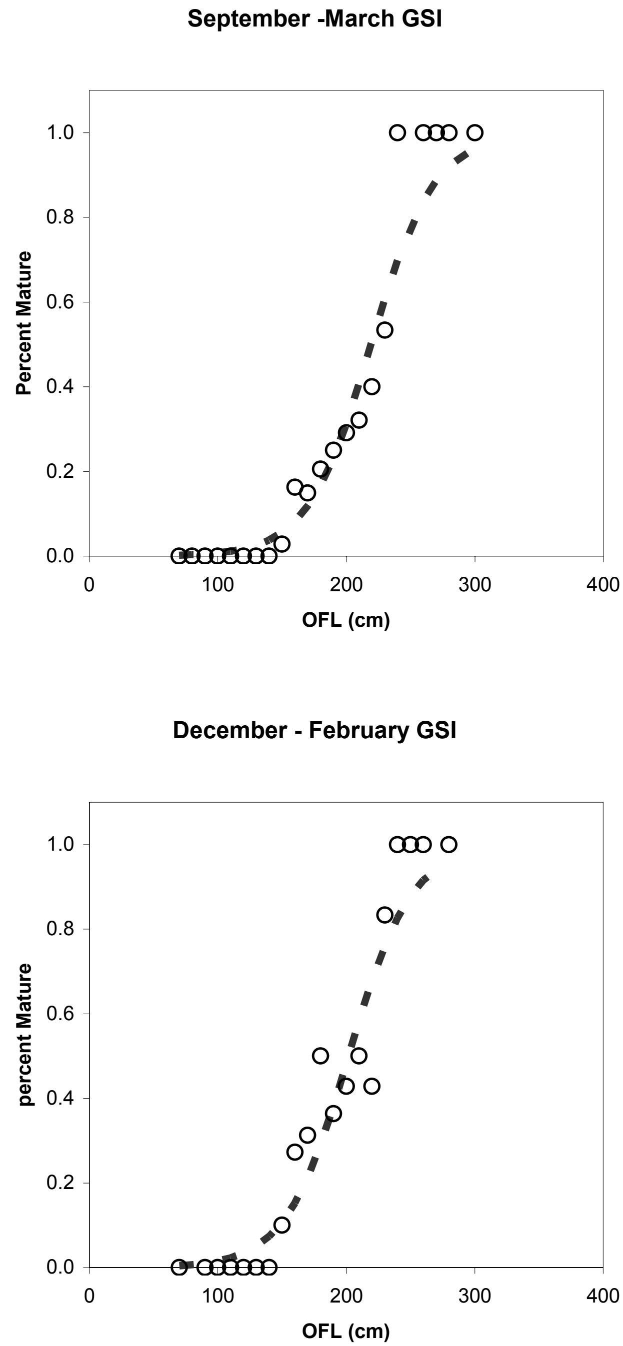


Figure 4. **Size at maturity curves for female *X. gladius* calculated for the entire spawning period (September to March) using gonadosomatic data. The L_{50} estimates were 219.3 cm from the entire spawning period (September to March, top panel) and 201.9 cm OFL using data from the peak spawning period (December to February, lower panel).**

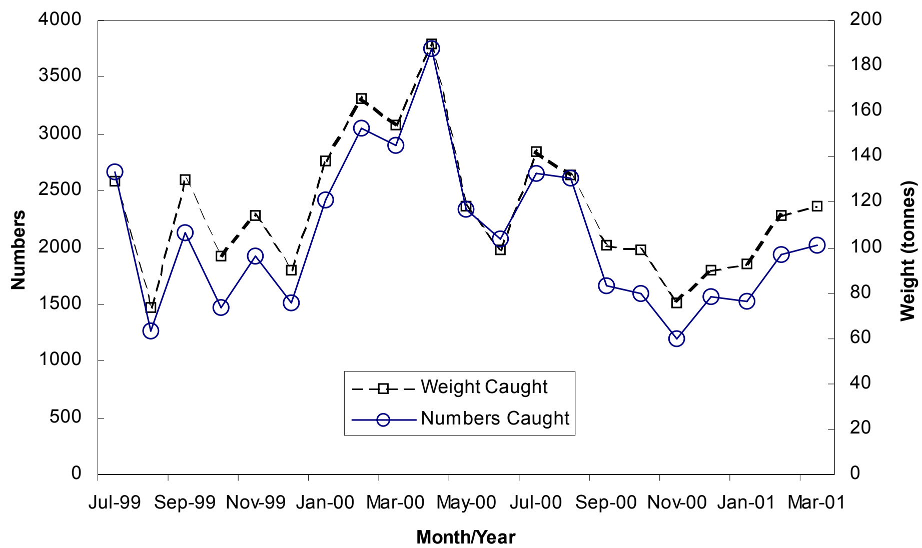


Figure 5. **Catch of *Xiphias gladius* from the Eastern Australian Fishing Zone during the study period.**

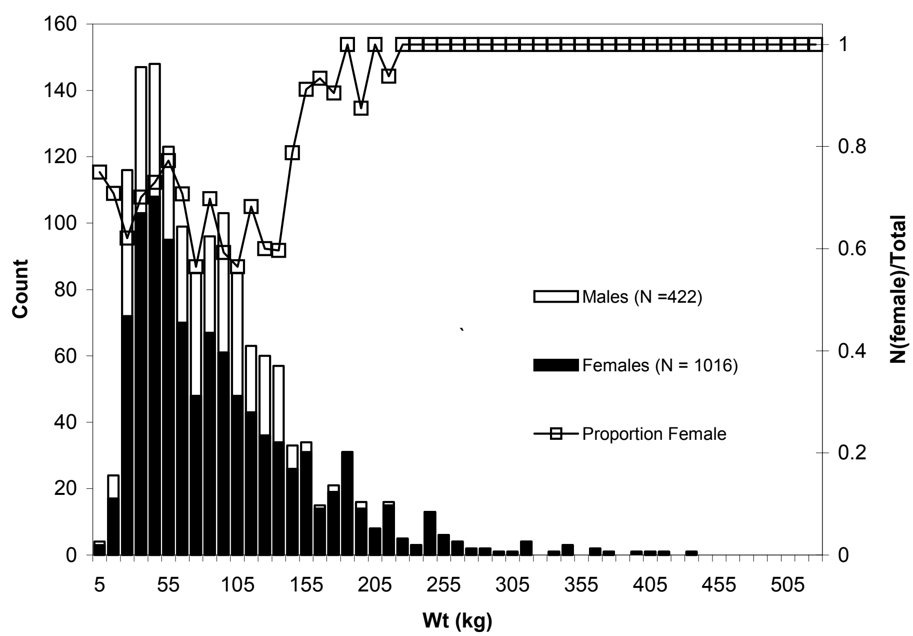


Figure 6. **Weight distribution of *X. gladius* showing the number of individuals per 10kg weight class and sex ratio (proportion of females to the total) against weight (kg). The weights were estimated from lengths using the length to weight conversion of De Martini (2000). Most of the catch is seen to be less than the 50% maturity mark (at approximately 140 kg).**

Table 3. Estimates of the total and total percentage (numbers in parentheses) of the female, male catch and the immature and mature proportion of the catch, within each sex over the study period (July 1999 – April 2001).

	Male	Female	Total
Catch in tonnes (% of total)	649.18 (29.32%)	1565.12 (70.68%)	2214.30
Total Mature (% of total)	473.96 (70.68%)	361.22(21.40%)	835.17 (38%)
Total Immature (tonnes)	175.22 (26.9%)	1203.9 (76.9%)	1379 (62%)

Discussion

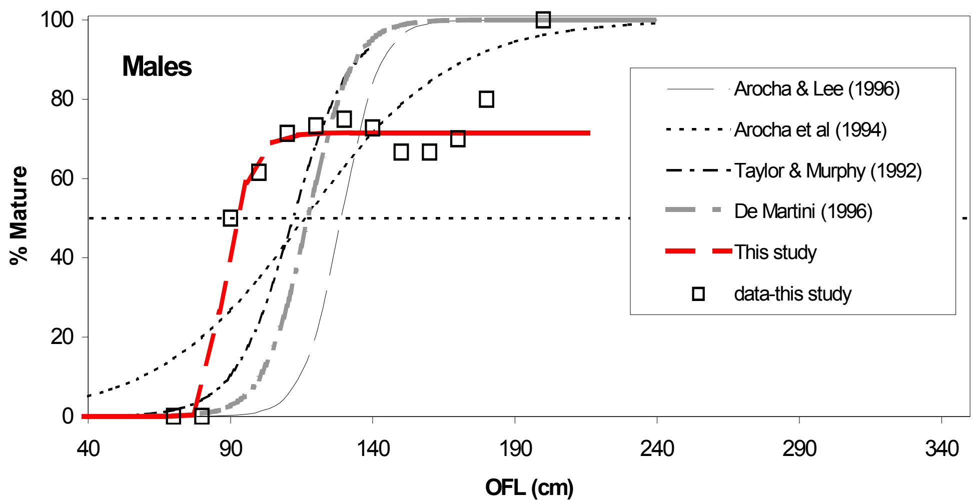
Determining size at maturity

Female size at 50% maturity, estimated using histological staging, was smaller than that estimated using GSI. The different results between methods of assessing maturity, underline the need for standardization of the techniques used to determine L_{50}. Of the two, the gonad index is the least reliable method as it does not account for the effect of mature, but spent, fish on the size-at-maturity relationship. These fish will have a relatively low gonad weight in relation to body weight compared to fish of similar size that are yet to spawn. Using a gonadosomatic index, they would effectively be counted as immature fish even if they have just spawned, thus inflating the size at which they first reached maturity (e.g. Knuckey and Sivakumaran 2001). In contrast, histological staging would render such fish as mature regardless of gonad size.

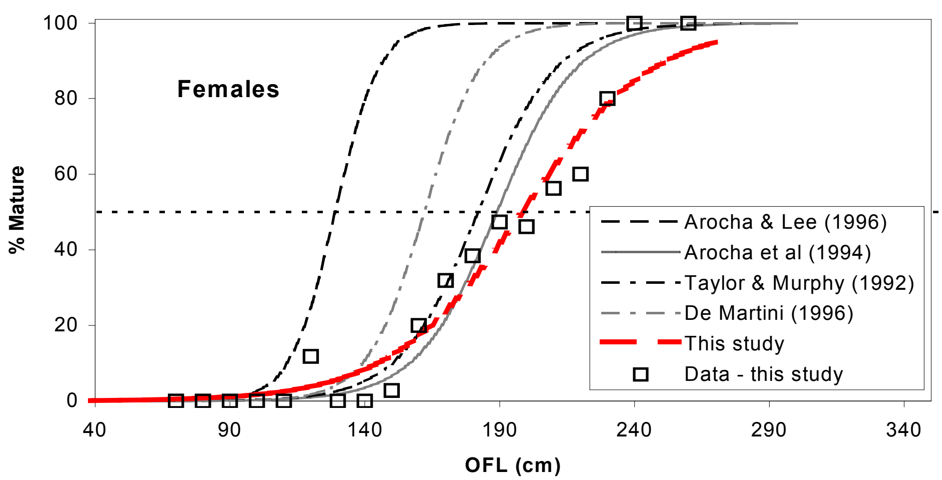
Size-at-maturity estimates for male swordfish have received relatively little attention in the literature, although recent studies are beginning to address this (e.g. De Martini et al. 2000). The lack of estimates may be due to the fact that determination of male maturity can be problematic, even with histology, and also due to a lack of data, since males are generally under-represented in the catch. This last point is particularly true for the present study. Our sample size was relatively small, particularly when compared to some of the data sets gathered from large-scale observer programs accessed by other studies (de la Serna et al 1996, De Martini et al 2000). In particular, the lack of data for large males may have produced a flatter gradient to the maturity curve, potentially resulting in a larger L_{50} estimate (Fig. 7). This may occur because post-spawning fish may have been classified as immature. Further sampling of male swordfish in the eastern Australian region is needed to reduce the uncertainty, due to small sample size, in the present estimate for these waters.

The significance of a high L_{50}

Size-at-maturity of female swordfish off eastern Australia was the highest of that reported for fisheries elsewhere, most notably for the Mediterranean fishery. The underlying reason(s) for this difference is not clear, but may be a reflection of the relatively recent history of the Australian fishery. Fisheries with a longer history of exploitation may impact on the size at which fish mature (Schaefer 2001). For example, the Mediterranean swordfish fishery has been in existence in some form since pre-Christian days, with increasing catches (up to 16,000 mt p.a.) since the 1960s (Ward and Elscott 2000). The L_{50} for female swordfish from this region estimated from GSI was 142.2 cm (de la Serna et al 1996), significantly less than that reported in the present study. This would indicate that females from the Mediterranean mature at least one year earlier than those off eastern Australia, if all fish follow the growth trajectory given by de la Serna et al (1996). Similar patterns of precocious sexual development have been reported for northern bluefin tuna from the Mediterranean Sea where fishing has also been prolonged (Schaefer 2001).



(a)



(b)

Figure 7. The maturity curves for (a) male and (b) female *X. gladius* from several studies including this one, highlighting the variation in maturity ogives for the species between and within locations. Arocha & Lee (1996), Arocha et al (1994) and Taylor and Murphy (1992) used data from the Atlantic fishery. De Martini (1996) used data from the western Pacific. This study has the largest female estimate of 50% maturity and the smallest male estimate. Also evident is that the male data suggest and narrower range of L50 estimates from greater variability in the slopes of the fitted models. The female data on the other hand gives similar shaped curves shifted along the size range.

As with the male swordfish, further monitoring would be valuable in reducing the variance around the reported female L_{50} value. It would also provide data to examine spatial and temporal variations that have the potential to impact on inputs for assessment of the swordfish stock in Australian waters.

The significance of a high proportion of immature fish in the catch

Historically, most swordfish landed by Australian longliners are between 35 and 250 kg dressed weight, averaging around 70 kg, with relatively few fish caught in the upper weight range (Ward and Elscot, 2000). Our data for the period of this study was consistent with this pattern. Importantly, extending the size-at- maturity estimates from the fish we sampled (~ 2.7% of the fishery) to the fishery statistics for the same period, we found that a significant proportion of the swordfish taken were immature (70% for females). However, as we have no real idea as to the actual spawning stock biomass of swordfish in the region, growth and selectivity functions, and limited knowledge of the geographic extent of the stock (Reeb et al. 2000), we can only speculate on whether the fishery is presently impacting on recruitment to the fishery and whether present fishing levels have the potential to impact on the future spawning stock biomass and egg production This points to the need for further study to assess growth, sex- and size specific selectivity and also for the development of abundance indices.

However, such indicators as declining catch rates, a decrease in the average size/weight of fish taken and the lack of new recruits to the fishery could indicate that the high proportion of immature fish in the catch is impacting on the stock. As yet no clear pattern can be seen with respect to any of these indicators in the Australian fishery. Campbell et al. (2002) provided evidence that in 2001 there was a downward shift in the size of the swordfish caught by the fishery relative to previous years. However, fishers observed unusually high numbers of small fish over the 2002 summer throughout the range of the fishery, suggesting that present fishing levels have not affected recruitment (B. Taylor, pers. com). Nevertheless, in the United States longline Atlantic fishery for swordfish, the problem of a high proportion of immature fish in the catch was recognized as a potential threat to the sustainable management of the fishery and a limit was set on the size of fish being landed (ICCAT 2001). It is noteworthy that their reported estimate of 58% of the catch being immature is less than the estimate we report here for the eastern Australian fishery. The United States has now outlawed the landing of swordfish under ~15 kg to discourage the retention of small fish.

Limitations and future directions

Small sample sizes precluded a spatial or temporal assessment of seasonal or monthly changes in sex ratio. Therefore considerable uncertainty surrounds the estimate of the percentage of the catch that is female or male at a given size. For this reason, and the uncertain aspects in the fitting of the maturity data mentioned above, we consider the assessment of the number of mature fish to be a useful, initial first step, but one that needs further development. Future work relevant to management would include the same analyses considered here, incorporating spatial and temporal components. Young et al (in prep) have found indications of changes in the size and sex structure of the population between inshore and offshore habitats. Such variation would be expected to create differential productivity across different areas and throughout the year, with effects on the maturity of the population and therefore egg production.

It is important to note that these analyses rely on results of studies from other regions, and these may not be valid for Australian fishing zone data. To determine whether the high proportion of immature fish in the catch is likely to affect the fishery, several key pieces of biological information are required. Firstly an age and size based selectivity relationship would enable understanding of whether fish are entering the fishery pre- or post –spawning. To do this requires an understanding of the growth of swordfish. A growth curve constructed from direct ageing estimates of swordfish from the Australian Fishing Zone would allow maturity-at-length to be related to age, and would therefore yield some idea of the productivity of the unfished and fished proportion of the population. Such a curve would also allow estimation of the number of seasons of spawning that females would have prior to entering the fishery. The length-weight relationship from De Martini et al (2000) uses data from the fishery in Hawaii. It is possible that the length-weight relationship is different for the Australian fishery, so that estimates of the weight at 50% maturity and the level of catch maturity may be biased, since these were calculated from landed tonnage and estimated weight distributions. Determining length-weight and age-length relationships for the Australian fishing zone is therefore of key importance in verifying the estimates from this study and also in the construction of population and stock assessment models and should be given a high priority in future research efforts.

Acknowledgements

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Young, J., Drake, A., Farley, J., Carter, T. and Brickhill, T. (submitted to MFR) Reproductive dynamics of broadbill swordfish, *Xiphias gladius*, in the domestic longline fishery off eastern Australia

6.3 Broadbill swordfish (*Xiphias gladius*) distribution in relation to oceanographic and feeding conditions in the eastern Australian Fishing Zone

Jock Young, Anita Drake and Clive Stanley

Abstract

Between July 1997 and February 2000 we monitored the catch of broadbill swordfish (*Xiphias gladius*) by one longliner fishing off eastern Australia equipped with an underway sampler that measured sea surface temperature (SST), salinity (SSS) and fluorescence (SSF). Year, month and moon phase at time and position of capture were also recorded. Stomach samples of 413 swordfish were sampled opportunistically throughout this period. The contribution of environmental variables to variations in the catch per unit effort (CPUE) were analysed using generalized linear regression in two ways. Firstly, using the catch excluding zero values, we were able to explain 31% of the total variation using the model (log CPUE~ temperature + salinity + fluorescence + month + year + moon phase + temperature:year + salinity: fluorescence). Of these terms, month, year, moon phase and the interaction between temperature and year were significant ($P<0.05$). The terms salinity ($P=0.06$) and fluorescence ($P=0.09$) were not quite significant. Using presence/absence data, we were able to explain 27% of the variation using the model (CPUE ~ temperature + salinity + fluorescence + month + year + moon). Of these terms, fluorescence, month and year were significantly different ($P<0.05$). Directly comparing the probability of catching swordfish to these factors indicated that swordfish were more concentrated in waters of higher temperature and lower fluorescence. Swordfish ate a mix of squid (72.5% by weight), fish (27.4% by weight) and occasionally crustacea (<0.1% by weight). The proportion of squid in the diet increased with size whereas the proportion of fish and crustacea decreased. Stepwise regression (prey mass ~ predator length + area + moon + month of capture + fluorescence) revealed that only predator length and fluorescence were significantly related to prey mass. Prey mass increased with predator size and decreased with increasing fluorescence although the reverse was true for prey number. We propose that the swordfish are more commonly found in clearer waters where they apparently have more success in catching larger prey species. The higher numbers of smaller prey (specifically crustacea) taken in the more turbid waters suggest they feed also in the fronts on smaller, more numerous species.

Introduction

The distribution of broadbill swordfish (hereafter referred to as swordfish) has been linked to a suite of environmental and physical variables in the Atlantic and Pacific Oceans (Podesta et al. 1993, Bigelow et al. 1999, Young et al. 2001, Sedberry and Loeffer 2001). Podesta et al. (1993) identified temperature as one of the main factors determining the distribution of swordfish. However, they noted the high variability in catch rates could not all be explained by temperature and suggested that other, unmeasured, factors were likely to influence catch rate. These variables may include sea surface temperature, salinity and fluorescence, proximity to temperature fronts, the presence of seamounts, the colour of the water, moon phase, weather conditions and fishing techniques such as the use of light sticks (Bigelow et al.1999, Young et al 2001). Swordfish are also known to make extensive migrations (Carey and Robinson 1981, Sedberry and Loeffer 2001). The underlying reasons for these associations and movements, however, are unclear although feeding and spawning are likely factors (Arocha this volume, De Martini et al. 2000).

This report has concentrated on the reproductive dynamics of swordfish in eastern Australian waters. We reported that distributional and movement patterns of the swordfish appeared to be influenced by reproductive behaviour. We provided evidence that the warm waters of the East Australia Current provided a suitable spawning environment to which spawning females migrated in late spring and summer to spawn. However, there are potentially other reasons for the observed patterns that may not be related to reproduction. For example, there is a spring increase in plankton production generally along the east coast of Australia that may provide increased prey levels that could attract these fish. We will therefore aim to continue our analysis of the regional oceanography that has resulted from our evaluation of ocean colour satellite imagery and longline catches off eastern Australia between 1997 and 1999 (Lyne et al. 2000, Young et al. 2000). We will also incorporate an analysis of stomach contents collected through this and the earlier ocean colour study.

In this chapter therefore we aim to firstly examine the relationships between swordfish catch and a suite of environmental variables. Secondly, we use an analysis of swordfish stomach collections to determine whether the observed relationships could be linked to the feeding ecology of the swordfish.

Methods

Data collection

Distributional and biological data of swordfish were collected from the eastern AFZ between latitudes 25 and 35 ºS (Fig. 1). In-situ oceanographic data was collected with an underway sampler (see Young et al. 2001) that collected temperature, salinity and fluorescence at the sea surface in relation to date, time of day and position measured by GPS. The sampler was connected to a computer that recorded the three variables at minute intervals at sea. The sampler was fitted to a longliner operating off the east coast of Australia initially from May 1997 to June 1999. The present study enabled its continuation through to May 2000. At ~ two-monthly intervals a CSIRO observer spent periods of a week or more on the longliner recording position and date of capture of swordfish. The observers collected biological data and samples including length, sex, gonads, stomach, otoliths and fin spine for each fish. These data were later matched with the underway files to link individual fish with all contemporaneous data collected.

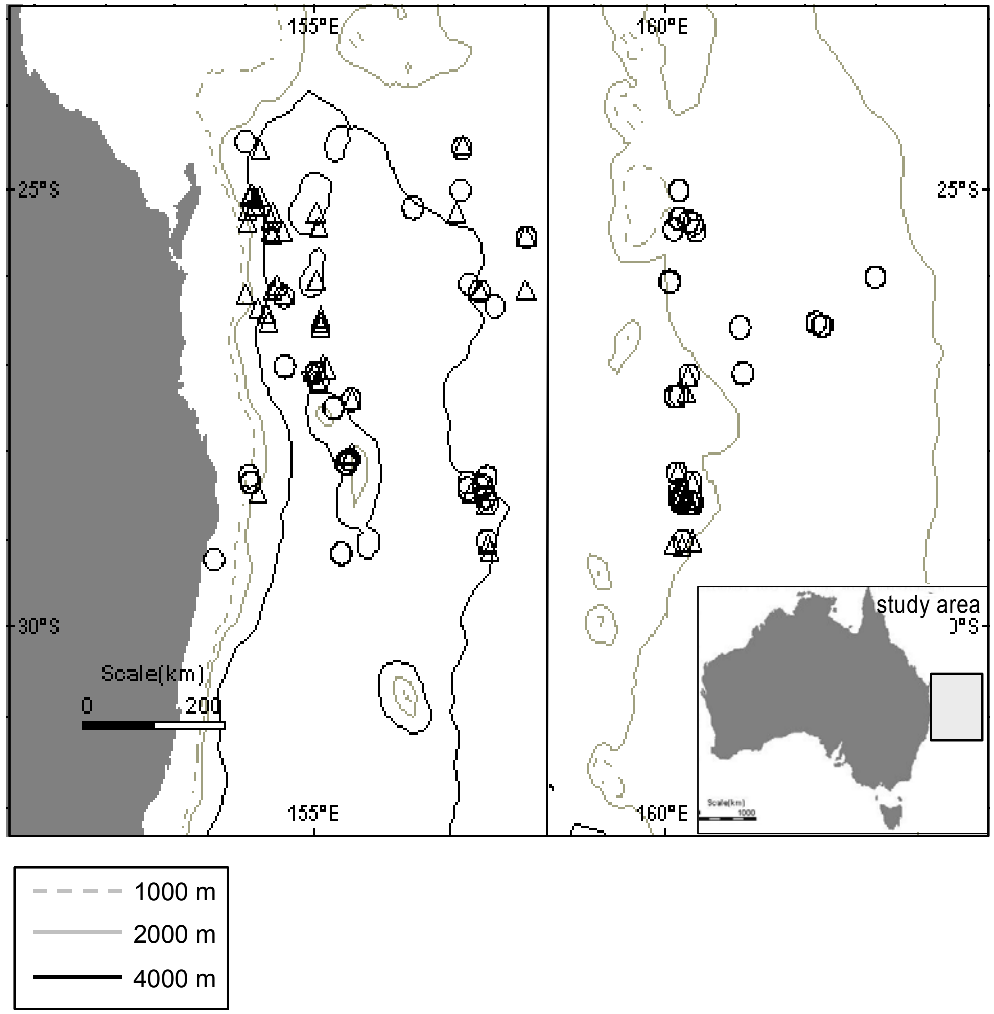

Figure 1: **Position of longline sets from which swordfish (*X. gladius*) captures were recorded (triangles), and from which swordfish were sampled for stomach contents (circles). Inshore samples were from the west of 158º E, offshore samples were from east of 158º E.**

Data analysis

We examined the relative effect of physical and environmental factors (defined in Table 1) on the catch rate of swordfish by the longliner through the application of generalised linear models (GLMs) using the statistical package S-Plus. The swordfish data were examined in two ways. Firstly, catch per unit effort (CPUE, in this case the number of swordfish per 200 hooks) was related to environmental parameters after excluding zero values from the data. A plot of mean CPUE (including zeros) and the variance of CPUE by month and year showed that the variance increased as the mean increased. The Gaussian model assumes that the variance is constant irrespective of the magnitude of the mean. Transforming the catch data to Log (CPUE) stabilized the means successfully so this transformation was used in the ensuing analyses. To avoid the scaling problems associated with adding a constant to account for zero values, zeros were excluded from the analysis. Forward stepwise regressions were used to determine the statistically significant terms in decreasing order of significance. Once the significant main effects had been determined all two-way interactions were tested for significance. To incorporate any information lost by excluding the zero values in the first analysis we examined the data in terms of the presence (CPUE >0) or absence (CPUE=0) of swordfish in the catches via a binomial analysis of the data. The probability parameter of the binomial distribution is modelled as a function of the co-variates. The results for both the quantitative and binomial analyses are presented graphically in the form of mean observed and mean fitted catch-per-unit-effort within intervals of covariate-values. That is, the means were calculated over ranges of the explanatory variable, chosen in such a way that there were a similar number of observations in each range or 'bin'. Observed and fitted mean values were then plotted against the mean of the explanatory variable in that range.

Feeding patterns

In the laboratory, stomach contents were weighed and given an estimate of fullness and digestion stage (Young et al. 1997) and the contents identified, weighed and counted. Hard parts (eg. squid beaks, otoliths) were not counted as individuals because we could not determine the time they had spent in the stomach. To standardize for fish length we divided mass by fish length to provide a standard by which fish across size-groupings could be compared. We then investigated feeding in terms of prey biomass, prey number, stomach fullness and state of digestion in relation to fluorescence, fish size, time of year, moon phase and whether they came from inshore (west of 158 °E) or offshore (east of 158 °E) waters using stepwise linear regressions. Data were log-transformed to stabilize the variance.

Results

Distribution in relation to physical variables

Examination of the scatter plots of catch effort in relation to the parameters measured suggested a number of possible relationships (Fig. 2). Interannual variations in catch rates were pronounced but other more subtle relationships were also observed pointing to relationships on a finer scale. In particular, the data suggested higher catch rates in waters with high sea surface salinity and low sea surface fluorescence. Although lower temperatures also appeared to be associated with higher catch rates, there were only zero values at temperatures below about 21 ºC. This may be because of the small number of observations in the low temperature range, or it may be a real effect. Also, although the catch rates were relatively low for temperatures above 26ºC, it is interesting to note that there were no zero catch values in this range.

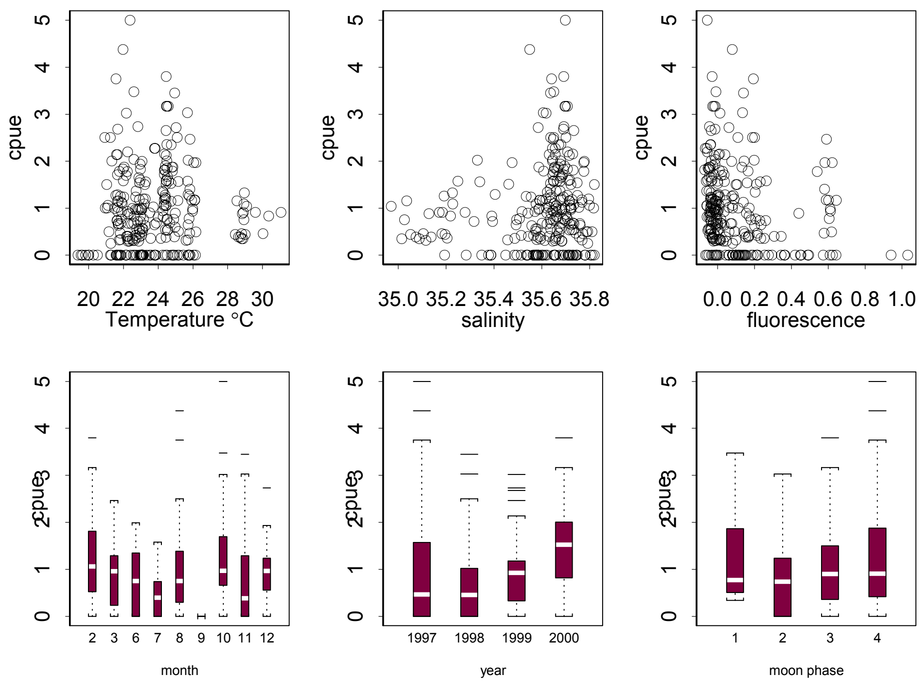

Figure 2: **CPUE (number of swordfish (*X. gladius*) per 200 hooks) plotted against the covariates: temperature, salinity and fluorescence in the top row, and month, year, moon phase in the lower row. The box plots show the interquartile range (filled bar) with the median (white horizontal line), and the extremes of the data as horizontal lines.**

Multivariate analyses

Modelling log (CPUE) for CPUE>0

Initially we modelled all the covariates (Table 1) as first order terms. The resulting analysis showed that salinity, month, year and moon were significant ($P<0.05$) but only explained 25% of the variation. By including interaction terms we were able to explain 31% of the total variation using the model (log CPUE~ temperature + salinity + fluorescence + month + year + moon phase + temperature: year + salinity: fluorescence). Of these terms, month, year, moon phase and the interaction between temperature and year were significant ($P<0.05$) (Table 2). The terms salinity ($P=0.06$) and fluorescence ($P=0.09$) were not quite significant. We attempted a further analysis combining months into seasons but little further information was gained by this manipulation. The resulting plots showed that mean CPUE was relatively constant over the range of temperatures with a decline at the highest temperatures (Fig. 3). Also indicated was an increase in the catch rate at higher salinities and at low fluorescence (Fig. 3).

Table 1: Descriptions of factors used in the analyses to identify factors influencing the distribution of swordfish (*X. gladius*) in eastern Australian waters (Catch data was standardised to the number of fish per 200 hooks).

Factor	Description	Range
Year	Years during which data were collected	1997-2001
Month	Month of the year during which data were collected	
Moon phase	New moon coded as 1, first quarter as 2, full moon as 3, last quarter as 4	1- 4
Area	Inshore (west of 158 ºE) or offshore (East of 158 ºE)	
Temperature	Median value of sea surface temperature for each section in ºC	20.94 – 31.07
Salinity	Median value for sea surface salinity for each section in parts per thousand	34.97 – 35.82
Fluorescence	Median values for sea surface fluorescence for each section in standard units mg m^{-3}	-0.0564 – 0.6646

Table 2: Results of the generalized linear model examining the affect of physical variables on swordfish (*X. gladius*) catch rates over a four year period including interactions.

(log cpue ~ temperature + salinity + fluorescence + month + year + moon + temperature : year + salinity :fluorescence)	Value	SE	T	P
Intercept	-35.26	20.55	-1.71	0.08
Temperature	-0.10	0.10	-1.02	0.31
Salinity	1.05	0.56	1.88	0.06
fluorescence	169.95	101.01	1.68	0.09
Month 1	0.68	0.76	0.89	0.37
Month 2	0.25	0.24	1.05	0.29
Month 3	-0.38	0.13	-2.95	0.00
Month 4	0.05	0.07	0.62	0.53
Month 5	0.15	0.06	2.66	0.01
Month 6	0.01	0.04	0.08	0.94
Month 7	0.13	0.04	3.21	0.00
1997	-4.31	1.59	-2.72	0.01
1998	2.63	1.29	2.03	0.04
2000	3.09	2.06	1.50	0.13
Moon 1	0.54	0.18	3.08	0.00
Moon 2	0.14	0.06	2.40	0.02
Moon 3	0.11	0.04	2.51	0.01
Tempyear 1	0.17	0.07	2.45	0.02
Tempyear 2	-0.12	0.06	-2.09	0.04
Tempyear 3	-0.11	0.08	-1.32	0.19
Sal:fluor	-4.71	2.83	-1.67	0.09

Multiple R-Squared: 0.31

F-statistic: 4.064 on 20 and 184 degrees of freedom, the p-value is 1.518e-007

Table 3: Significant factors resulting from binomial regression of the relationship between the presence (catch >0)/absence (catch =0) of swordfish (*X. gladius*) and the factors temperature, salinity, fluorescence, month, year and moon phase.

	Value	SE	t	P
Intercept	121.88	74.91	1.62	<0.05
Fluorescence	-12.25	4.65	-2.63	"
Month	6.12	2.18	2.80	"
Year 1	1.46	0.62	2.33	"
Year 3	1.25	0.32	3.84	"

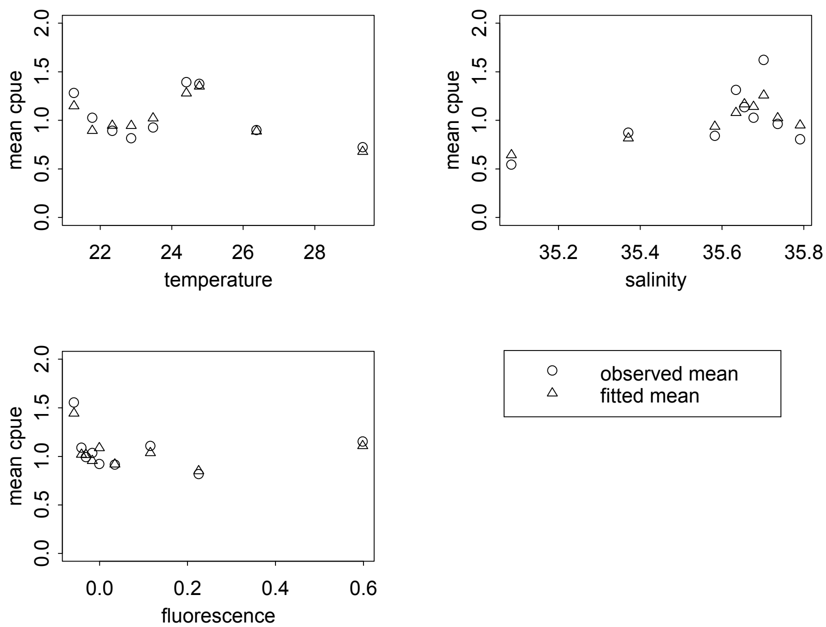

Figure 3. Results from the log (CPUE) GLM model without interaction terms. Mean observed and mean fitted CPUE within intervals of covariate-values, plotted versus each of the three environmental covariates (temperature, top left; salinity, top right and fluorescence, lower left).

Modelling the binomial response

The binomial model including temperature, salinity, fluorescence, month, year and moon phase explained 27% of the variance. This is clearly low, but is at the upper range of goodness-of-fit that could be achieved with this dataset. Of the factors included in the model, fluorescence, month and year were significant (Table 3).

For factor variables (such as year, month and moon), problems can arise when there are categories with only 0-observations, i.e. only "failures". This is the case for month 9, which only appears in one of the years (1997). However, leaving out this month had very little effect on parameter estimates and results, as is evident by comparing fitted values for data-rows present in both models. The average fitted values compared well with the average observed proportions in the chosen categories (Fig. 4). The plots suggested the probability of a non-zero catch rate increased as the temperature increased, but was relatively constant over the range of salinities observed. The probability of catching swordfish decreased with increasing fluorescence. However, there were a large number of 0's (observations) with associated fitted values that were quite high. Since the probabilities reflected the proportion of 1's, this indicated that, if used as a predictor, the model would have a relatively large error rate.

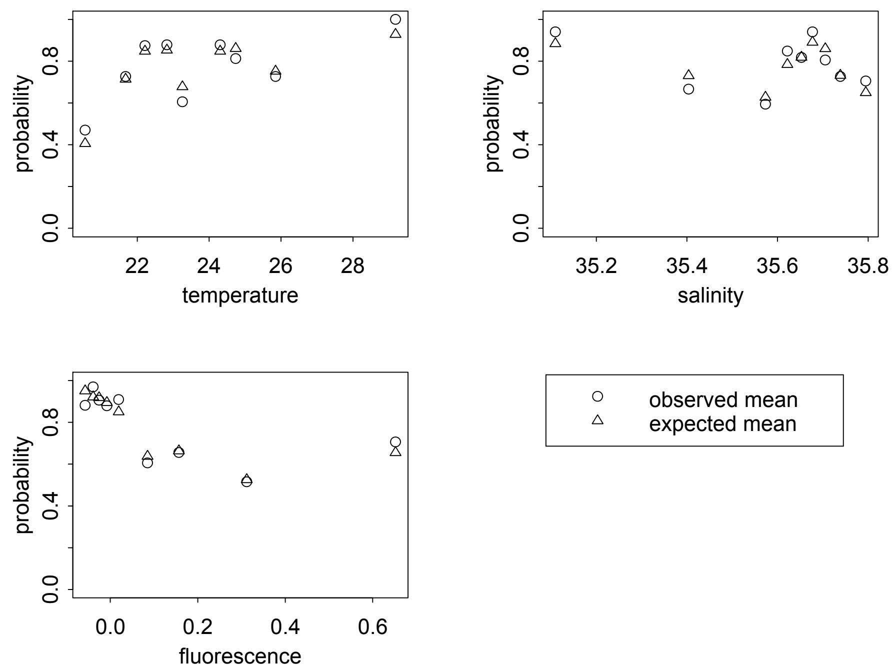

Figure 4. Results from the Binomial model. Proportions of observed 1's (observed mean) and fitted binomial probability (expected mean) plotted versus each of the three environmental covariates (temperature, top left; salinity, top right and fluorescence, lower left).

Feeding ecology

Swordfish ate a mix of squid (72.5% by weight), fish (27.4% by weight) and occasionally crustacea (<0.1% by weight) (Tables 4 and 5). The proportion of squid in the diet increased with size whereas the proportion of fish decreased (Fig. 5). Crustacea were only identified in fish less than 120 cm OFL. The most commonly recognized prey species was the ommastrephid squid *Nototodarus gouldii.* Maximum prey weight increased from a prey mass of <500 g for fish less than 100 cm OFL to as much as 5 kg in fish >200 cm OFL (Fig. 6). Prey length increased significantly with predator size (r^2=0.56, P<0.05).

Table 4: Proportions of the major prey taxa in the stomachs of 413 broadbill swordfish (*X. gladius*) caught off eastern Australia (%n, percentage of total number of prey; %w, percentage of total weight of prey; %f, percentage frequency of occurrence of a taxon in the stomachs examined).

Taxon	%n	%w	%f
Cephalopoda	61.85	72.57	83.96
Pisces	32.85	27.39	44.81
Crustacea	3.39	0.03	3.77
Other	2.25	0.01	<1.00

Feeding in relation to environmental variables

We compared prey mass, prey numbers, stomach fullness and digestion stage of landed swordfish with respect to time of year, moon phase, area of capture and fluorescence. There was no difference in prey biomass between seasons although mean prey number was significantly higher in winter (Kruskal Wallis test, $P<0.05$) (Fig. 7). There were no significant difference in prey biomass, prey number or stomach fullness between inshore and offshore waters, nor was there in relation to moon phase. Prey biomass was highest in waters with the lowest fluorescence but consisted of the lowest number of prey indicating that the swordfish were feeding on relatively larger prey in these waters (Fig. 7). The relatively higher numbers of prey in waters with higher fluorescence is explained in part by the increased numbers of small crustacea in the diets of fish from these waters (Fig. 8)

Stepwise regression using, in turn, prey mass (standardised for length), number of prey and stomach fullness as the response variable were computed against predator length, area, moon, month of capture and fluorescence as the main effects. When standardised prey mass was the response variable month and fluorescence were significant. Fluorescence had the main effect on prey number and stomach fullness revealed that only predator length and fluorescence were significantly related to prey mass.

Table 5: Composition of stomach contents of 413 broadbill swordfish (*X. gladius*) caught off eastern Australia between July 1997 and March 2001. The product (%n.%F) of percentage number of prey (%n) and percentage frequency of occurrence (%F) is a measure of importance of each prey type.

Taxon	n	%n	F	% F	%n.%F
Teleosts					
Unidentified teleosts	124	14.97	87	41.04	614.17
Alepisaurus ferox	6		2		
Brama brama	2	0.23	2	0.94	0.21
Centrolophus niger	2	0.23	2	0.94	0.21
Cubiceps caeruleus	3		3		
Diaphus sp.	2	0.23	2	0.94	0.21
Lestidiops sp.	1	0.11	1	0.47	0.05
Myctophidae	4	0.45	2	0.94	0.43
Pterycombus petersii	2	0.23	2	0.94	0.21
Seriolella brama	2		2		
Tetraodontidae	1	0.11	1	0.47	0.05
All teleosts	146	16.33	95	44.81	731.61
Cephalopoda					
Unidentified Cephalopoda	253	29.82	167	79.25	2362.98
Ommastrephidae	8	0.23	6	0.94	0.21
Cycloteuthis sp.	1	0.11	1	0.47	0.05
Histioteuthis sp.	1	0.11	1	0.47	0.05
Mastigoteuthis sp.	1	0.11	1	0.47	0.05
Moroteuthis sp.	2	0.23	1	0.47	0.11
Nototodarus gouldi	6	0.68	6	2.83	1.93
Ommastrephes bartrami	2	0.23	2	0.94	0.21
Ornithoteuthis volatilis	2	0.23	2	0.94	0.21
All cephalopods	274	31.07	178	83.96	2608.35
Crustacea					
Unidentified Crustacea	7	0.79	2	0.94	0.75
Penaedea	7	0.79	5	2.36	1.87
Caridea	1	0.11	1	0.47	0.05
All Crustacea	15	1.70	8	3.77	6.42
Other					
Polychaeta	10	1.13	2	0.94	1.07
Total prey	443				

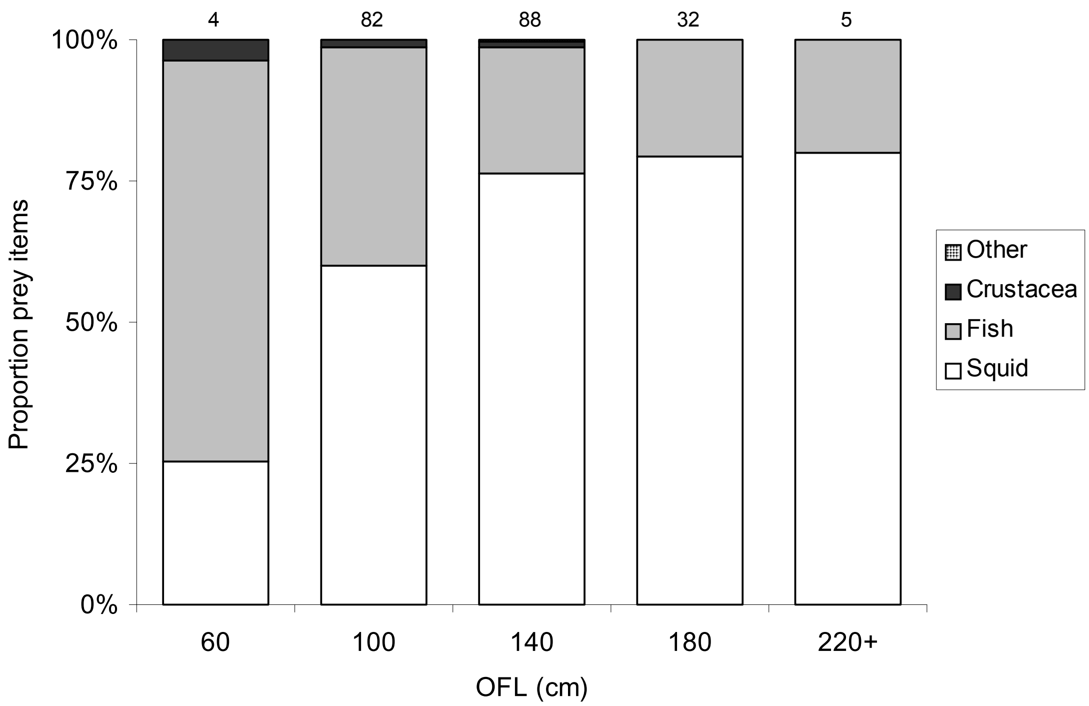

Figure 5: Proportion of the major prey taxa in relation to size of broadbill swordfish (*X. gladius)* off eastern Australia.

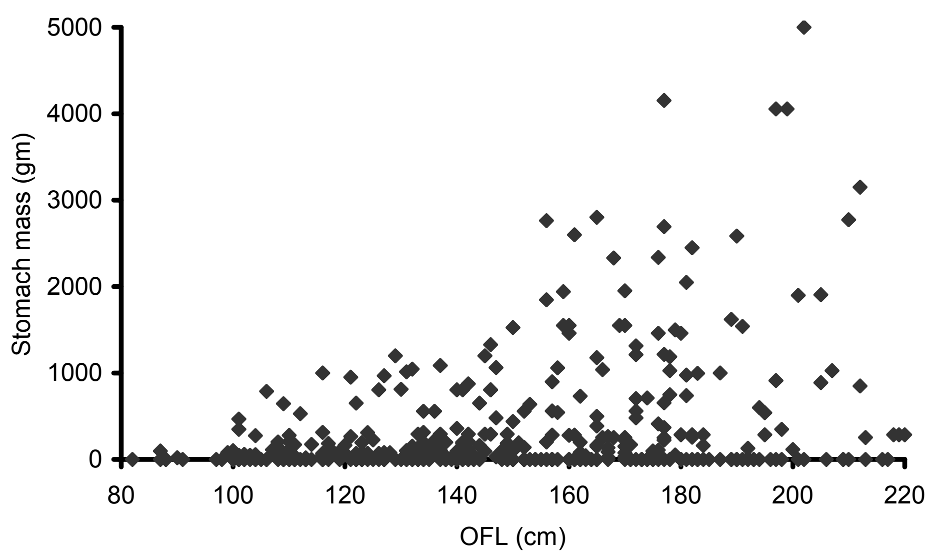

Figure 6: Stomach mass in relation to size of broadbill swordfish (*X. gladius*) off eastern Australia.

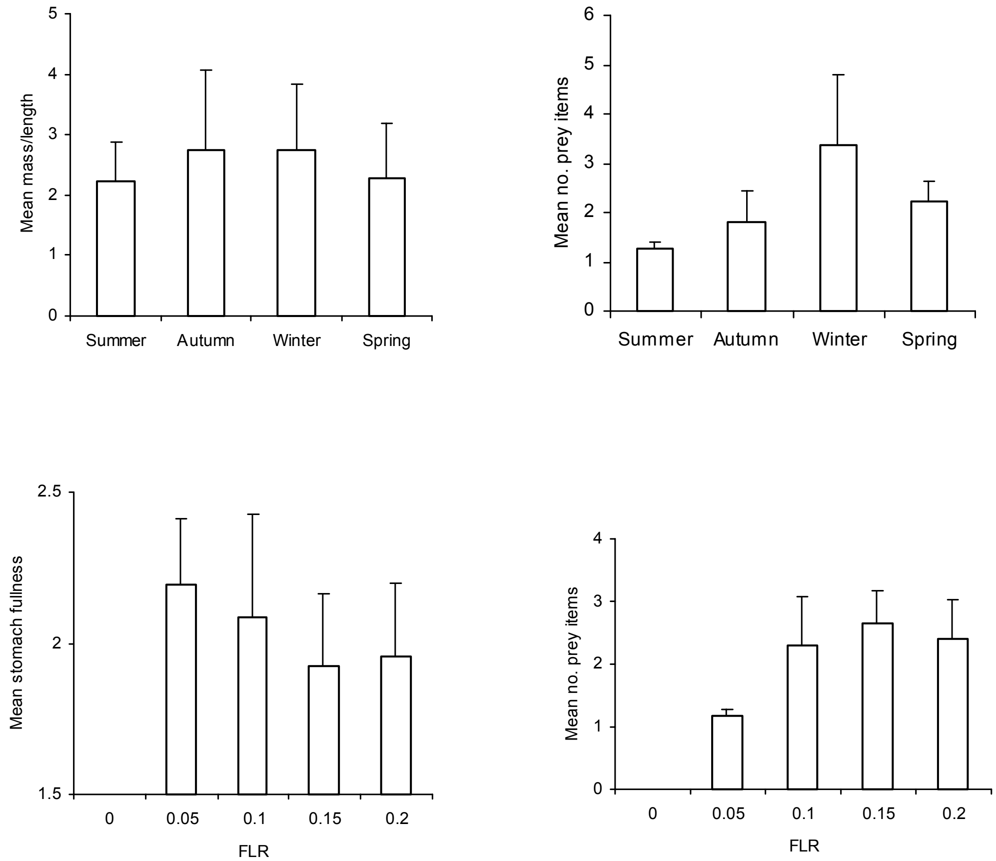

Figure 7: **Stomach fullness and numbers of prey eaten by broadbill swordfish (*X. gladius*) in relation to season and fluorescence (FLR in ug l-1) off eastern Australia.**

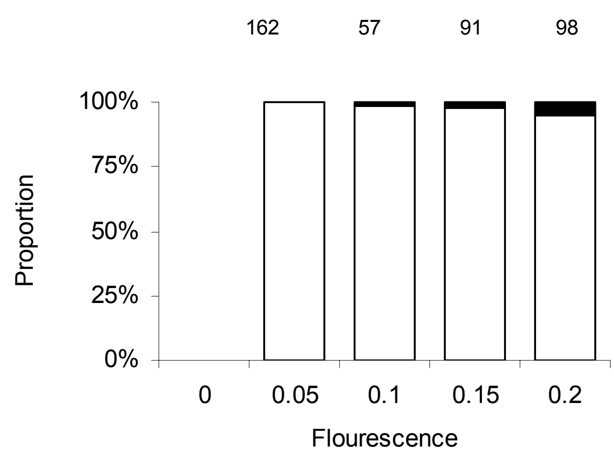

Figure 8: **Proportion of crustacea by weight in stomach contents of broadbill swordfish (*X. gladius*) in relation fluorescence off eastern Australia.**

Table 6: Significant factors resulting from step wise regressions of the relationship between (a) Mass/length (mass divided by length), (b) number of prey and (c) stomach fullness and the variables area (inshore or offshore [see map]), fluorescence, moon phase, season and fish length.

(a) Prey mass

	Value	SE	T	P
Intercept	2.83	0.61	4.61	0.00
Month	0.14	0.07	1.92	0.05
Fluorescence	-9.89	4.84	-2.04	0.04
Area				ns

Residual standard error: 4.76 on 408 DF

Multiple R-Squared: 0.0, F-statistic: 2.52 on 2 and 408 DF (P = 0.08)

(b) Number of prey

	Value	SE	T	P
Intercept	0.47	0.27	1.74	0.08
Fluorescence	4.52	1.76	2.56	0.01
Area	-0.16	0.10	-1.55	ns

Residual standard error: 2.04 on 408 DF

Multiple R-Squared: 0.03, F-statistic: 5.902 on 2 and 408 DF, (P = 0.00)

(c) Stomach fullness

	Value	SE	T	P
Intercept	1.91	0.34	5.48	0.00
Fluorescence	-2.05	1.12	-1.82	0.06
Area	0.002	0.01	1.49	ns

Residual standard error: 1.28 on 385 DF

Multiple R-Squared: 0.02, F-statistic: 3.017 on 2 and 385 DF (p= 0.05)

Discussion

Limitations to the data

Exploratory analyses of this dataset showed that it was not possible to reach firm conclusions regarding the significance of different co-variates in the statistical models. For example, small changes in the data coding (e.g. using 'season' or using 'month') affected the significance of terms in model outputs. That is, we could not conclusively show whether, for example, fluorescence was a significant factor for CPUE. Because the data were collected from a single vessel there is an inevitable lack of balance in the data. For example, sampling in one year (1997) was restricted to west of 158 ºE and in 2000 was largely east of this line. Nonetheless, there are biological and oceanographic reasons why one would expect the environmental variables we found to be significant and would play some role in the catch rate of swordfish. This is born out by the data.

Distribution in relation to physical variables

Both analyses of the catch data pointed to an association between catch and the physical variables salinity and fluorescence, albeit embedded within yearly, and in some cases, seasonal variations. Salinity has previously been inferred by Sakagawa (1989) as an important factor in the distribution of swordfish. It is unlikely that salinity per se affected swordfish distribution. However, the fact that relatively higher salinities were correlated with catch rates may indicate that the fish were cueing on areas where deeper more saline waters were upwelled into surface waters generating more active food webs (Harrison and Parsons 2000). Conversely, higher catches in autumn coinciding with an influx of higher salinity water at that time may indicate some broader scale relationship with the South Equatorial Current (see Fig. 2a, Chapter 6.1). On the other hand, fluorescence may relate directly to swordfish catches in that it is a measure of not only prey levels but also on the level of visibility that a swordfish encounters.

Catches peaked in autumn and spring, mirroring the pattern of catches by Japanese longliners in the same area (Ward 1996), and indicating the swordfish may be responding to peaks in productivity typical of these seasons. Catches in February in both years of the study were significantly lower than other times of year; also mirroring the Japanese catches (Ward 1996). This appears to be due, particularly in 1998, to the flood of warm nutrient-poor water down the coast at that time. One explanation for the low catches was that there was little feed in the area at that time. Ocean colour imagery for the period shows the clearest water extending beyond the distance of the vessel with little evidence of frontal structure. In an apparent contradiction, however, the model also found that catches were highest when fluorescence was lowest but also those catches were higher near temperature fronts. This suggests that although the broadbill prefer clearer waters, proximity to fronts (source of concentrations of feed) is also important (Sakagawa 1989, Podesta et al. 1993). Year was also a significant factor. However, as only four years of data were analysed this result was probably related more to seasonal factors than anything longer term. Nevertheless, this is likely to be a major factor as the fishery develops given the interannual variability of the major water mass movements off eastern Australia. Moon phase affected catch rates significantly. In contrast to Japanese catches in the same area that found highest catches around the full moon (Ward 1996), our study showed highest catches just before the full moon. However, this is more than likely related to the concentration of fishing effort as the longliner tended to make two trips each month, one either side of the moon, thus missing at least part of the full moon period.

Feeding patterns in relation to oceanography

The diet of swordfish off eastern Australia was dominated by, in order, cephalopods, fish and to a far lesser extent, crustacea, the latter in fish less than 100 cm OFL. We noted an ontogenetic shift in diet from mainly fish in swordfish less than 100 cm OFL to progressively more squid as the size of the swordfish increased. Many of the stomachs examined were very digested due to the long soak times of the longline sets and the subsequent digestion until, and probably after, death (Boggs 1992), making identification of individual species difficult. Nevertheless, we could identify a number of common cephalopods (e.g. *Nototodarus gouldi*) that have wide distributions in the area. The dominance of cephalopods in swordfish diets has been documented previously (Toll and Hess 1981, Hernandez-Garcia 1994, Velasco and Quintans 2000), although fish are the main prey in some areas (Scott and Tibbo 1967, Hernandez-Garcia 1994). Of the fish species we identified as prey, many have epi- to mesopelagic distributions indicating that the swordfish were feeding in the upper layers. This suggests that the swordfish were feeding at night as they usually descend to below 600 m during the day (Carey and Robinson 1981, Sedberry and Loeffer 2001). Previous studies have reported increased feeding with the full moon (Draganik and Cholyst 1988). However, although there was an indication of increased feeding over the full moon prey biomass was not significantly different to other times of the month. The main pattern we detected was the relationship between feeding and fluorescence concentration. We found that the swordfish fed more in the clearer (less fluorescent) waters away from the front. When in the front they appeared to feed on smaller prey items, particularly crustacea.

Movement in relation to prey concentrations

With little direct knowledge of swordfish movements off eastern Australia but with the knowledge that swordfish migrate over large distances (Carey and Robinson 1981, Sedberry and Loeffer 2001) we proposed in Chapter 6.1 that swordfish movements in the region could be related to their seasonal reproductive cycle. In that study we reported that the proportion of spawning females was significantly higher in the warmer waters extending down the coast of eastern Australia in the Austral spring. An alternative hypothesis is that movements could also be influenced by spatial and temporal variations in feeding (Arocha and Ehrhardt in prep.), as is reported commonly for other scombroid species (e.g. Sharp 2001). However, that hypothesis was not supported by this study. We found no relationship between geographic area and feeding intensity. Indices of feeding were almost identical between inshore and offshore waters of the study area, and mirrored the results found by Velasco and Quintans (2000) for a similar study in the Atlantic Ocean. Our results indicated a flexible feeding pattern that was responsive to fine scale oceanographic features. Swordfish fed mainly in low chlorophyll water but were capable of feeding in waters with higher chlorophyll levels where they modified their diet to feed on smaller prey including crustacea.

Acknowledgements

We would like to thank the skipper of the longliner FV Sniper, Mark Ebbels whose enthusiasm for the collection of the underway data enabled the continuation of this project for four years. We also thank Tony Jerome for sample collection and Chris Rathbone for satellite imagery.

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7. Conclusions

A summary of the outcomes of the project, detailing the objectives, whether they were met and any outcomes

1. All objectives were achieved by the study. We now have a clear understanding of the reproductive dynamics of swordfish off eastern Australia including when and where they spawn and the environmental factors with which spawning is correlated. We have determined their size-at-maturity, the ratio of females to males and an estimate of fecundity. We provided indirect evidence that the distribution of swordfish off eastern Australia may be related to spawning activity but could find no link with indices of feeding. We estimated the proportion of mature and immature fish in the catch and discussed these findings in relation to the fishery. Finally, we examined the distribution of swordfish in relation to fine and coarse scale physical variables. The results we found and the conclusions drawn are detailed below.

2. Swordfish have a protracted spawning period off eastern Australia between September and March with the greatest activity from December to February. Females began maturing at 150 cm OFL. Males were significantly smaller than females and represented less than one third of the sampled fish. Sex ratio differed significantly with respect to fish size and time of year. Males started maturing at ~80 cm OFL; ripe males were found from January to March but also in May and October suggesting an extended reproductive period. During the spawning period the proportion of spawning to inactive mature-sized females was significantly higher in waters west of Longitude 158°E than in waters to the east. Further to the east, samples taken from the New Zealand fishery showed no actively spawning fish during the main spawning period. Females were increasingly reproductively active as water temperature increased beyond 24°C and sea surface chlorophyll a decreased below 0.2 ug/l. Batch fecundity was linearly related to fish size with a mean batch fecundity of 1.66 million oocytes in females ranging in size from 173 to 232 cm OFL. The presence of hydrated oocytes and post-ovulatory follicles (POFs) in the same ovaries indicated multiple spawning, and depending on the time taken for POFs to degrade, may have been daily at the height of the spawning season.

3. The L_{50} for females was estimated at 193.6 (±0.51 SE) cm orbital fork length (OFL) using the Gompertz model and 199.8(±0.51 SE) using the logistic model. A further L_{50} was calculated at 219.3 cm from female gonadosomatic data taken from the entire spawning period. However if these data were restricted to the peak spawning period (December to February) this figure was reduced to 201.9 cm underlining the effect of mature, spent fish (small gonad size) on such calculations. The inclusion of the latter will generally overestimate maturity size and should be avoided. The male L_{50} was 85.8 cm using the Gompertz model or 102.3 cm OFL using a constrained version of the same. The size/weight frequencies were similar for both the sampled and total catch by the fishery between July 1999 and April 2001. We estimated that females comprised 70.7% of the total catch and males 29.3% of the total. We determined that 77% of the females caught were immature; whereas only 27% f the males caught were immature. To determine whether the high proportion of immature females will affect the future viability of the stock we will need to relate length at maturity to age at maturity for the region. This information is needed to yield some idea of the productivity of the unfished and fished proportion of the population.

4. The contribution of environmental variables to variations in the catch per unit effort (CPUE) was analysed using generalized linear regression in two ways. Firstly, using the catch excluding zero values, we were able to explain 31% of the total variation using the model (log CPUE~ temperature + salinity + fluorescence + month + year + moon phase + temperature:year + salinity: fluorescence). Of these terms, month, year, moon phase and the interaction between temperature and year were significant ($P<0.05$). The terms salinity ($P=0.06$) and fluorescence ($P=0.09$) were not quite significant. Using presence/absence data, we were able to explain 27% of the variation using the model (CPUE ~ temperature + salinity + fluorescence + month + year + moon). Of these terms, fluorescence, month and year were significantly different ($P<0.05$). Directly comparing the probability of catching swordfish to these factors indicated that swordfish were more concentrated in waters of higher temperature and lower fluorescence. Swordfish ate a mix of squid (72.5% by weight), fish (27.4% by weight) and occasionally crustacea (<0.1% by weight). The proportion of squid in the diet increased with size whereas the proportion of fish and crustacea decreased. Stepwise regression (prey mass ~ predator length + area + moon + month of capture + fluorescence) revealed that only predator length and fluorescence were significantly related to prey mass. Prey mass increased with predator size and decreased with increasing fluorescence although the reverse was true for prey number. We propose that the swordfish are more commonly found in clearer waters where they apparently have more success in catching larger prey species. The higher numbers of smaller prey (specifically crustacea) taken in the more turbid waters suggest they feed also in the fronts on smaller, more numerous species.

8. Benefits of the study

This study provides the first assessment of reproductive dynamics of swordfish in Australian waters. It has revealed a number of features of the animal's biology and proposed areas for future study that will support sustainable management of the fishery. For example, we now know that swordfish do spawn in Australian waters and that reproductive activity is concentrated within the Australian Fishing Zone in the East Australia Current. We also know that spawning takes place over an extended period between September and March, but with most reproductive activity between December and February. The study has shown that the females outnumber males by approximately 2 to 1 and that approximately 70% of the females captured are immature. This type of information has the potential to support specific management plans aimed at maintaining the viability of the fishery. The study has developed standardized methodologies for future studies of the animal's reproductive activity and established a baseline from which these studies can assess the health of the stock.

The benefits of studies such as this one usually take some time to flow through to management. However, this study was developed in conjunction with the development of an operational model for the fishery. As such, the information gained has been directly integrated into our understanding of the fishery. Specifically, the developing operational model relied on data from northern hemisphere studies. However, this study has shown that quite different population parameters exist for the species in Australian waters. For example, the size at maturity ogive with an L50 of 195 cm (OFL) for female swordfish replaces the knife-edged value of 170 cm used until this study was completed. This has important implications for the stock as it identifies the fact that female swordfish mature at a larger size in the Australian region than in any other region in the world where they are fished. A study presently underway will determine at what age this critical size is reached.

It was not the objective of this study to provide evidence for the movement of swordfish within the region. However, the presence of significantly more ripe female swordfish within the East Australia Current than offshore, and the presence of atretic and non spawning fish to the east during the spawning period, indicated there may be a spawning-led migration of female swordfish into the Australian Fishing Zone. Furthermore, the significantly low numbers of male swordfish during winter and spring than in summer and autumn indicate movement of males out of the region at this time. Previous sampling in more northern waters showing a more even sex ratio suggests that these males move northward into warmer waters. This information will also be taken into account as the operational model deals with the wider issues of movement and migration of the species.

Although sampling was restricted to the east coast of Australia the population parameters determined by the study can reasonably be used in the assessment of the Western Australian swordfish fishery until independent sampling is carried out in that region.

9. Further Development

The preceding analyses are the first description of swordfish reproductive biology and feeding in eastern Australian waters. As such they provide a baseline from which comparisons can and should be made to monitor some of the basic parameters needed to provide the inputs for sustainable management of the swordfish fishery in these waters. For example, as the fishery develops so will the need to identify shifts in the spatial and temporal patterns of spawning. Further questions, such as how interannual variations in oceanographic conditions affect spawning in the swordfish stock have yet to be addressed, and to do so will require a commitment to long term monitoring. The advantage of such research will be to deliver a more concise view of the extent and duration of spawning that can be fed into population assessment models. It could also identify sensitive time/area combinations where reproductively active females are concentrated.

Although our data suggests there may be a spawning-led migration of swordfish into the eastern Australian AFZ we can only speculate on the movement patterns of the swordfish in our region as a whole. Tagging is traditionally the most effective method for determining movement patterns. However, the solitary nature of this fish restricts the usefulness of conventional tagging. Archival tags are also limited in that these fish spend little time in surface waters, which is necessary for position fixing. Pop-off satellite tags as they develop appear to be the most suitable technology to elucidate movement patterns.

Size-at-maturity estimates determined for this study had relatively wide confidence intervals, particularly in the upper and lower size ranges of the male swordfish sampled. This was largely due to the limited numbers of fish for which histological data was available, particularly when compared with some of the studies completed recently in fisheries where observer coverage meant greater access to fish. Increased sampling would reduce the error around the estimates reported. Size-at-maturity estimates are also an effective way of monitoring the spawning capabilities of the stock and the impact of fishing on the parental biomass. A follow up study, in say five years, would allow a useful comparison of how the stock in eastern Australian waters is faring.

This study relied on weight-length relationships determined for the northern hemisphere. As with most variables associated with the swordfish there is considerable variability between regions, and according to feedback from the fishery, variation within regions, both temporally and spatially.

There is also anecdotal evidence that female swordfish increase in weight as the spawning season approaches. There is a need, therefore, for a structured study to determine the same for the local region with emphasis on temporal and spatial variations. Such a study could be incorporated into one on variations in the condition of swordfish, particularly with the development of the sashimi market.

This study has related the reproductive dynamics of the swordfish to size with no attempt to make any conversions to age-at-maturity, an important step in determining the time frame in which the stock in Australian waters can regenerate itself. Although studies of the age and growth of swordfish are available for fisheries in the Pacific, Indian and Atlantic Oceans there is considerable variability between them. Thus, to accurately convert size to age, a full examination of the age and growth of this species is needed for the Australian region. This need has already been recognized by FRDC and a project on this topic is underway by the authors.

Males are significantly smaller than females, are slower growing and do not live as long thus a sex-based length frequency analysis is needed for the stock. A shore-based size-monitoring program has been running for the past four years for the eastern Australian sector. However, as fish are brought to shore headed and gutted there is as yet no way of deciphering between the sexes. Research into protein-based identification of sexes is progressing (Le Bail et al. 1981), and a proposal to use a DNA-based technique to separate the sexes is being developed (Dr. P. Grewe, CSIRO Marine Research), which may be able to provide a "litmus" test of sex.

Finally, there is no information on the reproductive dynamics of swordfish from the developing Western Australian fishery, which will be needed to fully understand the biology of this species in the Australian region. For example, we do not know as yet whether swordfish spawn in the western AFZ, and if they do, does the Leeuwin Current act in the same way as the EAC by providing a suitable environment for the swordfish to spawn. Given the close association between recruitment and interannual variations in the Leeuwin Current reported for other fisheries (e.g. western rock lobster) the reproductive dynamics of the western Australian "stock" should be given a high priority in future research.

Other pelagic species

As yet there has been few data collected on the biology of other target and bycatch species within the domestic longline fishery off eastern Australia. The recent establishment of the EPBC Act (Environment Protection and Biodiversity Conservation Act 1999) requires that fisheries and the ecosystems from which they are taken must be managed sustainably. However, without the information on biological parameters needed to evaluate individual species impacts little progress can be made in this direction. For example, what is the reason for the clear seasonal cycle in the catch rate of striped marlin (Te*trapturus audax*) in the domestic fishery? Anecdotal collections indicate these may also be related to the reproductive dynamics of the species.

Reference

Le Bail, P. Y. and Breton, B. (1981) Rapid determination of the sex of pubertal salmonid fish by a technique of immunoagglutination. Aquaculture 22, 367 – 375

10. Intellectual Property

No intellectual property is claimed

11. Reports, publications and presentations

Written material

Young, J. (1999) "Broadbill research – can you help" Blue water boats and Sport fishing. Spring 1999

Young, J., Cowling, A., and Stanley, C. (2000) A two boat study of the relationship between swordfish catch rates and fine and broad scale physical and environmental variables off Eastern Australia. 13th Meeting of the Standing Committee on Tuna and Billfish, Noumea, New Caledonia. Working paper BBRG 14, 8 pp.

Young, J., Drake, A., Carter, T. Farley, J. (2000) Reproductive dynamics of broadbill swordfish (*Xiphias gladius*) in the eastern Australian AFZ – preliminary results. 13th Meeting of the Standing Committee on Tuna and Billfish, Noumea, New Caledonia. Working paper BBRG 12, 6 pp.

Jock Young, Anita Drake, Jessica Farley, Thor Carter and Michael Brickhill (submitted to Marine and Freshwater Research) Reproductive dynamics of broadbill swordfish, *Xiphias gladius*, in the domestic longline fishery off eastern Australia

Toby Patterson, Jock Young, Jeremy O'Reilly and Anita Drake (submitted to Marine and Freshwater Research) Catch of broadbill swordfish, *Xiphias gladius,* in relation to size-at-maturity in the eastern Australian Fishing Zone

Jock Young, Anita Drake and Clive Stanley(in preparation for Marine Biology) Broadbill swordfish (*Xiphias gladius*) distribution in relation to oceanographic and feeding conditions in the south-western Pacific Ocean

Seminars

Young, J. (2000) presented two papers to 13th Standing Committee on Tuna and Billfish in Noumea on: (1) "A two-boat study of the relationship between swordfish catch rates and fine and broad scale physical and environmental variables off Eastern Australia"; (2) "Reproductive dynamics of broadbill swordfish (*Xiphias gladius*) in the eastern Australian AFZ – preliminary results"

Young, J. (2000) AMSA Annual General Meeting Sydney "The relationship between swordfish and tuna catch rates and fine- and broad-scale physical and environmental variables off eastern Australia"Young, J. W. (2000) Biology of tuna and swordfish off eastern Australia. University of Tasmania seminar series

Young, J. (2001) presented research findings on the reproductive biology of swordfish to the New Zealand Fishermen's cooperative in Gisborne, New Zealand, May 2001

Young, J. (2001) "Broadbill swordfish *(Xiphias gladius)* in eastern Australian waters: a background and research update". Seminar presented to CSIRO Marine Research as part of Divisional Seminar series

(Abstract: Swordfish is one of four targeted species in the eastern Australian longline fishery – the other species are bigeye and yellowfin tuna and striped marlin. The fishery is a new one but is quickly becoming one of the most important fisheries in Australian waters. Although the Japanese have been catching swordfish in our region for decades it is only in the last five years that the Australian domestic fishery has taken off. As little is known of swordfish in Australian waters a series of research projects have begun to provide input into an operational model that is being developed for the fishery. In this seminar I provide a background to the fishery and discuss recent results from a FRDC-funded study of the reproductive dynamics of swordfish in Australian waters.)

Young, J., Drake, A. Carter, T., Brickhill, M. and Farley, J. (2001) "Reproductive biology of broadbill swordfish, Xiphias gladius, from eastern Australia". Seminar presented at the Third International Billfish Symposium, Cairns, Australia

Jock Young, Anita Drake and Toby Patterson (2002). Reproductive dynamics of broadbill swordfish, *Xiphias gladius*, and implications for the swordfish longline fishery in the eastern Australian fishing zone. 53rd International Tuna Conference, Lake Arrowhead, California, USA

12. Staff

(All staff are from CSIRO Division of Marine Research based at either Hobart, Tasmania* or Cleveland, Qld^)

Staff	**Position**
Jock Young*	Principal Investigator
Margaret Miller^	Technical assistance
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Michelle Barlow^	Histology
Thor Carter*	Field technician
Anita Drake*	Laboratory technician
Toby Patterson*	Statistical analyses
Michael Brickhill*	Summer student
Gary Fry^	Technical assistance
Jessica Farley*	Technical expertise

13. List of appendices

The following appendices are the raw data from which the preceding analyses were drawn. The data are archived on an Access data base at CSIRO Division of Marine Research and can be accessed through the principal investigator.

Appendix 1:

Summary of reproductive data for female broadbill swordfish (*X. gladius*) collected off eastern Australia tabled with collection and associated physical environmental data (SST, Sea Surface Temperature ºC; FLR, Fluorescence µg l-1; OFL, orbital fork length in cm; POFs, Postovulatory follicles)

Appendix 2:

Summary of reproductive data for male broadbill swordfish (*X. gladius*) collected off eastern Australia tabled with collection and associated physical environmental data (SST, Sea Surface Temperature in ºC; FLR, Fluorescence µg l^{-1}; OFL, orbital fork length in cm)

Appendix 3:

Summary of feeding data for broadbill swordfish (*X. gladius*) collected off eastern Australia tabled with collection and associated physical environmental data (Area, inshore = west of 158 ºE, offshore = east of 158 ºE; FLR, Fluorescence in µg l^{-1}; Moon phase, 0.25 = new moon, 1 = full moon)

Appendix 4:

Distributional data from which fine scale comparisons were made between broadbill swordfish (*X. gladius*) landings and environmental variables (BBL, broadbill swordfish; SST, sea surface temperature in ºC; SSS, sea surface salinity in ppt; SSF, sea surface fluorescence in µg l-1)

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
2	15/05/1999	26.13	157.35	26.0	0.108	182	70	616						
3	15/05/1999	26.57	157.95	24.4	0.085	143	30	162.8						
4	27/05/1999	27.15	155.13	24.0	0.116			261.1						
6	30/05/1999	26.72	156.38	20.1	0.164	175		1763.7						
8	15/06/1999	26.00	157.00	23.5	0.120		15	63.2						
10	15/06/1999	25.83	157.00	23.2	0.122		18	32.5						
11	15/06/1999	26.00	157.00	23.5	0.120		20	118.7						
12	15/06/1999	26.15	156.62	23.0	0.125		35	81.5						
13	15/06/1999	25.83	156.83	23.8	0.125		26	81.3						
14	15/06/1999	26.17	157.03	20.2	0.116		90	888.6						
15	15/06/1999	26.83	156.92	22.2	0.141		75	358.7						
16	15/06/1999	25.87	157.13	23.2	0.120		65	248.4						
17	15/06/1999	26.00	157.00	23.5	0.120		80	1099.3						
18	15/06/1999	25.83	156.83	23.8	0.125		0	495						
19	15/06/1999	25.00	156.00	22.5	0.159		65	1127.9						
20	04/07/1999	25.00	157.50		0.170	155		57.8						
22	04/07/1999	25.03	157.57		0.153	113		80.4						
23	04/07/1999	25.08	157.57		0.153	127								
24	05/07/1999	25.25	157.25		0.176	210		695.2						
26	05/07/1999	25.30	157.27		0.176	95								
28	06/07/1999	25.42	157.00		0.176	160		140.8						
30	06/07/1999	25.43	156.98		0.176	140		167.3						
31	06/07/1999	25.43	156.95		0.176	185		367.9						
41	08/07/1999	25.15	156.72	21.6	0.274	156		242						
59	25/07/1999	23.60	156.08		0.209	198		559.5						
61	06/07/1999	29.88	153.93	21.6	0.240	137		37.9						
64	03/07/1999	28.60	160.30		0.262	123		84						
79	04/07/1999	29.60	154.13		0.216	124		60.9						
89	08/07/1999	30.52	154.78		0.257	135		159.7						
100	18/08/1999	25.13	157.18	21.9	0.232	192		526.6		2	0	0	0	Imm/resting
101	18/08/1999	25.12	157.18	21.9	0.232	137		48.8		2	0	0	0	Imm/resting
102	18/08/1999	25.12	157.18	21.9	0.232	157		272.3		2	0	0	0	Imm/resting
104	18/08/1999	25.07	157.18	22.2	0.224	194		333.9		2	0	0	0	Imm/resting
105	18/08/1999	25.03	157.18	22.4	0.224	185		358.8		2	0	0	0	Imm/resting
106	18/08/1999	25.03	157.18	22.4	0.224	90		33.8		1	0	0	0	Imm/resting
107	21/08/1999	25.02	159.10	21.4	0.248	110		66.8		1	0	0	0	Imm/resting
108	21/08/1999	25.02	159.10	21.4	0.248	95		47.6		1	0	0	0	Imm/resting
109	21/08/1999	25.00	159.00	21.6	0.257	115				1	0	0	0	Imm/resting
110	21/08/1999	25.02	158.87	21.4	0.248	150		213.4		2	0	0	0	Imm/resting
111	21/08/1999	25.03	158.83	21.3	0.248	140				1	0	0	0	Imm/resting
112	21/08/1999	25.03	158.82	21.3	0.248	125		343.2		2	0	0	0	Imm/resting
114	21/08/1999	25.03	158.65	21.6	0.248	165		441.7		2	0	0	0	Imm/resting
115	21/08/1999	25.03	158.67	21.6	0.248	170		91		1	0	0	0	Imm/resting
116	21/08/1999	25.03	158.68	21.6	0.248	120				2	0	0	0	Imm/resting
117	31/07/1999	26.93	156.63	22.1	0.182	185				2	0	0	0	Imm/resting
119	01/08/1999	27.00	156.67	21.1	0.202	118		64.2		1	0	0	0	Imm/resting
121	01/08/1999	26.98	156.68	19.9	0.195	192		348.9		2	0	0	0	Imm/resting
122	02/08/1999	26.32	156.90	21.9	0.202	210		501.8		2	0	0	0	Imm/resting
123	02/08/1999	26.32	156.85	20.2	0.195	198		677		1	0	0	0	Imm/resting
125	03/08/1999	25.47	157.68	20.9	0.192	168		247.8		2	0	0	0	Imm/resting
126	04/08/1999	25.27	157.85	20.3	0.195	170		499		2	0	1	0	Post-spawning
127	04/08/1999	25.42	157.82	22.7	0.195	200		431.7		2	0	0	0	Imm/resting
128	05/08/1999	26.35	157.50	20.2	0.195	210		710.7		2	0	0	0	Imm/resting
129	19/08/1999	24.87	157.17	22.7	0.232	200		655.9		2	0	1	0	Post-spawning
130	19/08/1999	24.93	157.23	22.5	0.232	90		49.7		1	0	0	0	Imm/resting
131	20/08/1999	24.93	158.25	21.6	0.248	65		36.4		1	0	0	0	Imm/resting
133	20/08/1999	24.92	158.23	21.6	0.244	115		27.3		1	0	0	0	Imm/resting
134	20/08/1999	24.92	158.22	21.6	0.244	170		45.6		1	0	0	0	Imm/resting
137	20/08/1999	24.92	158.13	21.4	0.244	100		199.9		1	0	0	0	Imm/resting
138	20/08/1999	24.92	158.12	21.4	0.244	160		505.9		2	0	0	0	Imm/resting
140	20/08/1999	24.92	158.07	21.8	0.240	55		47.3		1	0	0	0	Imm/resting
141	31/07/1999	24.50	156.17	22.1	0.213	125		105.2		1	0	0	0	Imm/resting
142	31/07/1999	24.83	156.20	22.7	0.216	110		79.7		1	0	0	0	Imm/resting
143	31/07/1999	24.85	156.23	23.0	0.216	260		1094.9		2	0	0	0	Imm/resting
145	31/07/1999	24.87	156.27	23.2	0.216	185				2	0	0	0	Imm/resting
146	31/07/1999	24.97	156.30	23.2	0.216	130		55.9		1	0	0	0	Imm/resting
147	01/08/1999	24.97	155.83	21.6	0.224	148		225.3		2	0	0	0	Imm/resting

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
148	01/08/1999	24.93	155.80	20.6	0.224	129		83.5		1	0	0	0	Imm/resting
149	01/08/1999	24.97	155.92	20.8	0.224	169		290.2		2	0	0	0	Imm/resting
150	01/08/1999	24.97	155.92	20.8	0.224	149		178.3		2	0	1	0	Post-spawning
151	01/08/1999	24.97	155.97	21.3	0.216	203		841.8		2	0	1	0	Post-spawning
152	01/08/1999	24.97	156.00	21.1	0.216	135		88.2		1	0	0	0	Imm/resting
153	01/08/1999	24.97	155.98	21.3	0.216	140		145.2		1	0	0	0	Imm/resting
155	02/08/1999	24.87	155.50	21.3	0.224	159		129.5		1	0	0	0	Imm/resting
156	02/08/1999	24.92	155.52	21.6	0.224	120		53.7		1	0	0	0	Imm/resting
157	03/08/1999	25.98	154.98	17.8	0.209	158		159.7		1	0	0	0	Imm/resting
158	03/08/1999	24.92	154.98	22.2	0.216	149		179.6		2	0	0	0	Imm/resting
159	03/08/1999	24.87	154.82	22.2	0.213	225		961.9		2	0	0	0	Imm/resting
160	03/08/1999	24.85	154.77	21.9	0.213	162		151.4		1	0	0	0	Imm/resting
161	03/08/1999	24.85	154.75	21.6	0.213	250		1177		2	4	1	0	Post-spawning
162	03/08/1999	24.92	154.98	22.2	0.216	212		567.9		2	0	1	0	Post-spawning
163	04/08/1999	25.00	154.75	20.9	0.209	230		508.6		2	0	0	0	Imm/resting
164	04/08/1999	25.05	154.75	19.8	0.209	129				1	0	0	0	Imm/resting
165	04/08/1999	25.05	154.75	19.8	0.209	132		60.3		1	0	0	0	Imm/resting
167	04/08/1999	25.12	154.82	21.4	0.209	167		188.4		1	0	0	0	Imm/resting
169	18/08/1999	25.38	156.75	22.1	0.232	160		155.7		1	0	0	0	Imm/resting
171	18/08/1999	25.43	156.87	21.8	0.232	137		126.7		1	0	0	0	Imm/resting
173	18/08/1999	25.45	156.92	22.4	0.232	144		159.1		1	0	0	0	Imm/resting
178	20/08/1999	25.90	158.03	20.2	0.224	158		234.7		2	0	0	0	Imm/resting
179	20/08/1999	25.87	158.03	19.7	0.224	181		338		2	0	0	0	Imm/resting
180	20/08/1999	25.87	158.02	20.3	0.224	158		274		1	0	0	0	Imm/resting
182	20/08/1999	25.78	157.85	21.3	0.224	156		205.8		2	0	0	0	Imm/resting
184	21/08/1999	26.28	157.60	20.2	0.248	152		199.8		1	0	0	0	Imm/resting
185	21/08/1999	26.28	157.60	20.2	0.248	212		1009.7		3	2	1	0	Inactive
186	21/08/1999	26.25	157.62	19.1	0.248	124		63.4		1	0	0	0	Imm/resting
187	21/08/1999	26.02	157.98	18.4	0.248	206		714.7		2	0	0	0	Imm/resting
188	21/08/1999	26.02	157.98	18.4	0.248	177		441		2	0	0	0	Imm/resting
189	21/08/1999	26.03	157.98	18.3	0.248	168		297.2		2	0	0	0	Imm/resting
190	21/08/1999	26.05	157.95	19.4	0.248	164		283.9		1	0	0	0	Imm/resting
191	21/08/1999	26.07	157.93	20.3	0.248	170		384.2		2	0	0	0	Imm/resting
192	21/08/1999	25.82	158.12	20.8	0.248	190		329.3		2	0	0	0	Imm/resting
194	22/08/1999	26.18	158.08		0.257	120		75		1	0	0	0	Imm/resting
196	22/08/1999	26.02	157.90	20.3	0.257	125				1	0	0	0	Imm/resting
197	21/08/1997	25.30	154.58	22.5		220								
198	13/04/1995	33.07	160.53			180		6919.8						
199	11/08/1998	26.65	154.37	22.5	0.248	186		388.91		2	0	0	0	Imm/resting
200	11/08/1998	25.33	154.32	25.1	0.216	124		71.35		1	0	0	0	Imm/resting
201	10/08/1998	25.53	154.33	23.3	0.244	187		834.8		2	0	0	0	Imm/resting
202	11/08/1998	26.18	153.50	21.8	0.424	112		71.14		1	0	0	0	Imm/resting
203	12/08/1998	25.53	154.37	25.4	0.244	160		373.6		2	0	0	0	Imm/resting
204	11/08/1998	26.00	154.37	23.3	0.266	145		169.2		1	0	0	0	Imm/resting
205	11/08/1998	26.23	154.12	24.1	0.285	163		304.46		2	0	0	0	Imm/resting
206	10/08/1998	26.38	154.18	23.3	0.266	133		69		1	0	0	0	Imm/resting
207	29/03/1999					217				3	0	0	2	Spawning
208	28/03/1999					185		1000		2	4	1	0	Post-spawning
211	30/11/1998	26.15	155.12	19.9	0.103	122		88.33		1	0	0	0	Imm/resting
212	29/11/1998	26.72	155.10	19.9	0.101	139		206.43		1	0	0	0	Imm/resting
214	30/11/1998	26.12	155.10	25.9	0.096	138		96.35		1	0	0	0	Imm/resting
216	29/11/1998	26.82	155.12	23.3	0.105	129		208.8		2	4	1	0	Post-spawning
218	29/11/1998	26.85	155.12	24.1	0.108	139		169.9		2	0	0	0	Imm/resting
220	30/11/1998	26.12	155.10	25.9	0.096	162		146.6		2	0	0	0	Imm/resting
221	10/08/1998	26.23	154.12	23.0	0.285	116				1	0	0	0	Imm/resting
222	30/11/1998	26.17	155.15	19.9	0.122	173		4247		3	2	0	0	Inactive
224	18/09/1999	25.30	157.50	21.8	0.164	205		517.3						
225	18/09/1999	25.30	157.32	20.2	0.164	160		293.1						
229	19/09/1999	25.12	157.33	21.4	0.156	140		121.2						
231	21/09/1999	25.97	155.92	21.9	0.161	200								
234	21/09/1999	25.95	155.87	20.6	0.161	170		314						
237	21/09/1999	25.83	155.87	20.5	0.159	125		52.1						
239	24/07/1999	30.22	157.80		0.275	152		178.3						
242	01/08/1999	30.02	158.15	20.5	0.216	227								
244	02/08/1999	29.58	158.25	20.5	0.195	249		1941.1		2	4	1	0	Post-spawning
257	15/09/1999	26.65	157.00	21.4	0.244	135	40	177.6						

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
258	15/09/1999	26.65	157.05	21.3	0.240	145	45	100.3						
259	15/09/1999	26.65	157.13	21.8	0.240	165	85	745.6						
260	15/09/1999	26.65	157.17	21.8	0.240	230	130	1155.8		2	0	0	0	Imm/resting
261	16/09/1999	26.53	157.12	21.3	0.232	200	90	800.6		3	0	0	0	Inactive
262	16/09/1999	26.57	157.17	21.3	0.232	145	60	440.3						
263	16/09/1999	26.52	157.25	21.4	0.224	110	25	119.2						
264	16/09/1999	26.62	157.25	21.3	0.236	100	7							
265	16/09/1999	26.62	157.25	21.3	0.236	150	30	112.5						
266	16/09/1999	26.65	157.28	21.1	0.240	130	25							
267	16/09/1999	26.67	157.33	20.6	0.240	250	170	1601.7		2	0	0	0	Imm/resting
268	16/09/1999	26.67	157.38	20.8	0.240	200	100	711.2		2	0	0	0	Imm/resting
270	19/09/1999	26.08	156.87	21.4	0.213	170	45	756.3		2	0	0	0	Imm/resting
271	19/09/1999	26.08	156.88	21.3	0.213	160	35	86.3						
272	19/09/1999	26.08	156.92	21.1	0.213	180	60	232.3						
273	19/09/1999	26.08	156.97	21.4	0.205	130	25	452.9						
274	19/09/1999	26.08	156.98	21.4	0.205	210	70	110.5						
275	19/09/1999	26.08	157.00	21.3	0.205	180	50	126.6						
277	20/09/1999	25.83	156.92	21.1	0.179	105	5	75.2						
278	20/09/1999	25.83	156.95	21.3	0.179	200	80	1087.1		2	0	0	0	Imm/resting
279	20/09/1999	25.83	156.98	21.3	0.179	160	40	381.3						
280	16/10/1999	26.17	157.03	22.1	0.122	160	30	204.2						
281	16/10/1999	26.20	157.00	21.4	0.116	135	15	120						
282	16/10/1999	26.25	156.98	21.9	0.125	90	10	128.6						
283	16/10/1999	26.35	156.98	22.2	0.138	95	10	45						
284	16/10/1999	26.47	156.92	22.5	0.148	160	65	442.5						
285	16/10/1999	26.55	156.87	22.4	0.159	150	30	190.9						
286	17/10/1999	26.25	156.67	21.8	0.116	150	30	252.3						
287	17/10/1999	26.28	156.67	23.8	0.116	150	40	772.2						
288	17/10/1999	26.33	156.67	23.0	0.120	150	35	254.1						
289	17/10/1999	26.40	156.67	23.5	0.120	120	10							
290	17/10/1999	26.40	156.67	23.5	0.120	140	55	213.3						
291	17/10/1999	26.45	156.67	21.6	0.120	130	40	212.4						
292	17/10/1999	26.50	156.67	21.3	0.125	145	30	77.8						
293	17/10/1999	26.52	156.67	21.8	0.125	160	30	77.8						
294	17/10/1999	26.52	156.67	21.8	0.125	160	30							
296	17/10/1999	26.55	156.67	19.9	0.125	205	70	1561.4						
297	17/10/1999	26.67	156.67	22.5	0.129	95	10	73.9						
298	18/10/1999	26.10	156.60	24.3	0.098	205	80	1006.7						
299	18/10/1999	26.13	156.60	22.2	0.098	160	30	237						
300	18/10/1999	26.15	156.60	22.4	0.099	170	40	1021						
301	18/10/1999	26.15	156.60	22.4	0.094	120	7	59						
302	18/10/1999	26.23	156.60	24.3	0.094	170	50	184.1						
303	18/10/1999	26.23	156.60	24.3	0.094	160	40	369						
304	18/10/1999	26.25	156.60	24.3	0.116	95	8	33.9						
305	18/10/1999	26.33	156.60	24.1	0.120	180	40	520.1						
306	18/10/1999	26.43	156.60	23.8	0.120	120	35	122.6						
308	19/10/1999	26.43	156.60	23.2	0.120	200	80	3241.3		4	0	1	0	Spawning
309	19/10/1999	26.43	156.60	23.2	0.120	110	12	107.5						
310	19/10/1999	26.43	156.60	23.2	0.120	100	7	49.1						
311	19/10/1999	26.43	156.60	23.2	0.120	180	45	984.6		4	2	1	0	Spawning
312	19/10/1999	26.43	156.60	23.2	0.120	130	15							
313	19/10/1999	26.43	156.60	23.2	0.120	160	40	363						
316	16/10/1999	26.32	154.93	22.7	0.114	127		102.4						
318	17/10/1999	27.15	155.02	20.9	0.112	121		91.2						
321	17/10/1999	27.03	154.93	23.8	0.108	132		128						
325	18/10/1999	27.30	155.07	23.3	0.116	172		322.4						
327	18/10/1999	27.27	155.15	23.5	0.112	109		59.4						
328	18/10/1999	27.23	155.13	23.3	0.112	136		148.2						
329	18/10/1999	27.20	155.12	23.3	0.112	201		890.1						
330	18/10/1999	27.17	155.07	23.6	0.112	167		298.7						
333	19/10/1999	27.62	155.80	22.7	0.133	126		90						
334	19/10/1999	27.60	155.80	22.9	0.133	143		205.7						
335	19/10/1999	27.58	155.80	23.0	0.133	137		203						
336	19/10/1999	27.57	155.80	23.2	0.133	190		957						
337	19/10/1999	27.53	155.82	23.0	0.129	177		770.2						
339	19/10/1999	27.82	155.72	22.5	0.138	148		271.3						

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
341	20/10/1999	27.58	155.85	22.0	0.133	195		593.6						
345	20/10/1999	27.45	155.87	22.2	0.125	166		289.3						
346	20/10/1999	27.37	155.98	21.7	0.129	148		184						
348	20/10/1999	27.35	156.00	21.8	0.129	220		891.3						
351	21/10/1999	27.93	155.87	21.6	0.151	230		1368.3						
352	21/10/1999	27.92	155.87	21.8	0.151	120		57.7						
353	21/10/1999	27.85	155.87	21.9	0.143	168		296.8						
354	21/10/1999	27.70	155.85	22.1	0.138	237		2916.7		3	0	1	0	Inactive
356	21/10/1999	27.77	155.85	22.4	0.143	166		349.5						
357	21/10/1999	27.75	155.85	22.2	0.143	195		948.1						
358	21/10/1999	27.77	155.83	22.4	0.143	129		147.9						
360	21/10/1999	27.70	155.83	21.8	0.138	163		284						
361	21/10/1999	27.67	155.83	21.9	0.138	200		767.6						
362	21/10/1999	27.62	155.85	21.4	0.133	200		269.6						
363	21/10/1999	27.62	155.85	21.4	0.133	155		347.8						
364	21/10/1999	27.62	155.85	21.4	0.133	167		307.6						
365	21/10/1999	27.60	155.85	22.1	0.133	150		222.2						
366	21/10/1999	27.58	155.85	22.5	0.133	152		164.5						
368	21/10/1999	27.55	155.83	22.9	0.129	130		132.5						
369	21/10/1999	27.55	155.83	22.9	0.129	113		56.1						
370	21/10/1999	27.52	155.85	22.7	0.129	102				2	0	0	0	Imm/resting
371	21/10/1999	27.52	155.85	22.7	0.129	176		486						
373	22/10/1999	28.03	155.83	21.7	0.159	198		1226.8						Inactive
374	22/10/1999	27.97	155.83	21.6	0.151	113		90.3		3	0	0	0	
380	22/10/1999	27.78	155.82	21.7	0.143	138		209.2						
381	22/10/1999	27.68	155.80	21.7	0.138	162		244.4						
382	22/10/1999	27.68	155.80	21.8	0.138	208		1536.7		3	3	0	0	Inactive
385	22/10/1999	27.52	155.82	21.8	0.129	193		622.6						
386	16/12/1999	28.72	157.83	23.2		174		198	506	3	3	0	0	Inactive
387	16/12/1999	28.68	157.82	23.3		175		693.7						
388	16/12/1999	28.55	157.78	22.9		140		201.6		2	0	1	0	Post-spawning
389	16/12/1999	28.52	157.77	22.9		177		797.3		3	1	1	0	Inactive
390	16/12/1999	28.48	157.75	22.7		210		611	168	1	0	0	0	Imm/resting
391	16/12/1999	28.45	157.72	23.2		212		1740.4	608	3	3	0	0	Inactive
392	16/12/1999	28.45	157.72	23.2		257		754.96	186	2	0	0	0	Imm/resting
393	16/12/1999	28.45	157.72	23.2		195		1290.6	668	3	0	0	2	Spawning
394	17/12/1999	29.17	157.80	22.7		212		7527.6	1184	5	0	1	0	Spawning
395	17/12/1999	29.15	157.80	22.8		135		90.9		1	0	0	0	Imm/resting
396	17/12/1999	29.02	157.78	22.8		109		46		1	0	0	0	Imm/resting
397	17/12/1999	29.00	157.77	22.8		140		192.5		2	0	0	0	Imm/resting
399	17/12/1999	29.00	157.77	22.9		116		83.4		1	0	0	0	Imm/resting
400	17/12/1999	28.98	157.77	22.9		189		1768	758	3	2	1	0	Inactive
401	17/12/1999	28.92	157.75	22.9		197		583.7	248	2	0	0	0	Imm/resting
402	17/12/1999	28.90	157.75	23.0		156		268.1	208	2	0	0	0	Imm/resting
403	17/12/1999	28.90	157.73	23.0		150		234.4		2	0	0	0	Imm/resting
404	17/12/1999	28.90	157.73	23.0		205		2604.3	772	4	1	1	0	Spawning
406	17/12/1999	28.88	157.73	23.1		166		1399.4		4	1	1	0	Spawning
407	17/12/1999	28.87	157.72	23.0		202		686.4		2	0	0	0	Imm/resting
408	18/12/1999	29.03	157.80	22.9		150		209.1	182	1	0	0	0	Imm/resting
409	18/12/1999	29.03	157.80	22.8		171		577.3		1	0	0	0	Imm/resting
411	18/12/1999	28.88	157.75	23.0		160		183.9	456	2	0	0	0	Imm/resting
412	18/12/1999	28.85	157.75	23.0		157		264.2	206	2	0	0	0	Imm/resting
415	18/12/1999	28.75	157.72	23.1		195		2395.5	864	3	0	0	0	Inactive
416	18/12/1999	28.73	157.72	23.1		217		1252.5		2	0	1	0	Post-spawning
417	18/12/1999	28.73	157.70	23.1		263		19448.3	1200	4	2	1	0	Spawning
418	19/12/1999	28.95	157.77	23.0		175		964	530	3	0	1	0	Inactive
420	19/12/1999	28.80	157.72	23.0		209		1503.9		3	0	0	0	Inactive
421	19/12/1999	28.70	157.68	22.7		131		104.6		1	0	0	0	Imm/resting
423	20/12/1999	28.73	157.35	22.7	0.082	206		534.9		2	0	0	0	Imm/resting
424	20/12/1999	28.63	157.32	22.1	0.082	133		103		1	0	0	0	Imm/resting
425	20/12/1999	28.60	157.30	22.2	0.082	122		99.5		1	0	0	0	Imm/resting
426	20/12/1999	28.52	157.25	23.6	0.082	133		111.2		1	0	0	0	Imm/resting
427	20/12/1999	28.42	157.17	23.2	0.082	184		1955	998	3	2	1	0	Inactive
428	20/12/1999	28.40	157.17	23.2	0.082	159		356.7		2	0	0	0	Imm/resting
429	21/12/1999	28.68	157.28	23.5	0.082	179		313.6	388	1	0	0	0	Imm/resting
430	21/12/1999	28.67	157.28	23.3	0.082	174		381.8		2	0	0	0	Imm/resting

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
431	21/12/1999	28.65	157.27	23.3	0.082	226		4027.9		4	0	0	0	Spawning
433	09/12/1999	25.27	157.27	24.6	0.078	230	90	3288.6	1168	5	2	0	0	Spawning
434	09/12/1999	29.27	157.25	23.2	0.094	220	80	681.8						
435	09/12/1999	29.23	157.23	23.3	0.094	210	80	924.1						
436	09/12/1999	29.05	157.25	23.2	0.091	230	80	1377.4						
438	10/12/1999	29.35	158.13		0.091	230	85	2345.1	1030	5	2	0	0	Spawning
439	10/12/1999	29.17	157.22		0.098	180	55	322.3	180	1	0	0	0	Imm/resting
440	10/12/1999	29.17	157.22		0.098	280	170	7897.9	1112	5	2	0	0	Spawning
442	23/11/1999	30.97	161.40		0.192	120		81.7	84	1	0	0	0	Imm/resting
443	22/11/1999	31.08	161.17	21.1	0.185	122		111.4	76	1	0	0	0	Imm/resting
444	22/11/1999	31.08	161.17	21.1	0.185	107		49.8		1	0	0	0	Imm/resting
445	23/11/1999	30.97	161.40		0.192	111		72.3		1	0	0	0	Imm/resting
447	23/11/1999	30.97	161.40		0.192	137		103.7	112	1	0	0	0	Imm/resting
448	24/11/1999	30.95	161.95	21.6	0.129	156		200.3		2	0	0	0	Imm/resting
452	24/11/1999	30.95	161.40	21.4	0.192	161		290.3	240	2	0	0	0	Imm/resting
454	23/11/1999	30.97	161.40		0.192	112		62.3	90	1	0	0	0	Imm/resting
455	22/11/1999	31.05	161.17	21.8	0.188	171		510.7	256	2	0	0	0	Imm/resting
456	24/11/1999	30.95	161.40	21.4	0.192	181		446.4	312	2	0	0	0	Imm/resting
458	22/11/1999	31.08	161.17	21.1	0.185	181		418.5	202	2	0	0	0	Imm/resting
459	23/11/1999	30.97	161.40		0.192	183		556.8	186	1	0	0	0	Imm/resting
460	27/11/1999	31.07	161.15		0.148	167		855	556	3	2	1	0	Inactive
461	22/11/1999	31.08	161.17	21.1	0.185	167		635.9	174	1	0	0	0	Imm/resting
462	27/11/1999	31.07	161.15		0.148	196		630	168	1	0	0	0	Imm/resting
463	27/11/1999	31.07	161.15		0.148	188		485.5		2	0	0	0	Imm/resting
464	24/11/1999	30.95	161.40	21.4	0.192	171		413.4	266	2	0	0	0	Imm/resting
465	24/11/1999	30.95	161.40	21.4	0.192			535.3	350	3	0	0	0	
466	27/11/1999	31.07	161.15		0.148	234		1627.4	832					
467	22/11/1999	31.08	161.17	21.1	0.185	186		883.7	514	3	2	0	0	Inactive
468	24/11/1999	30.95	161.40	21.4	0.192	190		1058.9		3	1	1	0	Inactive
469	23/11/1999	30.97	161.40		0.192	189		919.9	526	3	2	0	0	Inactive
470	22/11/1999	31.08	161.17	21.1	0.185	185		1050.7	464	3	1	0	0	Inactive
471	23/11/1999	30.97	161.40		0.192	223		1506.7	572	3	2	1	0	Inactive
500	15/02/2000	26.83	160.42		0.108	220	90	1048.3						
503	16/02/2000	26.97	160.27		0.110	240	95	5939.3		5	0	0	0	Spawning
504	12/02/2000	27.58	160.42	25.2	0.077	123		59.9						
505	12/02/2000	27.58	160.38	25.2	0.077	117		51.9						
507	12/02/2000	27.57	160.37	25.2	0.077	214								
508	12/02/2000	27.57	160.37	25.2	0.077	144		585.2	218	2	0	0	0	Imm/resting
511	12/02/2000	27.60	160.18	25.1	0.077	154		171.9	196	1	0	0	0	Imm/resting
512	12/02/2000	27.62	160.15	25.2	0.079	121		85.5						
513	13/02/2000	27.25	160.53	25.0	0.108	123		47.2						
519	13/02/2000	27.32	160.48	25.1	0.100	157		425.9						
522	13/02/2000	27.37	160.45	25.1	0.100	165		3749.9	754	5	0	1	0	Spawning
526	13/02/2000	27.57	160.35	25.2	0.074	120		62.2	122	1	0	0	0	Imm/resting
527	14/02/2000	28.42	160.28	20.7	0.079	147		195	214	1	0	0	0	Imm/resting
528	14/02/2000	28.40	160.28	20.7	0.079	233		2322.9	1080	4	2	1	0	Spawning
529	14/02/2000	28.30	160.32	20.7	0.079	120		83.2	108	1	0	0	0	Imm/resting
530	14/02/2000	28.30	160.32	20.7	0.079	162		288.8	212	2	0	0	0	Imm/resting
531	14/02/2000	28.28	160.32	20.7	0.079	230		2249.4	1262					
533	14/02/2000	28.25	160.30	20.7	0.077	213		497.8	220	2	0	0	0	Imm/resting
534	14/02/2000	28.23	160.30	20.7	0.077	134		85.7						
537	14/02/2000	28.20	160.30	20.7	0.077	134		127.9	206	2	0	0	0	Imm/resting
542	16/02/2000	28.58	160.63	23.8	0.090	100								
544	16/02/2000	28.58	160.62	23.8	0.088	106		55.4						
545	16/02/2000	28.53	160.55	23.8	0.088	196		925.6						
546	16/02/2000	28.52	160.52	23.8	0.085	106		32	82	1	0	0	0	Imm/resting
547	16/02/2000	28.48	160.47	23.8	0.085	141		155.9						
548	16/02/2000	28.45	160.43	24.0	0.085	118		75.8						
549	16/02/2000	28.45	160.43	24.0	0.085	134		146.5						
550	20/12/1999					122								
552	16/02/2000	28.42	160.38	24.3	0.082	197		668.4	204	2	0	0	0	Imm/resting
554	16/02/2000	28.40	160.37	24.2	0.082	210		743.2	222	2	0	0	0	Imm/resting
555	01/02/2000							816.5						
556	16/02/2000	28.38	160.35	24.3	0.079	232		607.9	366					
557	01/02/2000							1563.7						
558	16/02/2000	28.35	160.33	24.5	0.079	141		46.5		2	0	0	0	Imm/resting

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
560	16/02/2000	28.33	160.32	24.5	0.079	170		269.1						
562	17/02/2000	28.73	160.35	24.4	0.082	122		83.7						
563	17/02/2000	28.67	160.33	19.4	0.077	125		107.8						
565	17/02/2000	28.58	160.28	23.2	0.082	118		71.3						
569	17/02/2000	28.42	160.33	22.1	0.079	127		91.2						
570	18/02/2000	29.07	160.42	23.3	0.082	103		22.7						
571	18/02/2000	29.03	160.42	23.6	0.079	190		436.8	418	2	0	0	0	Imm/resting
572	18/02/2000	29.00	160.42	23.0	0.079	109		46.9						
573	18/02/2000	28.97	160.40	20.6	0.079	143		131.2						
575	18/02/2000	28.80	160.35	24.5	0.079	149		321.8						
576	18/02/2000	28.80	160.33	24.5	0.079	219				3	0	1	1	Spawning
577	18/02/2000	28.78	160.33	24.5	0.082	171		792						
578	18/02/2000	28.67	160.18	24.5	0.077	160			492	2	0	1	0	Post-spawning
580	19/02/2000	28.98	160.38	24.4	0.079	176		722						
581	19/02/2000	28.93	160.35	24.3	0.077	146		171.3						
583	19/02/2000	28.83	160.28	24.3	0.078	130		124.2	124	1	0	0	0	Imm/resting
585	19/02/2000	28.78	160.25	24.4	0.077	177		544						
587	19/02/2000	28.72	160.35	24.3	0.081	180		6941	1502	5	0	0	0	Spawning
589	19/02/2000	28.70	160.20	24.3	0.077	147		361.9						
590	20/02/2000	28.90	160.48	23.3	0.088	233		1332.9	470	3	2	0	1	Spawning
593	20/02/2000	28.87	160.42	23.5	0.085	170		274.5	222					
594	20/02/2000	28.85	160.27	24.6	0.074	216		1036.2						
595	20/02/2000	28.85	160.27	24.6	0.074	216		916.2	220	1	0	0	0	Imm/resting
597	20/02/2000	28.83	160.23	24.1	0.074	190		290.6	228	1	0	0	0	Imm/resting
598	20/02/2000	28.83	160.23	24.1	0.074	100		29.2						
599	20/02/2000	28.83	160.22	24.0	0.074	131		110.4						
600	20/02/2000	28.83	160.17	23.3	0.072	103		56.8						
601	20/02/2000	28.82	160.13	24.3	0.074	146		189.9						
602	20/02/2000	28.75	160.02	24.0	0.072	152		168.4						
605	21/02/2000	28.97	160.58	24.4	0.085	161		438.4						
606	21/02/2000	28.97	160.57	24.4	0.085	168		335.2						
607	21/02/2000	28.95	160.55	24.0	0.088	194		481.5						
608	21/02/2000	28.95	160.55	24.0	0.088	205		5227.7	1116					
611	21/02/2000	28.88	160.48	24.1	0.088	213		829	214	1	0	0	0	Imm/resting
612	21/02/2000	28.88	160.45	24.0	0.088	122		67						
613	21/02/2000	28.88	160.42	24.0	0.082	141		145.5						
614	21/02/2000	28.88	160.40	24.0	0.082	133		68.8						
615	21/02/2000	28.87	160.40	24.1	0.085	218		606						
616	21/02/2000	28.87	160.38	24.0	0.085	146		216						
617	21/02/2000	28.87	160.37	24.1	0.085	131		107.2						
618	21/02/2000	28.87	160.35	24.1	0.078	175		411.3	190	1	0	0	0	Imm/resting
619	21/02/2000	28.85	160.33	24.4	0.078	207		607.2	252	1	0	0	0	Imm/resting
620	21/02/2000	28.87	160.33	24.3	0.078	157		215.6						
621	21/02/2000	28.87	160.33	24.1	0.078	157		127.8						
622	21/02/2000	28.85	160.28	24.0	0.078	197		658.7	200	1	0	0	0	Imm/resting
623	21/02/2000	28.83	160.23	24.0	0.074			95.5						
624	21/02/2000	28.83	160.18	23.8	0.074	171		316.4	206	1	0	0	0	Imm/resting
625	21/02/2000	28.83	160.18	23.8	0.074	161		383.1						
626	21/02/2000	28.82	160.15	23.8	0.074	228		1056.6	326	2	0	1	0	Post-spawning
629	22/02/2000	28.98	160.63	24.1	0.085	102		33.6	80	1	0	0	0	Imm/resting
630	23/02/2000	29.07	160.58	24.4	0.088	106		34						
631	22/02/2000	28.97	160.55	24.3	0.085	99								
633	22/02/2000	28.95	160.55	24.1	0.088	212		884.9	254	2	0	0	0	Imm/resting
636	22/02/2000	28.92	160.50	24.3	0.088	161		260.9	248	2	0	0	0	Imm/resting
640	22/02/2000	28.83	160.35	23.8	0.078	104		38						
641	22/02/2000	28.83	160.32	22.5	0.078	181		770.9						
642	22/02/2000	28.83	160.32	22.5	0.085	153		286.3						
644	22/02/2000	28.82	160.28	22.4	0.078	141		119.1						
645	22/02/2000	28.83	160.13	24.1	0.074	134		88.6	130	1	0	0	0	Imm/resting
647	22/02/2000	28.83	160.15	23.5	0.074	142		124						
649	23/02/2000	29.05	160.57	23.8	0.088	194		503.6	180	1	0	0	0	Imm/resting
650	23/02/2000	29.02	160.47	23.3	0.082	101		39						
651	23/02/2000	28.95	160.42	24.1	0.082	141		152.9						
653	23/02/2000	28.95	160.37	20.7	0.082	151		257.6						
654	24/02/2000	28.88	160.27	24.8	0.074	222		1075.2						
655	24/02/2000	28.88	160.27	24.8	0.074	222		1144.2	424	1	0	0	0	Imm/resting

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
656	24/02/2000	28.88	160.25	24.8	0.074	106		43.2						
658	24/02/2000	28.87	160.20	24.8	0.074	220		1252.2		1	0	0	0	Imm/resting
700	20/03/2000					183		460.3	210	1	0	0	0	Imm/resting
701	15/03/2000	30.22	162.28	24.3	0.103	177	85	540.7	188	1	0	0	0	Imm/resting
703	16/03/2000	30.25	162.42	18.4	0.105	177	80	481.08	228	2	0	1	0	Post-spawning
704	16/03/2000	30.28	162.45	18.9	0.105	168	70	457.4	204	1	0	0	0	Imm/resting
705	18/03/2000	30.05	161.87	23.2	0.108	186	80	564.18	206	2	0	0	0	Imm/resting
706	13/03/2000	29.32	160.97	23.2	0.113	215	120	623.12	450	2	0	0	0	Imm/resting
707	18/03/2000	30.20	162.00	23.5	0.105	208	110	1115.63	710	2	4	1	0	Post-spawning
708	17/03/2000	30.37	162.13	21.1	0.105	195	100	791.86	214	2	0	1	0	Post-spawning
709	20/03/2000	30.20	161.65	24.3	0.120	164	65	349.53	246	2	0	0	0	Imm/resting
710	17/03/2000	30.42	162.55	24.0	0.105	156	60	265.3	224	2	0	0	0	Imm/resting
712	12/03/2000	30.00	161.37		0.143	185	80	368.71	200	1	0	0	0	Imm/resting
716	12/03/2000	29.93	161.35		0.143	165	80	1379.9	816	4	0	0	0	Spawning
717	19/03/2000	30.48	161.90	24.1	0.108	204	120	3345.1	964	4	1	0	0	Spawning
718	16/03/2000	29.45	157.92	26.3	0.067	160	40	252.7	206	1	0	0	0	Imm/resting
719	19/03/2000	29.88	157.35	25.1	0.074	100	20	124.1	162	1	0	0	0	Imm/resting
720	17/03/2000	29.50	157.98	22.9	0.067	100	25	212.5	198	1	0	0	0	Imm/resting
721	20/03/2000	30.10	157.20	25.4	0.075	90	20	59.3	170	1	0	0	0	Imm/resting
722	19/03/2000	29.95	158.45	24.3	0.101	80	25	218.9	202	1	0	0	0	Imm/resting
723	15/03/2000	29.32	158.57	25.5	0.079	205	70	850.3	1130	1	0	0	0	Imm/resting
724	21/03/2000	30.53	157.27	20.2	0.079	195	80	2271.3	910	3	2	0	0	Inactive
725	19/03/2000	29.87	157.35	24.9	0.074	300	170	2990	1220	2	4	1	2	Inactive
728	14/03/2000	29.70	160.18	24.9	0.088	106		29.4	106	1	0	0	0	Imm/resting
729	14/03/2000	29.80	160.23	24.4	0.088	108		32.5		1	0	0	0	Imm/resting
732	22/03/2000	28.30	161.32	23.9	0.105	148		187.1	218	1	0	0	0	Imm/resting
735	13/03/2000	29.30	160.22	23.5	0.101	100		21.42	90	1	0	0	0	Imm/resting
736	13/03/2000	29.32	160.22	23.8	0.108	145		97.7	152	1	0	0	0	Imm/resting
742	17/03/2000	30.25	161.92	24.3	0.107	140		102.3	122	1	0	0	0	Imm/resting
746	13/03/2000	28.97	160.25	24.8	0.105	100		20.4	92	1	0	0	0	Imm/resting
747	16/03/2000	29.93	161.47	15.9	0.120	106		27.2	96	1	0	0	0	Imm/resting
748	22/03/2000	28.22	161.10	22.5	0.112	112		46.5	126	1	0	0	0	Imm/resting
753	17/03/2000	30.25	161.95	24.3	0.105	146		112.34	176	1	0	0	0	Imm/resting
755	17/03/2000	30.28	161.87	24.0	0.108	152		169.47	160	1	0	0	0	Imm/resting
757	14/03/2000	29.82	160.27	24.6	0.088	170		407.27	222	1	0	0	0	Imm/resting
758	17/03/2000	30.25	161.88	24.3	0.107	140		132.68	158	1	0	0	0	Imm/resting
759	22/03/2000	28.27	161.23	24.0		204		609.9	236	1	0	0	0	Imm/resting
760	22/03/2000	28.27	161.25	24.0	0.105	172		431.54	238	2	0	0	0	Imm/resting
761	22/03/2000	28.23	161.12	22.1	0.112	172		659.41	204	3	3	1	0	Inactive
763	17/03/2000	30.35	161.83	22.7	0.112	120		67.19	146	1	0	0	0	Imm/resting
765	16/03/2000	29.88	161.33	24.9	0.118	184		456.58	210	2	0	0	0	Imm/resting
766	17/03/2000	30.30	161.85	24.1	0.112	166			202	2	0	0	0	Imm/resting
767	24/02/2000					140		300.11	222	2	0	0	0	Imm/resting
768	27/02/2000					210		784.3	218	1	0	0	0	Imm/resting
769	26/02/2000					168		302.83	206	1	0	0	0	Imm/resting
770	27/02/2000					220		526.69	238	2	0	0	0	Imm/resting
771	27/02/2000					125	30	136.81	192	1	0	0	0	Imm/resting
778	24/02/2000					173		4553	1566	5	0	0	0	Spawning
779	26/02/2000					217		7161	1092	4	0	0	0	Spawning
780	27/02/2000					190		9680	1524	5	0	0	0	Spawning
781	18/10/1999	21.50	164.50	24.0	0.110	187	143	4940						
782	30/10/1999	22.10	165.77	25.2	0.108	190	120							
784	22/05/2000	29.12	160.22	23.2	0.133	140		65	146	1	0	0	0	Imm/resting
787	23/05/2000	28.88	160.30	17.5	0.116	133		94.2	142	1	0	0	0	Imm/resting
789	19/05/2000	29.42	160.02	20.8	0.091	128		117.2	134	1	0	0	0	Imm/resting
790	18/05/2000	29.35	159.97	21.6	0.151	155		305.7	208	2	0	0	0	Imm/resting
791	18/05/2000	29.37	159.97	21.4	0.151	113		36.1	106	1	0	0	0	Imm/resting
792	22/05/2000	28.82	160.42	23.6	0.116	150		161.1	174	1	0	0	0	Imm/resting
795	19/05/2000	29.13	160.23	20.7	0.133	174		642.3	578	2	4	0	0	Post-spawning
797	19/05/2000	29.15	160.23	20.7	0.131	190		506.6	252	1	0	0	0	Imm/resting
798	18/05/2000	29.25	159.93	20.2	0.125	171		291.1	184	1	0	0	0	Imm/resting
799	18/05/2000	29.27	159.97	21.3	0.125	171		320.5	212					
800	19/05/2000	29.18	160.22	20.7	0.131	163		173.8	188	1	0	0	0	Imm/resting
801	19/05/2000	29.30	160.07	20.6	0.133	175		569.7	210	1	0	0	0	Imm/resting
802	18/05/2000	29.25	159.95	20.2	0.125	139		159.6	216	2	0	0	0	Imm/resting
803	18/05/2000	29.42	160.08	20.2	0.170	157		267.2	214	2	0	0	0	Imm/resting

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
804	19/05/2000	29.42	160.02	20.8	0.170	145		171.9	214	1	0	0	0	Imm/resting
805	19/05/2000	29.35	160.02	20.6	0.148	201		534.9	282	2	0	0	0	Imm/resting
806	18/05/2000	29.40	160.05	18.3	0.170	180		473	334	2	0	0	0	Imm/resting
807	22/05/2000	28.83	160.42	23.3	0.116	185		526	264	2	0	0	0	Imm/resting
808	18/05/2000	29.42	160.13	18.6	0.170	146		197.6	228	1	0	0	0	Imm/resting
809	24/05/2000	28.63	160.57	22.9	0.116	126		86	126	1	0	0	0	Imm/resting
810	22/05/2000	28.85	160.40	17.8	0.116	107		36.9	92	1	0	0	0	Imm/resting
811	22/05/2000	28.85	160.40	17.8	0.116	229		1187.6	330	2	0	0	0	Imm/resting
813	18/05/2000	29.42	160.12	20.3	0.170	127		88.9	136	1	0	0	0	Imm/resting
816	17/05/2000	29.53	160.42	22.5	0.176	130		81.2	178	1	0	0	0	Imm/resting
817	23/05/2000	28.80	160.37	20.8	0.116	207		447.4	414	1	0	0	0	Imm/resting
818	14/05/2000	27.47	157.07	22.4	0.131	139		155.2	140	1	0	0	0	Imm/resting
820	14/05/2000	27.40	157.05	22.7	0.133	115		54.5	112	1	0	0	0	Imm/resting
822	14/05/2000	27.37	157.15	20.6	0.133	180		556.5	372	1	0	0	0	Imm/resting
823	17/05/2000	29.47	160.18	22.4	0.170	98		29.7	108	1	0	0	0	Imm/resting
824	19/05/2000	29.32	160.05	20.9	0.148	159		243.1	236	1	0	0	0	Imm/resting
826	17/05/2000	29.48	160.22	22.5	0.170	180		473.5	276	2	0	0	0	Imm/resting
829	17/05/2000	29.48	160.23	22.7	0.170	197		578.4	164	1	0	0	0	Imm/resting
830	17/05/2000	29.55	160.50	22.1	0.182	151		190.1	244	2	0	0	0	Imm/resting
831	14/05/2000	27.20	157.18	22.4	0.133	118		85.9	178	1	0	0	0	Imm/resting
833	23/05/2000	28.72	160.45	22.7	0.116	136		133.9	204	1	0	0	0	Imm/resting
834	19/05/2000	29.20	160.20	20.7	0.131	171		457.6	322	2	0	0	0	Imm/resting
835	23/05/2000	29.00	160.33	18.6	0.129	125		100.5	136	1	0	0	0	Imm/resting
836	23/05/2000	28.75	160.42	21.3	0.116	197		733.2	386	2	0	0	0	Imm/resting
837	17/05/2000	29.48	160.25	22.7	0.170	186		500.4	414	2	0	0	0	Imm/resting
840	14/05/2000	27.47	157.07	22.4	0.131	205		1179.8	424	3	3	0	0	Inactive
841	17/05/2000	29.47	160.18	22.4	0.170	176		568.7	224	2	0	0	0	Imm/resting
843	19/05/2000	29.18	160.22	20.7	0.131	142		229.9	254	2	0	0	0	Imm/resting
844	17/05/2000	29.38	160.15	22.5	0.145	128		105.5	186	1	0	0	0	Imm/resting
845	23/05/2000	28.72	160.45	22.7	0.116	174		308	240	2	0	0	0	Imm/resting
850	13/05/2000	26.30	156.97	23.2	0.112	137	58	127.8	150	1	0	0	0	Imm/resting
851	15/05/2000	26.35	156.98	23.3	0.116	122	45	140.9	174	1	0	0	0	Imm/resting
852	13/05/2000	26.30	156.97	23.2	0.112	107	40		110	1	0	0	0	Imm/resting
856	24/05/2000	20.97	153.83		0.105	115		47.4	106	1	0	0	0	Imm/resting
858	27/05/2000	23.78	154.48	24.3	0.101	124		70.4	108	1	0	0	0	Imm/resting
859	27/05/2000	23.73	154.52	24.3	0.091	126		92	122	1	0	0	0	Imm/resting
860	27/05/2000	23.52	154.62	24.4	0.085	110		60.5		1	0	0	0	Imm/resting
861	27/05/2000	23.58	154.57	24.6	0.085	113		57	134	1	0	0	0	Imm/resting
865	25/05/2000	20.98	154.78	25.5	0.094	148		198.9	140	1	0	0	0	Imm/resting
867	24/05/2000	20.93	153.78	26.2	0.103	119		71.1	182	1	0	0	0	Imm/resting
868	22/05/2000	20.20	153.55		0.099	145		287.8	212	2	0	0	0	Imm/resting
870	26/05/2000	22.07	154.47	26.0	0.098	123		92.6	130	1	0	0	0	Imm/resting
876	26/05/2000	22.10	154.47	26.0	0.098	130		100	126	1	0	0	0	Imm/resting
877	25/05/2000	20.98	154.73	25.7	0.094	126		71.3	140	1	0	0	0	Imm/resting
878	26/05/2000	22.15	154.45	19.8	0.094	137		152.8	174	1	0	0	0	Imm/resting
879	26/05/2000	22.15	154.40	25.9	0.094	109		57.6	128	1	0	0	0	Imm/resting
883	22/05/2000	20.02	152.47			95		25.9	94	1	0	0	0	Imm/resting
884	22/05/2000	20.03	153.50		0.098	108		54.5	142	1	0	0	0	Imm/resting
885	23/05/2000	20.12	153.48	25.5	0.098	99		25.5		1	0	0	0	Imm/resting
886	24/05/2000	20.02	153.85	25.5	0.105	210		1032.4	308	2	4	1	0	Post-spawning
887	19/05/2000	29.87	161.07	20.8	0.202	124	25	66.3	106	1	0	0	0	Imm/resting
891	22/05/2000	30.17	161.13	21.6	0.202	214	120	734	260	2	0	0	0	Imm/resting
892	22/05/2000	30.13	161.08	21.4	0.202	135	45	137.3	194	1	0	0	0	Imm/resting
893	16/05/2000	30.38	161.20	22.4	0.220	198	90	602	234	1	0	0	0	Imm/resting
895	17/05/2000	29.98	161.12	22.4	0.202	193	90	541.3	264	2	0	0	0	Imm/resting
896	16/05/2000	30.45	161.30	22.7	0.224	190	90	509.2	200	1	0	0	0	Imm/resting
897	17/05/2000	29.97	161.10	22.2	0.202	165	75	290.2	198	2	0	0	0	Imm/resting
899	18/05/2000	29.93	161.25	21.8	0.202	131	40	121.4	158	1	0	0	0	Imm/resting
900	19/05/2000	29.87	161.07	20.8	0.202	140	45	154.9	178	1	0	0	0	Imm/resting
901	14/05/2000	30.40	161.42	22.2	0.232	174	70	517.3	846	1	4	1	0	Post-spawning
904	15/05/2000	27.83	157.18	22.5	0.125	116		70.1	140	1	0	0	0	Imm/resting
905	14/05/2000	27.25	157.18	22.4	0.133	127		114	138	1	0	0	0	Imm/resting
907	17/05/2000	29.48	160.20	22.7	0.170	149		161.8	132	1	0	0	0	Imm/resting
910	23/05/2000	28.75	160.42	21.3	0.116	152		241.4	192	2	0	0	0	Imm/resting
911	15/05/2000	27.53	157.08	22.5	0.116	220		767.9	334					
912	17/05/2000	29.55	160.50	22.1	0.182	184		87	162	1	0	0	0	Imm/resting

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
913	16/05/2000	30.40	161.25	22.7	0.224	202	95	656.6	324	1	0	0	0	Imm/resting
914	15/05/2000	27.58	157.07	22.5	0.129	173		360.1	220	2	0	0	0	Imm/resting
915	15/05/2000	27.68	157.07	22.2	0.129	218		869.4		1	0	1	0	Post-spawning
916	15/05/2000	27.78	157.17	22.2	0.125	177		1727.1	1144	5	2	1	0	Spawning
917	20/05/2000	33.93	164.15	15.7	0.257	260	200	1153.9	314	2	0	0	0	Imm/resting
918	22/05/2000	30.63	162.22	19.1	0.176	216	80	784.7	690	2	4	1	0	Post-spawning
919	20/05/2000	33.97	164.15		0.257	238	140	1239.4	314	2	0	0	0	Imm/resting
920	20/05/2000	34.00	164.15	13.5	0.266	220	90	963.4	214	2	0	0	0	Imm/resting
921	21/05/2000	33.65	163.23	20.8	0.275	215	100	536.4	320	2	0	0	0	Imm/resting
922	21/05/2000	33.60	163.37	21.3	0.275	195	70		254	2	0	0	0	Imm/resting
924	20/05/2000	33.93	164.15	15.7	0.257	159	32	198.6	208	2	0	0	0	Imm/resting
925	22/05/2000	33.53	159.57	21.4	0.232	190	35	291.5	392	2	0	0	0	Imm/resting
927	22/05/2000	33.53	159.57	21.4	0.232	185	35		228	2	0	0	0	Imm/resting
929	20/05/2000	33.72	163.58		0.258	215	110	1099.3	242	2	0	0	0	Imm/resting
930	22/05/2000	30.65	162.22	16.1	0.176	127	30	63.8	134	1	0	0	0	Imm/resting
932	21/05/2000	33.97	163.65	20.9	0.275	123	30	93.7	104	1	0	0	0	Imm/resting
933	21/05/2000	33.97	163.65	20.9	0.275	127	30	70.2	104	1	0	0	0	Imm/resting
934	20/05/2000	34.00	164.15	13.5	0.266	117	20	46.3	106	1	0	0	0	Imm/resting
935	22/05/2000	33.53	159.57	21.4	0.232	156	45	299.6	342	1	0	0	0	Imm/resting
937	12/04/2000	20.87	154.17	25.5	0.079	121	25	95	202	2	0	0	0	Imm/resting
939	13/04/2000	20.02	154.20	19.7	0.085	124	25	68.7	128	1	0	0	0	Imm/resting
941	15/04/2000	21.03	154.03	27.1	0.053	132	35	166.8	178	1	0	0	0	Imm/resting
942	14/04/2000	20.93	153.97	19.7	0.064	230	100	674.8	168	2	0	0	0	Imm/resting
943	15/04/2000	21.02	154.02	27.0	0.058	138	45	113.7	150	1	0	0	0	Imm/resting
945	16/04/2000	20.97	153.72	27.0	0.060	120	25	65.6	114	1	0	0	0	Imm/resting
947	22/04/2000	23.72	155.65	19.9	0.075	166	75	280.6	176	1	0	0	0	Imm/resting
949	22/04/2000	23.77	155.68	20.0	0.075	137	45	131.8	154	1	0	0	0	Imm/resting
950	23/04/2000	24.08	155.95	20.0		165	75	275	196	1	0	0	0	Imm/resting
953	22/06/2000	30.97	159.28	19.9	0.316	163	65	417.9	232	2	0	0	0	Imm/resting
955	22/06/2000	30.52	159.58	20.3	0.351	115	15	77	108	1	0	0	0	Imm/resting
959	23/06/2000	30.03	160.02	21.1	0.327	123	15	81	108	1	0	0	0	Imm/resting
961	23/06/2000	30.07	160.05	21.3	0.327	145		169.5	166					
965	21/04/2000	28.33	154.30	19.7	0.091	183	110		1284	2	4	1	0	Post-spawning
966	22/04/2000	28.13	154.45	24.1	0.091	117	60	54.6	108	1	0	0	0	Imm/resting
967	21/04/2000	28.35	154.28	19.7	0.094	170	100			2	0	0	0	Imm/resting
969	22/04/2000	28.13	154.45	24.1	0.091	220	150	1318.8	686	2	0	1	0	Post-spawning
970	14/06/2000	27.40	161.68	20.9	0.232	125		94.8	190	1	0	0	0	Imm/resting
971	10/06/2000	20.47	161.58	21.5	0.133	169			226	1	0	0	0	Imm/resting
972	15/06/2000	27.95	161.73	20.2	0.240	196		737.7	646	2	0	0	0	Imm/resting
973	15/06/2000	27.70	161.70	20.6	0.216	183		616.7	636	2	0	0	0	Imm/resting
974	16/06/2000	28.10	160.67	20.9	0.216	180		322.7	366	2	0	0	0	Imm/resting
976	17/06/2000	28.10	160.60	21.5	0.209	184		585.9	554	3	3	0	0	Inactive
977	17/06/2000	27.05	160.62	22.1	0.209	187			398	2	0	0	0	Imm/resting
979	16/06/2000	28.03	160.72	21.3	0.216	159		290.4	386	2	0	0	0	Imm/resting
980	19/06/2000	27.82	160.67	21.4	0.248	183	55	396	286	2	0	0	0	Imm/resting
981	14/06/2000	27.78	161.70	21.6	0.216	188		441.2	222	1	0	0	0	Imm/resting
982	16/06/2000	28.03	160.77	21.3	0.216	160		394.9	320	2	0	0	0	Imm/resting
983	16/06/2000	28.05	160.68	21.3	0.216	176		506.8	304	2	0	0	0	Imm/resting
984	17/06/2000	27.12	160.60	22.2	0.209	106		41.1	90	1	0	0	0	Imm/resting
985	16/06/2000	28.18	160.55	21.4	0.216	264		2839.1	304	2	0	0	0	Imm/resting
986	11/06/2000	27.85	161.43	16.8	0.224	179		469.8	254	1	0	0	0	Imm/resting
987	22/06/2000	27.85	161.00	20.8	0.257	180		597.7	472	2	0	0	0	Imm/resting
988	17/06/2000	28.00	160.68	20.9	0.209	156	40	244.4	164					
990	16/06/2000	28.03	160.92	20.9	0.216	120		77.2	122	1	0	0	0	Imm/resting
992	22/06/2000	27.87	161.07	21.4	0.266	159			276	1	0	0	0	Imm/resting
993	16/06/2000	28.03	160.72	21.3	0.216	107		49.4	120	1	0	0	0	Imm/resting
995	11/06/2000	28.02	161.35	21.7	0.224	170		300.2	206	1	0	0	0	Imm/resting
996	17/06/2000	28.02	160.68	21.1	0.209	114	23	40.8	102	1	0	0	0	Imm/resting
997	19/06/2000	27.87	160.82	21.4	0.253	168	40	334.6	196	1	0	0	0	Imm/resting
1000	10/05/2000	34.23	162.77		0.266	145	60	126.1	140	1	0	0	0	Imm/resting
1001	24/05/2000	33.97	163.23	20.8	0.266	168	80	276.8	218	1	0	0	0	Imm/resting
1002	24/05/2000	34.00	163.17	20.9	0.266	165	70	219	218	2	0	0	0	Imm/resting
1003	24/05/2000	34.00	163.18	20.8	0.266	206	120	718	210	1	0	0	0	Imm/resting
1004	24/05/2000	34.03	163.07	20.9	0.266	127	40	135.9	184	2	0	0	0	Imm/resting
1005	14/05/2000	34.02	163.08	21.4	0.275	212	160	846.9	618	2	0	0	0	Imm/resting
1006	24/05/2000	34.07	163.03	20.6	0.266	145	50	236.3	194	1	0	0	0	Imm/resting
1007	24/05/2000	34.07	162.78	21.1	0.266	160	70	81	138	1	0	0	0	Imm/resting

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1009	25/05/2000	34.32	163.10	20.3	0.202	136	40	161.7	184	1	0	0	0	Imm/resting
1010	25/05/2000	34.35	163.05	21.3	0.209	220	120	1011.9	596	2	0	0	0	Imm/resting
1011	25/05/2000	34.32	163.08	20.6	0.202	273	250	1395	1256	2	0	0	0	Imm/resting
1012	25/05/2000	34.38	162.85	20.9	0.216	190	120	624.2	288	2	0	0	0	Imm/resting
1013	25/05/2000	34.45	162.72	21.3	0.224	180	80		246	2	0	0	0	Imm/resting
1014	25/05/2000	34.53	162.72	21.4	0.232	170	70	247.8	204	1	0	0	0	Imm/resting
1016	25/05/2000	34.50	162.72	20.3	0.232	170	80		208	1	0	0	0	Imm/resting
1017	10/07/2000	29.35	157.55	20.8	0.376	190	120	839	230	2	4	0	0	Post-spawning
1018	10/07/2000	29.45	157.57	20.9	0.389	100	30	144.7	192	1	0	0	0	Imm/resting
1019	10/07/2000	29.40	157.57	20.9	0.389	130	55	268.1	414	2	0	0	0	Imm/resting
1020	10/07/2000	29.50	157.60	21.1	0.382	180	100	626.7	464	2	0	0	0	Imm/resting
1021	10/07/2000	29.55	157.77	20.6	0.363	100	30	81.53	164	1	0	0	0	Imm/resting
1022	10/07/2000	29.67	157.55	20.3	0.376	130	70	279.9	238	2	0	0	0	Imm/resting
1023	11/07/2000	29.20	157.75	20.2	0.389	125	60	354.8	240	1	0	0	0	Imm/resting
1024	11/07/2000	29.33	157.77	21.1	0.363	175	140		262	2	0	0	0	Imm/resting
1025	11/07/2000	29.37	157.83		0.363	137	60	445	520	2	0	0	0	Imm/resting
1026	11/07/2000	29.42	157.90		0.345	70	30	133.5	186	1	0	0	0	Imm/resting
1027	11/07/2000	29.42	157.83	21.1	0.357	60	10	57.3	126	1	0	0	0	Imm/resting
1028	18/07/2000	23.50	154.83	21.9	0.182	120	60	453.4	460	3	2	1	0	Inactive
1029	14/07/2000	26.62	159.30	22.1	0.240	183			330	1	0	0	0	Imm/resting
1030	14/07/2000	26.68	159.32	22.2	0.248	178		459.4	272	2	0	0	0	Imm/resting
1032	14/07/2000	26.70	159.30	21.8	0.240	160		263.1						
1033	14/07/2000	26.78	159.28	22.1	0.248	165		209.4	282	1	0	0	0	Imm/resting
1034	14/07/2000	26.83	159.28	21.9	0.232	142		128.7	208	1	0	0	0	Imm/resting
1035	16/07/2000	25.67	158.43	21.1	0.195	150		160	168	1	0	0	0	Imm/resting
1036	16/07/2000	25.67	158.40	21.6	0.195	147		217.6	254	1	0	0	0	Imm/resting
1037	16/07/2000	25.70	158.50	21.3	0.195	123		92.4	158	1	0	0	0	Imm/resting
1038	16/07/2000	25.70	158.52	21.3	0.275	144		207.3	248	1	0	0	0	Imm/resting
1039	23/07/2000	25.47	153.90	22.7	0.253	202		669.3	460	2	0	0	0	Imm/resting
1040	23/07/2000	25.43	153.87	22.7	0.248	123		19.3	112	1	0	0	0	Imm/resting
1041	23/07/2000	25.42	153.85	22.7	0.257	130		109.4	176	1	0	0	0	Imm/resting
1042	09/07/2000	28.77	154.30	21.6	0.271	150		196.6	196	1	0	0	0	Imm/resting
1044	10/07/2000	28.77	154.30	20.0	0.271	140		165.2	224	1	0	0	0	Imm/resting
1045	10/07/2000	28.77	154.30	20.0	0.271	151		354.4	538	2	0	0	0	Imm/resting
1046	11/07/2000	28.77	154.30		0.271	191		632.3	444	2	0	0	0	Imm/resting
1047	11/07/2000	28.77	154.30		0.271	177			252	1	0	0	0	Imm/resting
1048	13/07/2000	29.15	154.42	21.4	0.232	125	35	89.5	178	1	0	0	0	Imm/resting
1049	13/07/2000	28.17	154.42	18.3	0.266	128	80	485.5	474	2	0	0	0	Imm/resting
1050	14/07/2000	28.27	154.38	21.3	0.266	174	75	320.3	208	1	0	0	0	Imm/resting
1051	14/07/2000	28.42	154.33	21.6	0.257	151	55	136.5	166	1	0	0	0	Imm/resting
1053	18/06/2000	29.72	159.23		0.295	115	20	73.5	140	1	0	0	0	Imm/resting
1055	09/06/2000	28.82	160.32		0.220	120	25	64.7	136	1	0	0	0	Imm/resting
1057	10/06/2000	29.07	160.45		0.280	140	50	214.7	218	2	0	0	0	Imm/resting
1058	11/06/2000	28.57	160.38	16.8	0.232	167	60	289.5	308	2	0	0	0	Imm/resting
1060	15/06/2000	28.47	160.52		0.224	185	70	465.4	206	1	0	0	0	Imm/resting
1061	15/06/2000	28.50	160.48	20.8	0.224	135	35		236	1	0	0	0	Imm/resting
1063	15/06/2000	28.60	160.42	21.4	0.232	190	90	541.6	324					
1065	16/06/2000	29.62	159.78	20.8	0.266	192	80	679.5	330	2	0	0	0	Imm/resting
1067	18/06/2000	29.65	159.32	20.3	0.275	164	60	276.7	390	2	0	0	0	Imm/resting
1068	19/06/2000	29.52	159.68	20.6	0.271	138	35	164.7	200	1	0	0	0	Imm/resting
1071	23/06/2000	30.28	154.17	21.8	0.295	200	90	577.2	352	2	0	0	0	Imm/resting
1072	11/08/2000	29.42	158.57	20.2	0.376	145	65	499.3	386	2	0	0	0	Imm/resting
1073	12/08/2000	29.33	158.57		0.363	265	210	1727.1	942	2	0	0	0	Imm/resting
1074	12/08/2000	29.50	158.60	19.5	0.376	140	60	392.2	226	1	0	0	0	Imm/resting
1075	13/08/2000	29.42	158.60	20.4	0.271	260	180	1326.8	268	2	0	1	0	Post-spawning
1076	13/08/2000	29.50	158.60	21.1	0.266	120	15	79.7	122					
1077	14/08/2000	29.10	158.60	20.3	0.339	275	170		360	2	0	0	0	Imm/resting
1078	14/08/2000	29.25	158.60	19.4	0.351	160	75	767.5	286	2	0	0	0	Imm/resting
1079	14/08/2000	29.33	158.57		0.275	160	60	508.8	240	2	0	1	0	Post-spawning
1080	16/08/2000	28.75	158.72	19.7	0.316	200	95	812.7	272	2	0	0	0	Imm/resting
1081	16/08/2000	28.72	158.73	19.7	0.316	200	90	735	384	1	0	0	0	Imm/resting
1082	19/08/2000	28.67	158.65	19.5	0.340	225	130	1537.8	572	3	0	0	0	Inactive
1083	14/08/2000	28.50	160.83	21.6	0.253	210	120	781.4	346	2	0	0	0	Imm/resting
1084	14/08/2000	28.50	160.83	21.6	0.253	151	65	329.6	250	1	0	0	0	Imm/resting
1088	16/08/2000	23.62	155.65	21.8	0.159	149	60	229.7	210	1	0	0	0	Imm/resting
1091	17/08/2000	23.88	155.78	21.8	0.176	217	100	1014.6	418	2	4	0	0	Post-spawning
1092	17/08/2000	23.80	155.72	22.1	0.170	136	40	155.8	210					

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1094	19/08/2000	24.42	155.88	20.6	0.195	242	160	1255.7	254	2	0	0	0	Imm/resting
1095	19/08/2000	24.42	155.88	20.6	0.195	161	60	222.7	224	1	0	0	0	Imm/resting
1096	19/08/2000	24.50	155.82	20.6	0.195	211	140	733.3	466	2	4	0	0	Post-spawning
1097	19/08/2000	24.50	155.80	20.9	0.195	110	25	47.5	112					
1098	19/08/2000	24.05	155.65	21.3	0.185	197	100	575.7	384	2	0	0	0	Imm/resting
1099	20/08/2000	24.67	156.15	20.9	0.209	153	50	268.1	236	1	0	0	0	Imm/resting
1100	20/08/2000	24.68	156.17	20.9	0.209	166	60	280.6	206	1	0	0	0	Imm/resting
1101	20/08/2000	24.65	156.07	20.8	0.209	160	60	379.8	296	2	0	0	0	Imm/resting
1102	20/08/2000	24.58	156.02	21.6	0.209	200	100	692.2	538	2	0	0	0	Imm/resting
1104	09/08/2000	26.87	161.28	20.6	0.257	120		127.5	208					
1105	09/08/2000	26.88	161.27	21.1	0.257	126		131.6	236					
1106	09/08/2000	26.88	161.25	20.5	0.257	159		367.7	262					
1108	09/08/2000	26.88	161.23	20.5	0.257	140		144.7	188					
1110	10/08/2000	27.02	161.42	21.3	0.253	186		378.3	370	2	0	0	0	Imm/resting
1111	10/08/2000	27.02	161.40	21.6	0.257	166		321.6	236	2	0	0	0	Imm/resting
1112	10/08/2000	27.02	161.37	21.6	0.257	150		253.3	282	2	0	0	0	Imm/resting
1114	11/08/2000	27.02	161.70	20.6	0.240	160		105.7	210	1	0	0	0	Imm/resting
1115	11/08/2000	27.05	161.63	20.5	0.240	226		1605.6	264	2	4	0	0	Post-spawning
1117	11/08/2000	27.05	161.60	20.8	0.248	202		478.7	362	1	0	0	0	Imm/resting
1118	11/08/2000	27.08	161.43	21.4	0.253	131		121.4	178					
1120	12/08/2000	27.02	162.02	21.0	0.248	150		303.7	234	1	0	0	0	Imm/resting
1121	12/08/2000	27.00	161.88	20.9	0.240	187		772.9	426	2	0	0	0	Imm/resting
1122	12/08/2000	26.95	161.88	20.9	0.240	190		380	268	1	0	0	0	Imm/resting
1123	13/08/2000	26.73	161.37	21.3	0.249	159		309.4	214	2	0	0	0	Imm/resting
1125	13/08/2000	26.78	161.42	20.9	0.240	190		442.2	320	2	0	0	0	Imm/resting
1126	13/08/2000	26.78	161.43	20.9	0.240	189		566.5	404	2	0	0	0	Imm/resting
1127	13/08/2000	26.80	161.45	21.4	0.240	124		109.5	174					
1128	13/08/2000	26.82	161.47	21.3	0.240	122		105.9	172					
1129	13/08/2000	26.88	161.48	21.1	0.240	180		372.4	412	2	0	0	0	Imm/resting
1131	14/08/2000	26.85	161.47	21.1	0.240	152		217.4	302	2	0	0	0	Imm/resting
1132	14/08/2000	26.82	161.43	20.9	0.240	207		1777.2	588	3	3	1	0	Inactive
1133	15/08/2000	26.73	161.07	21.3	0.224	118		61.3	112					
1136	16/08/2000	26.72	160.90	21.6	0.220	212		781.7	260	2	0	0	0	Imm/resting
1137	17/08/2000	26.83	161.02	21.4	0.216	240		2147.6	308	2	0	1	0	Post-spawning
1139	13/08/2000	36.57	151.43	19.3	0.417	200		603.5	330	2	0	0	0	Imm/resting
1140	11/09/2000	26.02	160.12	20.5	0.118	202		2000.3	840	4	2	1	0	Spawning
1141	10/09/2000	26.08	160.10	21.4	0.209	176		262.2	248	1	0	0	0	Imm/resting
1143	08/09/2000	27.10	161.18	20.3	0.240	101		25.25	102					
1145	08/09/2000	27.17	161.18	20.8	0.240	117		51.56	126					
1147	07/09/2000	26.93	160.93	21.1	0.240	104		41.2	112					
1148	08/09/2000	26.77	161.27	20.9	0.240	186		690.1	254	2	0	0	0	Imm/resting
1149	08/09/2000	26.77	161.27	20.9	0.240	131		123.2	212					
1150	08/09/2000	27.03	161.18	20.6	0.240	183		527.6	446	2	0	0	0	Imm/resting
1152	10/09/2000	26.42	159.90	21.1	0.209	129		100.3	138					
1154	10/09/2000	26.13	160.10	21.3	0.209	110		54.5	106					
1157	10/09/2000	26.52	159.90	21.3	0.209	109		77.7	156					
1159	11/09/2000	25.97	160.13	20.3	0.205	148		174.3	256	2	0	0	0	Imm/resting
1160	10/09/2000	26.62	159.88	21.4	0.209	150		309.3	226	1	0	0	0	Imm/resting
1161	11/09/2000	26.37	160.00	20.8	0.205	154		173.4	182	1	0	0	0	Imm/resting
1162	10/09/2000	26.07	160.10	21.6	0.240	126		91.9	158					
1163	11/09/2000	26.02	160.13	20.5	0.205	136		164.4	230					
1164	11/09/2000	26.07	160.12	20.5	0.205	138		152	226					
1165	11/09/2000	26.17	160.10	20.3	0.205	131		114.2	138					
1168	11/09/2000	26.37	160.00	20.8	0.205	108		54.7	126					
1169	13/09/2000	25.52	160.32	18.3	0.188	190		576.6	284	2	0	0	0	Imm/resting
1170	11/09/2000	26.35	160.00	20.8	0.205	148		173.4	272	1	0	0	0	Imm/resting
1172	13/09/2000	25.58	160.30	18.3	0.188	159		317.1	212	1	0	0	0	Imm/resting
1173	13/09/2000	25.58	160.30	20.7	0.188	140		146.9	184	1	0	0	0	Imm/resting
1174	13/09/2000	25.62	160.30	18.6	0.188	156		270	372	2	0	0	0	Imm/resting
1176	13/09/2000	25.65	160.30	21.1	0.188	155		285.2	280	2	0	0	0	Imm/resting
1177	13/09/2000	25.67	160.30	19.9	0.188	233		1295.1	540	3	0	0	0	Inactive
1180	13/09/2000	25.72	160.28	20.5	0.188	220		1233.4	226	1	0	0	0	Imm/resting
1181	13/09/2000	25.73	160.28	20.0	0.188	108		50.2	116					
1183	13/09/2000	25.78	160.25	18.3	0.188	161		267.6	260	1	0	0	0	Imm/resting
1184	13/09/2000	25.80	160.23	18.3	0.188	165		362.2	282	1	0	0	0	Imm/resting
1186	13/09/2000	25.85	160.18	20.8	0.188	142		143.5	188	1	0	0	0	Imm/resting
1187	13/09/2000	25.92	160.07	20.8	0.188	123		82.3	160					

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1188	14/09/2000	25.60	160.33	21.3	0.164	190		567.8	256	2	0	0	0	Imm/resting
1189	13/09/2000	25.97	160.03	20.5	0.188	164		252.9	384	2	0	0	0	Imm/resting
1190	14/09/2000	25.73	160.27	21.6	0.164	125		155.2	220					
1191	14/09/2000	25.83	160.15	21.6	0.164	156		233.9	214	1	0	0	0	Imm/resting
1192	14/09/2000	25.77	160.20	21.3	0.164	157		187.9	190	1	0	0	0	Imm/resting
1193	14/09/2000	25.82	160.15	21.6	0.164	98		24.3	98					
1194	14/09/2000	25.80	160.17	21.4	0.164	120			152					
1197	16/09/2000	25.60	160.55	20.7	0.170	193		503.8	254	1	0	0	0	Imm/resting
1198	16/09/2000	25.60	160.55	20.7	0.170			131.9	206	1	0	0	0	
1199	16/09/2000	25.60	160.57	20.7	0.170	170		302.6	290	1	0	0	0	Imm/resting
1201	16/09/2000	25.63	160.48	20.7	0.170	124		109.1	144					
1203	16/09/2000	25.65	160.42	20.7	0.170	161		326	532	1	0	0	0	Imm/resting
1204	16/09/2000	25.63	160.37	20.7	0.159	232		916.2	480	2	0	0	0	Imm/resting
1205	16/09/2000	25.65	160.35	20.7	0.170	188		677.4	216	1	0	0	0	Imm/resting
1207	16/09/2000	25.60	160.33	20.7	0.159	120		47.7	214					
1208	16/09/2000	25.60	160.33	20.7	0.159	132		113.3	138					
1209	16/09/2000	25.60	160.35	20.7	0.159	111		41.3	108					
1210	16/09/2000	25.60	160.35	20.7	0.159	144		185.3	242	1	0	0	0	Imm/resting
1211	16/09/2000	25.63	160.20	20.7	0.170	176		381.4	352	2	0	0	0	Imm/resting
1212	16/09/2000	25.63	160.23	20.7	0.159	198		547.1	280	1	0	0	0	Imm/resting
1213	17/09/2000	27.40	159.17	21.4	0.192	111	20	50	142					
1214	15/09/2000	27.60	159.25	20.5	0.195	130	35	73	144					
1215	15/09/2000	27.58	159.25	20.5	0.195	166	70	244	244	2	0	0	0	Imm/resting
1216	19/09/2000	27.10	157.70	21.8	0.138	131	30	105.5	184					
1217	17/09/2000	27.32	159.13	20.9	0.195	215	120		566	3	3	1	0	Inactive
1218	16/09/2000	27.73	159.53	20.6	0.202	143	40	153.3	216	1	0	0	0	Imm/resting
1219	16/09/2000	27.75	159.52	20.6	0.202	173	80	432.8	224	1	0	0	0	Imm/resting
1220	17/09/2000	27.55	159.27	17.9	0.188	180	80	475.6	406	1	0	0	0	Imm/resting
1221	18/09/2000	27.18	159.50	14.8	0.156	238	180	162.8	526	3	0	0	0	Inactive
1223	17/09/2000	27.82	159.42	20.9	0.202	160	60	273.5	196	1	0	0	0	Imm/resting
1225	19/09/2000	27.28	158.77	20.5	0.188	179	70	475.2	570	2	0	0	0	Imm/resting
1226	19/09/2000	27.18	158.63	21.9	0.167	145	60	225.9	246	2	0	0	0	Imm/resting
1227	17/09/2000	27.00	157.67	21.6	0.141	170	70	784.3	480	2	0	0	0	Imm/resting
1228	05/09/2000	27.67	156.93	21.1	0.455	100	20	77.7	116					
1229	05/09/2000	27.50	156.97	22.7	0.403	130	45		210					
1230	05/09/2000	27.53	156.98	22.7	0.403	90	20	104.9	160					
1231	08/09/2000	27.67	159.67	20.3	0.370	80	10	155.6	130					
1232	05/09/2000	27.58	156.95	22.1	0.439	130	40	345	198					
1233	09/09/2000	27.97	159.70	20.3	0.389	200	115	580.7	256	2	0	0	0	Imm/resting
1234	08/09/2000	27.67	159.77	20.5	0.357	125	40	417.9	250					
1235	07/09/2000	28.17	159.83	20.6	0.376	80	10	66.1	98					
1236	07/09/2000	28.08	159.83		0.376	130	40	484.8	228					
1237	07/09/2000	27.97	159.85	20.6	0.382	210	120	864.5	592	2	0	0	0	Imm/resting
1238	09/09/2000	27.67	159.83	20.9	0.351	130	30	228.1	236					
1239	10/09/2000	27.73	160.00	21.1	0.351	140	40	168.7	176	1	0	0	0	Imm/resting
1240	10/09/2000	27.73	159.97	21.1	0.351	140	40	231.8	210	2	0	0	0	Imm/resting
1241	10/09/2000	27.82	159.57	20.9	0.376	120	30	69.2	102					
1242	10/09/2000	27.80	159.70	20.8	0.376	195	100	1086.5	1014	1	0	1	0	Post-spawning
1243	12/09/2000	27.00	158.45	20.9	0.376	175	100	837.9	482	2	0	0	0	Imm/resting
1244	12/09/2000	27.03	158.35	20.8	0.363	130	40	202.3	188					
1245	12/09/2000	27.03	158.53	20.9	0.417	159	60	302.4	204	1	0	0	0	Imm/resting
1246	12/09/2000	27.10	158.67	20.9	0.417	120	30	148.2	162					
1247	10/09/2000	27.73	159.63	20.6	0.376	120	35	118.5	184					
1248	13/09/2000	26.67	158.00	20.9	0.285	120	40	198.7	166					
1249	13/09/2000	26.80	158.03	21.1	0.327	155	60	389.5	248	2	0	0	0	Imm/resting
1250	13/09/2000	26.87	158.17	20.3	0.357	140	45	258.5	210	1	0	0	0	Imm/resting
1251	13/09/2000	26.83	158.10	21.1	0.339	158	60	279.9	244	1	0	0	0	Imm/resting
1252	13/09/2000	26.87	158.17	20.3	0.357	110	30	95.4	102					
1253	14/09/2000	26.75	158.50	20.9	0.153	210	105		402	2	0	0	0	Imm/resting
1254	14/09/2000	28.75	158.45	20.8	0.248	70	10	49.8	106					
1255	14/09/2000	26.80	158.37	19.1	0.159	160	60	375.3	244	1	0	0	0	Imm/resting
1256	15/09/2000	26.78	158.33	21.8	0.153	160	60	279.9	304	2	0	0	0	Imm/resting
1257	15/09/2000	26.73	158.50	20.5	0.153	140	40	333.1	254	2	0	0	0	Imm/resting
1258	13/09/2000	26.83	158.10	21.1	0.339	125	30	102.4	176					
1259	15/09/2000	26.78	158.67	20.6	0.164	160	70	710.7	436	2	0	0	0	Imm/resting
1260	16/09/2000	26.82	158.33	21.4	0.153	250	140	887.1	274	2	0	0	0	Imm/resting
1262	17/09/2000	25.65	160.67	21.4	0.167	101		42.1	132					

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1263	17/09/2000	25.65	160.67	21.4	0.167	184		653.9	454	2	0	0	0	Imm/resting
1265	17/09/2000	25.65	160.58	21.1	0.167	120		96.5	126					
1267	17/09/2000	25.65	160.55	20.9	0.167	162		349	284	2	0	0	0	Imm/resting
1268	17/09/2000	25.65	160.53	20.8	0.167	148		20.2	192	1	0	0	0	Imm/resting
1269	17/09/2000	25.65	160.45	20.9	0.167	116		79.6	146					
1270	17/09/2000	25.65	160.45	20.9	0.167	149		201	164	1	0	0	0	Imm/resting
1271	17/09/2000	25.65	160.38	21.1	0.167	114		51.8	112					
1272	17/09/2000	25.65	160.43	20.9	0.167	116		46.8	114					
1274	17/09/2000	25.67	160.32	20.9	0.167	178		444.3	334	2	0	0	0	Imm/resting
1278	18/09/2000	25.75	160.67	21.4	0.164	111		79.8	130					
1279	18/09/2000	25.78	160.52	21.6	0.170	133		139.1	182					
1281	18/09/2000	25.77	160.48	21.6	0.170	173		315.6	236	2	0	0	0	Imm/resting
1282	18/09/2000	25.77	160.48	21.6	0.170	104		38.5	96					
1283	18/09/2000	25.72	160.50	21.3	0.170	123		124	138					
1284	18/09/2000	25.67	160.53	20.3	0.170	149		142.5	224	1	0	0	0	Imm/resting
1286	18/09/2000	25.63	160.45	21.3	0.170	122		113.7	148					
1287	18/09/2000	25.63	160.48	20.5	0.170	141		144.8	136	1	0	0	0	Imm/resting
1288	18/09/2000	25.63	160.43	21.3	0.170	181		395.2	332	2	0	0	0	Imm/resting
1292	07/09/2000	26.93	161.22	21.3	0.216	123		116.5	168					
1295	07/09/2000	26.92	161.13	21.1	0.224	157		211.8	262	1	0	0	0	Imm/resting
1296	07/09/2000	26.92	161.15	20.9	0.224	235		893.4	320	1	0	0	0	Imm/resting
1297	07/09/2000	26.92	161.08	21.3	0.224	119		88.1	112					
1298	07/09/2000	26.92	161.12	21.1	0.224	88		12.8	66					
1299	07/09/2000	26.92	161.08	21.3	0.224	137			194					
1303	08/09/2000	26.92	161.22	20.9	0.240	180		625	464	2	0	0	0	Imm/resting
1304	08/09/2000	26.92	161.23	20.9	0.240	176		522.2	470	2	0	0	0	Imm/resting
1305	08/09/2000	26.85	161.27	21.1	0.240	117		57.6	120					
1306	08/09/2000	26.85	161.27	21.1	0.240	121		81.4	126					
1307	08/09/2000	26.90	161.23	20.9	0.240	176		263.2	244	2	0	0	0	Imm/resting
1308	15/09/2000	25.32	160.40	20.8	0.164	118		61.5	120					
1309	08/09/2000	26.85	161.27	21.1	0.240	190		507.5	516	2	0	0	0	Imm/resting
1310	15/09/2000	25.35	160.40	20.7	0.164	165		260.9	250	2	0	0	0	Imm/resting
1311	15/09/2000	25.38	160.40	20.9	0.164	179		438.3	190	1	0	0	0	Imm/resting
1312	15/09/2000	25.40	160.40	21.3	0.164	120		82.4	162					
1313	15/09/2000	25.50	160.37	20.7	0.164	178		459.4	238	1	0	0	0	Imm/resting
1315	15/09/2000	25.70	160.27	20.7	0.164	138		242.5	194					
1316	15/09/2000	25.77	160.27	20.7	0.164	201		773.7	380	1	0	0	0	Imm/resting
1317	15/09/2000	25.77	160.27	20.7	0.164	140		189.8	200	1	0	0	0	Imm/resting
1318	15/09/2000	25.78	160.27	20.7	0.164	153		236.3	226	1	0	0	0	Imm/resting
1319	15/09/2000	25.77	160.27	20.7	0.164	183		453	166	1	0	0	0	Imm/resting
1320	12/09/2000	26.20	160.07	20.8	0.202	172		300.4	224	1	0	0	0	Imm/resting
1321	14/09/2000	25.72	160.28	21.6	0.164	179		374.3	262	1	0	0	0	Imm/resting
1323	12/09/2000	25.73	160.23	20.8	0.202	182		551.8	266	1	0	0	0	Imm/resting
1325	12/09/2000	25.85	160.20	20.9	0.202	121		82.3	138					
1326	12/09/2000	25.92	160.17	20.9	0.202	132		196.7	180					
1327	12/09/2000	25.93	160.15	20.9	0.202	100		28.4	106					
1328	12/09/2000	26.15	160.08	20.9	0.202	111		50.5	102					
1329	12/09/2000	26.07	160.10	20.8	0.202	158		248.8	316	1	0	0	0	Imm/resting
1330	12/09/2000	26.17	160.08	20.9	0.202	127		142.5	188					
1331	12/09/2000	26.20	160.07	20.8	0.202	209		1072.5	286	2	0	0	0	Imm/resting
1332	12/09/2000	26.23	160.07	20.9	0.224	126		123.1	200					
1333	12/09/2000	26.20	160.07	20.8	0.202	146		171.7	190	1	0	0	0	Imm/resting
1336	14/09/2000	25.67	160.30	21.4	0.164	136		131.7	182					
1337	14/09/2000	25.67	160.30	21.4	0.164	113		49.5	134					
1338	14/09/2000	25.57	160.33	20.9	0.164	149		198.8	224	1	0	0	0	Imm/resting
1340	16/09/2000	27.50	162.00	20.9	0.236	129		111.4	114					
1341	18/09/2000	27.50	162.00	20.3	0.236	234		1339.7	344	2	0	1	0	Post-spawning
1342	18/09/2000	27.50	162.00	20.3	0.236	154		304.2	204	1	0	0	0	Imm/resting
1344	15/09/2000	27.68	159.37	20.6	0.202	175	80	443.1	220	1	0	0	0	Imm/resting
1346	16/09/2000	27.75	159.63	20.6	0.202	129	50	97	144					
1347	16/09/2000	27.73	159.55	20.6	0.202	127	30	106.5	122					
1349	16/09/2000	25.67	156.42	22.4	0.120	140	50	206.8	148	1	0	0	0	Imm/resting
1350	16/09/2000	25.67	156.42	22.4	0.120	140	50	190.6	174	2	0	0	0	Imm/resting
1351	16/09/2000	25.67	156.42	22.4	0.120	145	55	182.9	202	1	0	0	0	Imm/resting
1352	17/09/2000	26.78	156.45	21.8	0.143	130	35	87.3	126					
1354	18/09/2000	26.50	156.57	22.7	0.143	143	80	190.2	190	1	0	0	0	Imm/resting
1355	19/09/2000	26.23	156.50	20.3	0.143	123	30	138	94					

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1356	14/09/2000	25.52	160.35	20.8	0.164	270		6334	852	4	2	1	0	Spawning
1357	14/09/2000	25.77	160.22	21.4	0.164	211		682.5	580	2	0	0	0	Imm/resting
1358	05/09/2000	25.33	154.08	22.1	0.170	144	40	158.6	178	1	0	0	0	Imm/resting
1359	18/09/2000	30.17	154.07	20.8	0.389	154	70	673.4	214	1	0	0	0	Imm/resting
1360	07/10/2000	30.63	158.68	21.1	0.403	135	40	259.8	192					
1361	07/10/2000	30.58	158.68	21.3	0.403	165	70	596.1	250	2	0	0	0	Imm/resting
1362	07/10/2000	30.58	158.68	21.3	0.403	165	70	684	230	1	0	0	0	Imm/resting
1363	07/10/2000	30.58	158.68	21.3	0.403	140	45	320.2	240	2	0	0	0	Imm/resting
1364	10/10/2000	29.40	158.37		0.232	90	30	78.7	122					
1365	09/10/2000	30.37	157.63	21.1	0.271	130	40	343.2	204					
1366	10/10/2000	29.40	158.48		0.236	150	60	862.8	244	1	0	0	0	Imm/resting
1367	11/10/2000	29.42	158.50	20.4	0.236	190	120	1140.3	298	2	0	0	0	Imm/resting
1368	11/10/2000	29.50	158.45	20.4	0.240	130	35	142.8	188					
1369	11/10/2000	29.48	158.43	20.4	0.236	135	45	210.3	196					
1370	11/10/2000	29.45	158.33	20.4	0.236	138	45	167.5	190					
1372	13/10/2000	28.85	157.22	16.8	0.232	150	50	530.8	274	2	0	0	0	Imm/resting
1373	18/10/2000	28.08	155.67		0.153	187	150	1624.7	544	3	1	0	0	Inactive
1374	18/10/2000	28.17	155.72		0.153	195	140	1048	244	1	0	0	0	Imm/resting
1375	18/10/2000	28.00	155.68		0.143	160	60	493.9	198	1	0	0	0	Imm/resting
1376	19/10/2000	28.42	155.70	20.0	0.188	230	200	4377.7	758	3	2	1	0	Inactive
1377	19/10/2000	28.25	155.68	20.0	0.159	210	150	1125.4	584	3	0	0	0	Inactive
1378	16/10/2000	27.92	157.65	22.5	0.125	197	90	930.3	568	3	0	0	0	Inactive
1380	12/10/2000	27.47	157.13	20.2	0.136	237	130	3805	816	4	1	1	0	Spawning
1381	08/10/2000	27.47	157.13	21.6	0.136	130		134.9	134					
1382	10/10/2000	27.47	157.13	22.2	0.136	181		447.9	234	1	0	0	0	Imm/resting
1383	10/10/2000	27.47	157.13	22.2	0.136	195		855.3	318	2	0	0	0	Imm/resting
1384	10/10/2000	27.47	157.13	22.2	0.136	152		256	184	1	0	0	0	Imm/resting
1387	11/10/2000	27.47	157.13	20.2	0.136	130		166.7	160					
1388	11/10/2000	27.47	157.13	20.2	0.136	164	65	334.2	164	1	0	0	0	Imm/resting
1389	11/10/2000	27.47	157.13	20.2	0.136	138	70	406.6	198					
1390	12/10/2000	27.47	157.13	20.2	0.136	168	70	329	238	2	0	0	0	Imm/resting
1391	12/10/2000	27.47	157.13	20.2	0.136	184	70	394.4	316	2	0	0	0	Imm/resting
1393	12/10/2000	27.47	157.13	20.2	0.136	134	25	129.1	174					
1395	12/10/2000	27.47	157.13	20.2	0.136	113	15	56.2	128					
1396	12/10/2000	27.47	157.13	20.2	0.136	119	20	133.8	128					
1398	13/10/2000	27.88	157.73	16.5	0.118	153	50	300.5	206	1	0	0	0	Imm/resting
1399	16/10/2000	27.68	157.57	22.9	0.159	245	160	6108.8	872	3	1	1	0	Inactive
1401	13/10/2000	27.85	157.65	20.5	0.120	210	100	1244.6	562	3	0	0	0	Inactive
1402	16/10/2000	27.92	157.65	22.5	0.125	137	40	171.1	224					
1404	16/10/2000	27.93	157.67	22.4	0.125	162	45	280.1	472	2	0	0	0	Imm/resting
1405	17/10/2000	27.77	157.53	21.9	0.156	134	30	135.5	134					
1406	16/10/2000	27.82	157.62	21.8	0.170	140	35	133.5	202	1	0	0	0	Imm/resting
1407	08/10/2000	27.47	157.13	21.6	0.136	105	15		114					
1408	17/10/2000	27.83	157.57	22.5	0.155	202	120	847.3	244	2	0	0	0	Imm/resting
1409	17/10/2000	27.77	157.53	21.9	0.156	140	40	244.6	208	1	0	0	0	Imm/resting
1410	08/10/2000	27.47	157.13	21.6	0.136	176	70	514.6	244	2	0	0	0	Imm/resting
1411	03/11/2000					165		1449.1	666	3	0	0	3	Spawning
1412	04/11/2000					185		4353	792	3	1	1	0	Inactive
1413	04/11/2000					125		230	204	2	0	0	0	Imm/resting
1414	04/11/2000					190		3322.6	884	3	2	1	0	Inactive
1415	04/11/2000					150		414.5	232	2	0	0	0	Imm/resting
1416	04/11/2000					100		86	116	1	0	0	0	Imm/resting
1417	05/11/2000					160		1233.8	620	3	0	0	0	Inactive
1418	09/11/2000					125		166.9	200	1	0	0	0	Imm/resting
1419	12/11/2000					170		3513.4	1084	5	2	1	3	Spawning
1420	13/11/2000					160		3269.8	1084	5	1	0	0	Spawning
1421	13/11/2000					180		1003.4	568	3	1	0	0	Inactive
1422	28/11/1999	20.33	166.85	21.7	0.108	248		10175	1138	3	0	0	2	Spawning
1423	29/11/1999	20.35	166.97	21.7	0.112	199		7010	1204	5	0	1	2	Spawning
1424	30/11/1999	20.43	167.03	25.2	0.112	166		425	474	2	0	0	0	Imm/resting
1425	01/12/1999	20.93	166.52		0.088	180		705	224	2	0	1	0	Post-spawning
1426	05/12/1999	21.23	166.07	21.6	0.164	217		4785	1064	3	1	1	1	Spawning
1427	04/12/1999	21.28	166.13	21.6	0.156	97		50	84	1	0	0	0	Imm/resting
1428	06/12/1999	21.17	165.97	21.6	0.170	216		12100	1188	4	1	0	2	Spawning
1429	19/12/1999	20.00	164.50	30.9		175	135	8950	1312	5	0	0	3	Spawning
1430	23/11/1999					190	173		1160	5	1	1	0	Spawning
1431	24/12/1999					200	190		1178	5	1	0	3	Spawning

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1432	29/12/1999					192	141		1038	5	0	0	2	Spawning
1433	15/06/2000					148	77	155	176	1	0	0	0	Imm/resting
1434	19/02/1996					121		500	514	3	0	0	0	
1442	08/12/2000	24.12	153.73	19.6	0.156	110		43.53	94	1	0	0	0	Imm/resting
1443	08/12/2000	24.10	153.77	19.6	0.156	138		203.6	174	1	0	0	0	Imm/resting
1446	08/12/2000	24.18	153.67	19.6	0.156	226		5152.3	848	3	1	1	0	Inactive
1447	08/12/2000	24.18	153.83	19.7	0.156	213		8462.7	1126	3	0	0	2	Spawning
1448	16/11/2000	27.12	162.60	21.1	0.114	251		1491.5	358	2	4	0	0	Post-spawning
1450	10/11/2000	27.38	162.73	21.4	0.105	222		2013.5	562	3	2	1	0	Inactive
1451	05/01/2001	29.22	155.60	24.6	0.094	123		83.3	124	1	0	0	0	Imm/resting
1452	05/01/2001	28.92	155.42	24.0	0.094	95		35.2	72	1	0	0	0	Imm/resting
1453	06/01/2001	28.68	154.08	23.5	0.133	132		176.1	328					
1455	05/01/2001	28.90	155.42	24.3	0.094	88			60	1	0	0	0	Imm/resting
1456	05/01/2001	28.90	155.40	24.8	0.094	160		266.4	240	2	0	0	0	Imm/resting
1457	05/01/2001	29.08	155.53	24.4	0.094	177		960.9	604	3	3	1	0	Inactive
1459	06/01/2001	28.68	154.08	23.5	0.133	87			94	1	0	0	0	Imm/resting
1463	05/01/2001	28.28	155.72	24.1	0.101	137		135.4	142	1	0	0	0	Imm/resting
1465	05/01/2001	28.28	155.72	24.1	0.101	75		10.85	58	1	0	0	0	Imm/resting
1466	05/01/2001	28.28	155.72	24.1	0.101	186		404.5	238	2	0	0	0	Imm/resting
1468	05/01/2001	28.28	155.72	24.1	0.101	140		128.2	150	1	0	0	0	Imm/resting
1469	05/01/2001	28.28	155.72	24.1	0.101	138		117	154	1	0	0	0	Imm/resting
1471	05/01/2001	28.28	155.72	24.1	0.101	136		174.5	228	2	0	0	0	Imm/resting
1472	05/01/2001	28.28	155.72	24.1	0.101	116		73.7	136	1	0	0	0	Imm/resting
1473	06/12/2000	29.75	158.83		0.099	181	70	1209.2	708	3	2	1	0	Inactive
1474	15/12/2000	30.60	156.32		0.105	208	100	2820.5	898	3	1	1	0	Inactive
1475	08/01/2001	27.60	154.20	27.0	0.127	208			1536	5	0	0	0	Spawning
1477	07/11/2000	27.08	162.20	22.2	0.133	190		663.8	312	2	0	0	0	Imm/resting
1478	05/11/2000	26.33	161.57	23.2	0.125	167		302.4	200	1	0	0	0	Imm/resting
1484	08/11/2000	27.17	162.18		0.138	135		173.8	146	1	0	0	0	Imm/resting
1485	06/12/2000	24.17	153.83	25.5	0.143	232	120	12032.4	1652	5	0	1	0	Spawning
1486	10/12/2000	26.18	154.05	26.3	0.098	221	140	11577.7	1646	5	0	1	0	Spawning
1489	17/01/2001	28.57	154.12	21.4	0.103	157		242.6	214	2	0	0	0	Imm/resting
1490	08/01/2001	29.40	153.95		0.107	116			122	1	0	0	0	Imm/resting
1493	09/12/2000	28.87	159.22	23.2	0.112	160	40	295.9	260	2	0	0	0	Imm/resting
1494	11/12/2000	29.62	158.10	24.0	0.077	231	150	2910.8	608	3	1	1	0	Inactive
1495	08/12/2000	28.87	159.22	22.5	0.112	176	60	367.8	224	2	0	0	0	Imm/resting
1496	11/12/2000	29.50	158.18	24.0	0.072	187	70	458.7	208	2	0	0	0	Imm/resting
1497	14/12/2000	29.80	156.33		0.082	199	110	2329.5	706	3	2	1	0	Inactive
1498	16/12/2000	30.85	156.35	23.5	0.107	152	35	182.5	182	1	0	0	0	Imm/resting
1499	06/12/2000	29.67	158.90	22.4	0.101	208	120	3314.9	770	3	2	1	0	Inactive
1500	15/12/2000	30.65	156.37		0.105	210	150	5742.6	920	4	2	1	0	Spawning
1501	07/01/2001	28.57	154.12	25.1	0.125	174		4360.6	1496	5	1	0	0	Spawning
1504	07/01/2001	27.85	154.58	20.0	0.125	142		190.9	152	1	0	0	0	Imm/resting
1506	06/01/2001	28.12	155.75	22.5	0.101	148		122.1	200	1	0	0	0	Imm/resting
1507	09/01/2001	27.85	154.60	24.4	0.125	76		10.69	66	1	0	0	0	Imm/resting
1509	09/01/2001	27.85	154.60	24.4	0.125	133		114.3	126	1	0	0	0	Imm/resting
1510	06/01/2001	28.12	155.75	22.5	0.101	176		3118.7	990	3	0	1	0	Inactive
1511	09/01/2001	27.85	154.60	24.4	0.125	128		71.6	140	1	0	0	0	Imm/resting
1512	06/01/2001	28.12	155.75	22.5	0.101	168		246.8	274	2	0	0	0	Imm/resting
1514	09/01/2001	27.85	154.60	24.4	0.125	117		91.2	184	1	0	0	0	Imm/resting
1515	07/01/2001	27.85	154.58	20.0	0.125	73		5.4	64	1	0	0	0	Imm/resting
1518	08/01/2001	27.60	154.20	27.0	0.127	144		194.1	172	2	0	0	0	Imm/resting
1519	06/01/2001	28.12	155.75		0.101	120		52	116	1	0	0	0	Imm/resting
1520	08/01/2001	27.60	154.20	27.0	0.127	167		5516.2	1470	5	0	0	2	Spawning
1521	08/01/2001	27.60	154.20	27.0	0.127	104		46	104	1	0	0	0	Imm/resting
1522	08/01/2001	27.60	154.20	27.0	0.127	123		120.2	208	1	0	0	0	Imm/resting
1523	08/01/2001	27.60	154.20	27.0	0.127	141		182.1	190	1	0	0	0	Imm/resting
1524	05/11/2000	26.35	161.57	23.3	0.125	174		384.8	306	2	0	0	0	Imm/resting
1526	05/11/2000	26.28	161.45	23.3	0.122	132		256.2	230	1	0	0	0	Imm/resting
1528	06/11/2000	26.48	161.67	21.8	0.151	176		661.6	216	2	0	0	0	Imm/resting
1530	06/11/2000	26.42	161.55	21.9	0.133	181		628.7	246	2	0	0	0	Imm/resting
1531	06/11/2000	26.40	161.52	22.0	0.125	198		721.1	218	2	0	0	0	Imm/resting
1532	07/11/2000	27.05	162.17	22.5	0.133	129		115.9	130	1	0	0	0	Imm/resting
1533	08/11/2000	27.27	162.42	21.5	0.123	156			240	2	0	0	0	Imm/resting
1535	08/11/2000	27.22	162.30	21.6	0.129	158		322.6	228	2	0	0	0	Imm/resting
1537	09/11/2000	27.45	162.80	22.7	0.108	193		545.4	286	2	0	0	0	Imm/resting
1538	09/11/2000	27.43	162.78	22.7	0.108	176		1028.1	598	3	0	0	0	Inactive

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1539	09/11/2000	27.35	162.63	22.2	0.108	182		431.3	198	1	0	0	0	Imm/resting
1541	12/11/2000	27.67	163.50	22.1	0.101	203		666.7	254	2	0	0	0	Imm/resting
1542	08/01/2000	29.40	153.95	24.9	0.148	242		11465.1	1238	4	0	1	2	Spawning
1543	08/01/2001	29.40	153.95	19.7	0.107	197		7530.5	1468	5	0	1	3	Spawning
1544	08/01/2001	29.40	153.95	19.7	0.107	189		4988.4	1112	4	0	1	3	Spawning
1546	04/03/2001	26.52	163.22	25.4	0.056	165		209	204	1	0	0	0	Imm/resting
1549	01/02/2001	27.98	155.83		0.074	139		107.7		1	0	0	0	Imm/resting
1550	04/03/2001	26.77	163.37	25.7	0.059	199		761.5	282	1	4	0	0	Post-spawning
1554	01/03/2001	27.87	155.53	26.3	0.064	136		100.3	140					
1555	28/02/2001	28.15	155.80	26.0	0.084	97		33.8	84					
1556	28/02/2001	28.22	155.73	26.0	0.091	160		243.8	214	1	0	0	0	Imm/resting
1557	04/03/2001	26.67	163.30	25.7	0.056	169		259.9	208	2	0	0	0	Imm/resting
1563	04/03/2001	26.52	163.22	25.4	0.056	134		133.1	112					
1565	28/02/2001	28.22	155.73	26.0	0.091	135		138.7	170					
1566	01/03/2001	27.83	155.43	25.3	0.066	110		44.3	102					
1568	01/03/2001	27.83	155.43	25.3	0.066	210		589.9		1	0	0	0	Imm/resting
1569	06/03/2001	26.78	163.12	26.0	0.056	190		824.6	364	1	0	1	0	Post-spawning
1570	08/03/2001	26.88	162.47		0.062	139		129	152					
1571	08/03/2001	26.88	162.27		0.058	211		543.2	208	1	0	0	0	Imm/resting
1572	08/03/2001	26.88	162.47		0.062	123		113.6	162					
1573	09/03/2001	26.92	162.60		0.061	210		646.3	206	1	0	0	0	Imm/resting
1574	09/03/2001	26.97	162.32		0.060	122		61.1	128					
1575	08/03/2001	26.93	162.38		0.061	138		133.6	150					
1577	09/03/2001	26.90	162.50		0.062	122		68.1	136					
1578	08/03/2001	26.93	162.38		0.061	130		139.7	184					
1579	09/03/2001	26.90	162.23		0.058	215		802.5	372	2	4	1	0	Post-spawning
1580	09/03/2001	26.93	162.42		0.061	210		569.5	216	1	0	0	0	Imm/resting
1582	09/03/2001	26.92	162.60		0.061	131		119.8	178					
1586	05/03/2001	26.48	163.62	27.1	0.065	128		92.5	158					
1587	07/03/2001	26.82	162.62	25.4	0.060	118		119.6	194					
1590	07/03/2001	26.80	162.72	25.7	0.060	172		220.9	218	2	0	0	0	Imm/resting
1591	05/03/2001	26.53	163.73	27.4	0.065	150		236.4	196	2	0	0	0	Imm/resting
1592	05/03/2001	26.53	163.73	27.4	0.065	145		196	172	1	0	0	0	Imm/resting
1596	06/03/2001	26.83	163.00	26.0	0.057	208		524.2	226	1	0	0	0	Imm/resting
1597	06/03/2001	26.78	163.12	26.0	0.056	130		104.8	136					
1598	06/03/2001	26.90	163.05	25.5	0.065	105		30.9	98					
1599	07/03/2001	26.83	162.98	25.9	0.058	202		509.1	186	1	0	0	0	Imm/resting
1600	07/03/2001	26.77	162.80	25.9	0.058	99		35.1	106					
1603	05/03/2001	26.53	163.73	27.4	0.065	137		126.2	216					
1604	07/03/2001	26.82	162.62	25.4	0.060	216		1687	1346	3	0	0	2	Spawning
1606	05/01/2001	23.30	154.50	24.9	0.070	102	25	27.4	92					
1607	05/01/2001	23.32	154.55	25.1	0.070	159	40	219.9	206	1	0	0	0	Imm/resting
1612	11/01/2001	23.42	155.05	25.9	0.082	139	40	127.9	178					
1613	08/01/2001	23.53	155.03	26.5	0.153	217	85	8636.7	1498	5	0	0	3	Spawning
1614	15/02/2001	25.92	155.03	25.7	0.060	172	80	4168.1	1060	4	0	0	3	Spawning
1615	05/02/2001	26.43	154.07	27.3	0.105	154	80	4563.2	1002	4	0	1	0	Spawning
1616	09/02/2001	23.00	166.00	26.8		132								
1617	10/02/2001	23.00	166.00	27.4		123		165						
1618	10/02/2001	23.00	166.00	27.4		156		130						
1619	10/02/2001	23.00	166.00	27.4		136		210						
1620	10/02/2001	23.00	166.00	27.4		127		150						
1623	10/03/2001	27.97	155.68	22.4	0.112	185		5127.7		5	0	0	0	Spawning
1626	11/03/2001	28.37	155.73	24.6	0.085	196		7042		4	0	0	3	Spawning
1629	12/03/2001	28.97	155.77	25.5	0.088	196		1718.5		4	0	0	3	Spawning
1630	12/03/2001	28.93	155.75	25.4	0.088	195		443.2		1	0	0	0	Imm/resting
1632	12/03/2001	28.77	155.72	25.7	0.091	212		1171.4		1	0	1	0	Post-spawning
1635	16/03/2001	29.32	155.67	24.1	0.098	180		5896.4		4	0	1	3	Spawning
1636	19/01/2001	35.07	172.13		0.202	133	51	149.4	160					
1637	08/01/2001	36.67	176.75		0.209	171		350.9	190	1	0	0	0	
1638	14/01/2001	37.42	177.80		0.389	134		130.7	108					
1639	14/01/2001	37.42	177.80		0.389	133		150.4	154					
1640	14/01/2001	37.42	177.80		0.389	104		52.8	96					
1641	15/01/2001	37.40	177.80		0.389	195		812.4	204					
1642	15/01/2001	37.40	177.80		0.389	97		62.5	88					
1643	18/01/2001	37.33	178.25		0.417	158		258	174	1	0	0	0	
1644	18/01/2001	37.33	178.25		0.417	153		219.8	194	2	0	0	0	
1645	26/01/2001	38.42	179.08		0.216	144		230.7	226					

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1646	26/01/2001	38.42	179.08		0.216	113		82.4	116					
1647	29/01/2001	37.12	178.12		0.188	185		640.7	200	1	4	0	0	
1648	29/01/2001	37.12	178.12		0.188	127		137.4	128					
1649	29/01/2001	37.12	178.12		0.188	158		221.8	186	1	0	0	0	
1650	29/01/2001	37.12	178.12		0.188	96		51	96					
1651	30/01/2001	37.28	178.30		0.275	169		340.6	160	1	0	0	0	
1652	31/01/2001	37.28	178.50		0.345	175		763.9	176	1	4	1	0	
1653	31/01/2001	37.28	178.50		0.345	134		147.6	146					
1654	05/02/2001	37.45	178.28		0.232	166		290.7	268	2	0	0	0	
1655	13/02/2001	37.17	176.87		0.216	141		186.9	168					
1656	13/02/2001	37.17	176.87		0.216	116		81.6	150					
1657	13/02/2001	37.17	176.87		0.216	113		67.7	120					
1658	13/02/2001	37.17	176.87		0.216	134		112.2	126					
1659	13/02/2001	37.17	176.87		0.216	199		484.9	290	2	0	0	0	
1660	14/02/2001	37.15	176.87		0.216	179		359.5	241	2	0	0	0	
1661	15/02/2001	37.13	176.83		0.216	130		94.8	172					
1662		37.07	177.80	20.6		114		65	124					
1663		37.05	177.58	20.8		133		173.7	158					
1664		37.33	177.50	21.1		108		49.4	116					
1665		37.32	177.52	21.2		128		118.8	148					
1666		37.08	177.60	20.7		153		296.7	178	1	0	0	0	
1667		37.07	177.58	20.6		153		319	186					
1668		37.25	177.60	20.5		101		206.5	140					
1669		37.03	177.52	20.3		108			90					
1670		37.03	177.52	20.3		130		158.9	160					
1671		37.15	177.30	20.7		131		135.7	166					
1672		37.15	177.28	20.7		93		20.1	76					
1673		37.27	178.10	20.4		98		41.1	112					
1674		37.27	178.00	20.3		133		189.1	158					
1675		37.38	178.02	20.2		214		1229.8	302	2	0	0	0	
1676		37.32	178.08	21.7		119		114.1	126					
1677		37.42	177.97	20.2		150		203.1	158	1	0	0	0	
1678		37.42	177.97	20.6		160		236.8	152	1	0	0	0	
1679		37.62	177.72	20.4		196		660.7	198	1	0	0	0	
1680		37.30	177.37	20.8		110		61.3	140					
1681		37.30	177.35	20.8		122		139.8	164					
1682		37.28	177.30	20.6		116		87.1	158					
1683		39.58	178.50	20.3		170		376.8	210	1	0	0	0	
1684		39.43	178.60	20.0		230		1994.1	444	2	0	0	0	
1685		39.58	178.52	19.5		201		787.1	258					
1686		39.58	178.52	19.5		138		195.5	178					
1687		39.57	178.57	19.5		138		141.2	160					
1688		39.65	178.58	19.4		112		58.4	102					
1689		39.63	178.58	19.4		142		199.5	168					
1690		39.62	178.60	19.4		147		213	156					
1691		39.58	178.62	19.4		135		159.7	206					
1692		40.00	178.13	19.9		102		59	116					
1693		39.98	178.12	19.9		121		71.8	122					
1694		39.98	178.12	19.9		204		818.1	228	2	0	0	0	
1695		39.95	178.12	20.1		101		38.7	90					
1696		39.88	178.12	20.2		106		67.6	108					
1697		39.15	179.00	20.4		103		37.2	106					
1698		38.18	178.98	20.7		108		66.1	116					
1699		38.18	178.98	20.7		216		662	248	2	0	0	0	
1700		38.28	178.95	21.2		111		56.9	116					
1701		38.08	178.97	20.4		222		1042.6	194	1	0	0	0	
1702		38.15	178.97	20.6		182		374.3	338	1	0	0	0	
1703		37.60	179.33	21.7		187		445.5	180	1	0	0	0	
1704		37.67	179.20	21.7		203		581.4	242	1	0	0	0	
1705		37.35	178.63	21.6		120		645.4	216					
1706		37.37	178.65	21.9		187		60.2	116	1	0	0	0	
1707		37.15	177.53	21.9		248		459.6	232	2	0	0	0	
1708		37.13	177.55	22.0		190		1510	296	2	0	0	0	
1709		37.13	177.55	22.0		190		671.6	272	2	0	0	0	
1710	08/02/2001	35.10	171.93		0.216	215	180	938.1	252	2	0	0	0	
1711	12/02/2001	35.15	172.20		0.170	165	72	256.9	230	1	0	0	0	
1712	12/02/2001	35.15	172.20		0.170	162	82	310.5	240	2	0	0	0	

Appendix 1.

Sample no.	Date caught	Latitude	Longitude	SST	FLR	OFL (cm)	Weight (kg)	Total gonad wt. (g)	Mean oocyte diam. (um)	Oocyte stage	Alpha atresia	Beta atresia	POFs	Classification
1713	08/02/2001	35.10	171.93		0.216	163	73	383.1	278	2	0	0	0	
1714	09/02/2001	34.92	171.90		0.257	203	125	836	306	2	0	0	0	
1715	10/02/2001	34.92	171.92		0.257	199	180	962.1	306	2	0	0	0	
1716	11/02/2001	34.32	172.12		0.487	181	112	626.2	234	1	0	0	0	
1717	09/02/2001	34.92	171.90		0.257	252	220	1492	210	1	0	0	0	
1718	04/02/2001	36.45	173.40		0.240	216	185	1015.8	210	2	4	0	0	
1719	31/01/2001	36.77	173.02		0.275	206	145	610.9	186	1	0	0	0	
1720	27/01/2001	36.40	173.07		0.266	185	108	359.1	266	1	0	0	0	
1721	26/01/2001	36.33	172.85		0.266	163	79	291.2	210	1	0	0	0	
1722	08/02/2001	35.10	171.93		0.216	190	104	515.1	200	1	0	0	0	
1723	03/02/2001	36.57	173.53		0.248	205	125	815	188	1	0	0	0	
1724	09/02/2001	34.92	171.90		0.257	142	46	208.5	156					
1725	04/02/2001	36.45	173.40		0.240	142	51	157.6	154					
1726	11/02/2001	34.32	172.12		0.487	115	24	63	134					
1728	08/02/2001	36.08	171.93	23.0	0.198	187	97	334.5	208	1	0	0	0	
1729	26/01/2001	35.10	171.93	25.0	0.176	118	31	85.1	108					
1730	26/01/2001	36.33	172.85		0.266	140	34	92	136					
1731	04/02/2001	36.45	173.40		0.240	129	45	164.6	124					
1732	08/11/1998					209								
1733	27/11/2001	37.57	151.57			258		15						

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
1	5/15/99	26.13	157.33	14.3	0.2441	151.5	40	60.5	3	Y
21	7/4/99	25.08	157.53	15.7	0.2570	110		94.1		
25	7/5/99	25.33	157.30	15.7	0.2570	130				
27	7/5/99	25.32	157.30	15.9	0.1202	165		33.2		
29	7/6/99	25.42	157.02	15.9	0.1202	130				
35	7/7/99	25.08	156.50	15.9	0.2661	140		24.0		
36	7/7/99	25.07	156.50	16.8	0.1884	204		85.1		
40	7/8/99	25.15	156.67	17.5	0.1161	137		54.4		
44	7/8/99	25.15	156.80	17.5	0.2661	112		4.0		
45	7/8/99	25.15	156.80	18.1	0.1245	110		3.4		
46	7/8/99	25.15	156.82	18.3	0.1884	112		53.6		
56	7/24/99	24.48	155.78	18.9	0.2018	167		29.6		
58	7/25/99	23.58	156.00	19.1	0.1613	215				
65	7/6/99	28.00	160.50	19.1	0.0851	142		26.1		
81	7/4/99	29.50	154.00	19.6	0.1558	185		94.4		
87	7/7/99	30.13	154.10	19.6	0.1558	191		67.2		
88	7/7/99	30.08	154.08	19.7	0.0794	190		124.1		
103	8/18/99	25.10	157.18	19.7	0.1094	160		59.2	2	Y
113	8/21/99	25.03	158.80	19.7	0.0635	180			3	Y
118	7/31/99	26.93	156.63	19.7	0.0912	165		97.4	3	Y
120	8/1/99	26.97	156.67	19.7	0.0912	185			3	Y
124	8/2/99	25.67	157.53	19.7	0.1558	188		74.4	3	Y
132	8/20/99	24.92	158.25	19.7	0.1558	140		45.5	3	Y
135	8/20/99	24.92	158.17	19.7	0.1669	190		95.2		N
136	8/20/99	24.92	158.15	19.7	0.1066	70		120.2	3	Y
139	8/20/99	24.92	158.10	19.7	0.1066	50		18.7	3	Y
144	7/31/99	24.85	156.23	19.8	0.0912	215		60.4	4	Y
154	8/2/99	24.83	155.50	19.8	0.1479	150			4	Y
166	8/4/99	25.08	154.77	19.9	0.1884	172			4	Y
168	8/18/99	25.18	157.20	19.9	0.1669	167		108.3		N
172	8/18/99	25.18	157.20	20.0		162		58.9	3	Y
174	8/18/99	25.18	157.20	20.0	0.1245	180			3	Y
175	8/19/99	25.12	157.03	20.0	0.1245	137		47.5	4	Y
176	8/19/99	25.12	157.03	20.2	0.1950	174		58.5	2	Y
177	8/20/99	25.62	157.67	20.2	0.2239	192		133.5		N
181	8/20/99	25.62	157.67	20.2	0.2661	186		167.8	3	Y
183	8/20/99	25.62	157.67	20.2	0.1884	150		33.5	4	Y
193	8/21/99	25.92	157.93	20.2	0.1357	119		8.9	4	Y
195	8/22/99	25.97	157.88	20.2	0.1357	160		83.3	2	Y
209	11/29/98	26.67	155.13	20.2	0.1357	158			2	Y
210	11/30/98	26.08	155.08	20.2	0.1357	142		56.8	3	Y
213	11/30/98	26.12	155.10	20.3	0.2483	176		119.9		N
215	11/30/98	26.07	155.07	20.3	0.1698	136		87.8		N
217	11/29/98	26.47	155.07	20.3	0.1479	167		114.7	2	Y
219	11/29/98	26.47	155.07	20.3	0.1884	167		121.3	2	Y
223	9/18/99	25.30	157.50	20.3	0.1669	155		40.6		
226	9/19/99	25.05	157.30	20.4	0.2317	167				
227	9/19/99	25.05	157.30	20.5	0.3448	153				
228	9/19/99	25.08	157.32	20.5	0.2570	188		120.4		
230	9/19/99	25.12	157.33	20.5	0.2483	135				
232	9/21/99	25.95	155.88	20.5	0.1698	150				
233	9/21/99	25.95	155.87	20.5	0.1950	122				
235	9/21/99	25.92	155.87	20.6	0.1613	155		78.6		
236	9/21/99	25.90	155.85	20.6	0.1479	175		244.9		
240	7/24/99	30.15	157.75	20.6	0.2661	200		712.2		
243	8/1/99	30.03	158.18	20.6	0.2707	170		412.0		
245	9/27/99	27.98	158.63	20.6	0.2054	150		40.9		
295	10/17/99			20.6	0.1669	135		66.4		N
307	10/19/99			20.6	0.2018	120		95.9		N
314	10/19/99			20.6	0.2018	130		74.6		
315	10/19/99			20.7	0.0794	160		96.5		
319	10/17/99	27.08	154.95	20.7	0.0767	164		100.9		
323	10/17/99	27.02	154.93	20.7	0.0767	152		78.3		
324	10/17/99	26.87	154.85	20.7	0.0741	140		78.1		
326	10/18/99	27.30	155.13	20.7	0.0794	110		9.9		
331	10/18/99	27.15	155.05	20.7	0.0754	152				N
332	10/18/99	27.10	155.02	20.7	0.1311	102				

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
338	10/19/99	27.50	155.82	20.7	0.1334	192		189.1		
342	10/20/99	27.55	155.85	20.7	0.1698	143		35.5		
343	10/20/99	27.53	155.85	20.7	0.1698	169		121.1		
344	10/20/99	27.52	155.85	20.7	0.1585	125		27.5		
349	10/20/99	27.32	156.00	20.7	0.1641	168		100.6		
350	10/21/99	27.98	155.87	20.8	0.2740	173		111.5		
355	10/21/99	27.77	155.85	20.8	0.1047	162		111.4		
359	10/21/99	27.72	155.83	20.8		123		20.0		
367	10/21/99	27.58	155.85	20.8	0.2399	162		77.8		
372	10/22/99	28.05	155.85	20.8	0.2054	157		80.8		
375	10/22/99	27.97	155.83	20.8	0.1641	151		68.8		
376	10/22/99	27.97	155.83	20.9	0.2317	108		52.3		
377	10/22/99	27.87	155.82	20.9	0.1613	179		47.3		
378	10/22/99	27.83	155.82	20.9	0.2163	153		73.9		
379	10/22/99	27.78	155.82	20.9	0.2054	159		92.8		
383	10/22/99	27.60	155.80	20.9	0.3331	187		146.5		
384	10/22/99	27.53	155.82	20.9	0.2163	168		83.4		
405	12/17/99	28.65	157.72	20.9	0.1669	156		72.0		
410	12/18/99	28.50	157.68	20.9	0.2239	177		144.8		
414	12/18/99	28.50	157.68	20.9	0.2018	163		142.4	4	Y
419	12/19/99	28.87	157.73	20.9	0.2018	150		76.9		N
432	12/21/99	28.45	157.37	20.9	0.2239	164			2	Y
441	11/24/99	30.95	161.40	21.0	0.2483	166		52.6	6	Y
446	11/27/99	30.07	161.15	21.1	0.2399	107				
449	11/23/99	30.97	161.40	21.1	0.2239	142				
450	11/22/99	31.08	161.17	21.1	0.1613	129		19.3		
451	11/24/99	30.95	161.40	21.1	0.1852	198		66.7		
453	11/23/99	30.97	161.40	21.1	0.0767	99		4.0		
457	11/24/99	30.95	161.40	21.1	0.1047	180		558.6		
501	2/15/00			21.1	0.1161	220				
502	2/15/00			21.1	0.2570	120			5	Y
506	2/12/00	27.57	160.20	21.1	0.2485	207		84.1	6	Y
510	2/12/00	27.60	160.27	21.1	0.2399	116		10.4		
514	2/13/00	27.25	160.53	21.1	0.2239	175		109.7		
515	2/13/00	27.27	160.52	21.1	0.2399	173		31.9		
516	2/13/00	27.27	160.52	21.1	0.1884	177		102.9		
517	2/13/00	27.28	160.50	21.1	0.1698	119				
518	2/13/00	27.30	160.50	21.1	0.2163	103		3.0		
520	2/13/00	27.32	160.48	21.1	0.1288	153		82.7		
521	2/13/00	27.33	160.48	21.2	0.2661	189		199.4		
523	2/13/00	27.50	160.33	21.3	0.2483	124		11.9		
524	2/13/00	27.55	160.35	21.3	0.2317	179		61.2		
525	2/13/00	27.57	160.35	21.3	0.2951	114		17.0		
532	2/14/00	28.27	160.30	21.3	0.2163	177		105.1		
536	2/14/00	28.22	160.30	21.3	0.2527	147		62.5		
538	2/14/00	28.13	160.33	21.3	0.2239	165		86.6		
539	2/14/00	28.08	160.15	21.3	0.2239	162		78.0		
540	2/14/00	28.08	160.37	21.3	0.2317	142		18.6	4	Y
541	2/14/00	28.05	160.40	21.3	0.2089	109		10.1		
543	2/16/00	28.58	160.63	21.3	0.2089	150		74.6		
551	2/16/00	28.42	160.38	21.3	0.1698	109		11.0	3	Y
559	2/16/00	28.33	160.32	21.3	0.2239	100		4.9		
561	2/17/00	28.73	160.35	21.3	0.2239	165		69.0		
564	2/17/00	28.62	160.32	21.3	0.2239	102		11.4		
566	2/17/00	28.53	160.28	21.3	0.1641	118		13.5		
567	2/17/00	28.43	160.30	21.4	0.2441	104		4.7		
568	2/17/00	28.43	160.30	21.4	0.2239	107		10.0		
574	2/18/00	28.83	160.33	21.4	0.1558	101		4.6		
579	2/18/00	28.65	160.17	21.4	0.1917	161		30.0		
582	2/19/00	28.92	160.33	21.4	0.1917	119		8.7		
584	2/19/00	28.82	160.28	21.4	0.1917	171		103.1		
586	2/19/00	28.77	160.23	21.4	0.1266	188		77.2		
588	2/19/00	28.72	160.23	21.4	0.1505	167		139.4		
592	2/20/00	28.90	160.48	21.4	0.2317	162		95.7		
596	2/20/00	28.85	160.27	21.4	0.2951	142		101.2		
603	2/21/00	29.00	160.63	21.4	0.3273	117		9.0		
604	2/21/00	28.97	160.88	21.4	0.2661	152		63.8		

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
609	2/21/00	28.95	160.55	21.4	0.2018	184		178.3		
610	2/21/00	28.90	160.50	21.4	0.2089	152		61.2		
628	2/22/00	29.00	160.65	21.4	0.2089	100		6.8		
635	2/22/00	28.93	160.52	21.4	0.1641	157		56.7		
638	2/22/00	28.88	160.40	21.4	0.1641	172		100.9		
639	2/22/00	28.85	160.35	21.4	0.1641	148		35.4		
643	2/22/00	28.83	160.33	21.4	0.1429	108		11.1		
652	2/23/00	28.95	160.40	21.6	0.2740	104		16.5		
657	2/23/00	28.87	160.22	21.6	0.2441	194		451.9		
702	3/14/00	30.35	161.67	21.6	0.2239	181	80	97.2		N
711	3/13/00	29.63	161.30	21.6	0.1505	125	20	19.5	3	Y
713	3/14/00	30.20	161.70	21.6	0.1505	182	90	127.4		N
714	3/19/00	30.50	161.85	21.6	0.1505	144	50	22.3	4	Y
715	3/15/00	30.25	162.23	21.6	0.1505	169	75	82.9	4	Y
726	3/22/00	27.52	160.35	21.6	0.2089	132		16.3	4	Y
727	3/14/00	28.85	160.27	21.6	0.3055	170		68.9		N
730	3/14/00	28.70	160.18	21.6	0.1641	106		10.1	2	Y
731	3/14/00	28.70	160.20	21.6	0.1820	141		47.7	5	Y
733	3/16/00	29.92	161.42	21.6	0.1758	105		5.9	4	Y
734	3/14/00	28.87	160.28	21.6	0.1669	112			2	Y
737	3/22/00			21.6	0.1698	197		106.4		N
738	3/14/00	28.78	160.23	21.6	0.1698	167		70.3	3	Y
739	3/22/00			21.8	0.2707	170		104.3		N
740	3/13/00	29.00	160.22	21.8	0.2740	157		76.3	4	Y
741	3/24/00	27.68	160.82	21.8	0.2740	168		72.2	4	Y
743	3/16/00	29.93	161.48	21.8	0.2441	133		26.3	4	Y
744	3/14/00	28.68	160.18	21.8	0.2089	169		37.7	6	Y
745	3/14/00	28.85	160.28	21.8	0.1641	154		30.9	6	Y
749	3/13/00	28.28	160.22	21.8	0.1245	145		60.3		N
750	3/16/00	29.93	161.48	21.8	0.1161	114		11.1	2	Y
751	3/14/00	28.57	160.27	21.8	0.2317	187		145.3		N
752	3/17/00	30.23	161.90	21.8	0.1641	161		64.4		N
754	3/17/00	30.33	161.83	21.8	0.2570	160		72.0	3	Y
756	3/22/00	27.68	160.83	21.8	0.1641	208		159.4		N
762	3/17/00	30.25	162.00	21.9	0.2483	106		17.0		N
764	3/17/00	30.32	161.85	21.9	0.2317	116		9.0	4	Y
772	2/27/00			21.9	0.1698	150	50			N
773	2/24/00			21.9	0.2089	125				N
774	2/26/00			21.9	0.2485	132			5	Y
775	2/24/00			21.9	0.1641	175		113.1		N
776	2/26/00			21.9	0.1884	150		86.9	5	Y
777	2/23/00			22.1	0.2317	185		135.4	4	Y
783	5/22/00	29.12	160.22	22.1	0.1820	196		144.7		N
785	5/22/00	28.93	160.40	22.1	0.2317	170		120.7		N
786	5/18/00	29.37	159.97	22.1	0.2317	182		77.0	4	Y
788	5/22/00	29.05	160.28	22.1	0.1820	139		28.0		N
793	5/19/00	29.22	160.18	22.1	0.2317	174		47.7	3	Y
794	5/18/00	29.42	160.12	22.2	0.2707	112		9.8	4	Y
796	5/19/00	29.13	160.23	22.2	0.1380	161		46.3	3	Y
812	5/18/00	29.27	159.90	22.2	0.1698	92		3.0	4	Y
814	5/19/00	29.33	160.03	22.2	0.1311	129		17.8	4	Y
815	5/18/00	29.38	160.02	22.2	0.2661	94		6.0	4	Y
819	5/17/00	29.43	160.18	22.2	0.1357	112		11.6		N
821	5/17/00	29.55	160.50	22.2	0.0881	184		81.9	4	Y
825	5/17/00	29.40	160.17	22.4	0.1429	171		57.3	4	Y
827	5/23/00	28.88	160.30	22.4	0.0767	114			4	Y
828	5/17/00	29.42	160.18	22.4	0.1698	149		38.4	4	Y
832	5/17/00	29.50	160.28	22.4	0.2201	148		38.3	4	Y
838	5/14/00	27.48	157.07	22.4	0.1245	173		52.3	4	Y
839	5/23/00	28.82	160.38	22.5	0.2399	167		67.3	4	Y
842	5/22/00	29.12	160.28	22.5	0.1334	169		40.3	4	Y
846	5/12/00	26.37	157.05	22.5	0.1122	152	80	82.8	4	Y
847	5/12/00	26.28	157.12	22.5	0.1122	180	110	82.1	4	Y
848	5/12/00	26.37	157.03	22.5	0.1311	127	65		3	Y
849	5/15/00	26.30	156.97	22.5	0.2239	170	100	60.1	4	Y
853	5/13/00	26.23	157.28	22.5	0.1758	159	90		4	Y
854	5/12/00	26.35	157.00	22.5	0.1311	155	80	129.7	4	Y

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
855	5/22/00	19.93	153.38	22.5	0.1558	154		71.1	4	Y
857	5/27/00	23.58	154.57	22.5	0.1245	113		16.1	4	Y
862	5/24/00	21.13	153.67	22.5	0.1012	128		16.0	4	Y
863	5/24/00	21.10	153.75	22.5	0.1012	101		7.6	4	Y
864	5/24/00	20.97	153.83	22.5	0.1012	137		34.1	4	Y
866	5/22/00	20.20	153.55	22.7	0.1758	150		63.8	4	Y
869	5/22/00	20.97	153.43	22.7	0.1266	168		149.3		N
871	5/26/00	22.23	154.53	22.7	0.1585	115		27.4	5	Y
872	5/23/00	20.33	153.50	22.9	0.0851	130			4	Y
873	5/22/00	19.95	153.42	22.9	0.1122	105		21.7	4	Y
874	5/25/00	20.98	154.73	22.9	0.1479	171		91.4		N
875	5/23/00	20.33	153.50	22.9	0.1202	123		40.6	4	Y
880	5/23/00	20.05	153.43	22.9	0.1380	131			4	Y
881	5/23/00	20.12	153.48	23.0	0.2163	125		15.9	4	Y
882	5/23/00	20.20	153.53	23.0	0.1288	153				N
888	5/18/00	29.93	161.22	23.0	0.1454	146	50	44.8	5	Y
889	5/15/00	27.53	157.07	23.0	0.1122	155		53.9	3	Y
890	5/16/00	30.42	161.30	23.0	0.1084	178	80	94.0		N
894	5/16/00	30.37	161.20	23.0	0.1161	191	85			N
898	5/15/00	30.25	161.42	23.0	0.2020	191	80	92.8	4	Y
902	5/14/00	30.52	161.38	23.2	0.1202	128	35	22.7	4	Y
903	5/15/00	27.75	157.07	23.2	0.1202	173		60.7	4	Y
906	5/17/00	29.52	160.33	23.2	0.1202	113		6.7	4	Y
908	5/17/00	29.38	160.08	23.2	0.1334	164		68.6	3	Y
909	5/15/00	27.53	157.07	23.2	0.1454	126		16.0	4	Y
923	5/20/00	33.80	163.73	23.2	0.1142	185	50	96.3	4	Y
926	5/22/00	33.53	159.57	23.2	0.1142	155	30		2	Y
928	5/20/00	33.93	164.15	23.2	0.1122	118	15		2	Y
931	5/20/00	33.93	164.15	23.2	0.0851	191	80	58.4		N
936	4/12/00	20.85	154.15	23.2	0.1047	185	85	121.2		N
938	4/13/00	21.83	154.17	23.2	0.1223	163	60	135.7	3	Y
940	4/14/00	20.93	153.97	23.3	0.1142	124	25	12.3	4	Y
944	4/21/00	23.97	155.55	23.3	0.0881	111	20	4.6	2	Y
946	4/21/00	24.02	155.62	23.3	0.0741	135	75		4	Y
948	4/25/00	23.73	155.22	23.5	0.1122	172	90	106.5	4	Y
951	4/23/00	24.07	155.92	23.5	0.0822	175	85	148.6		N
952	4/25/00	23.73	155.22	23.5	0.0781	155	65	73.3		N
954	6/22/00	30.53	159.42	23.5	0.1334	172	65	66.8	3	Y
956	6/22/00	30.52	159.55	23.5	0.1334	136				N
957	6/23/00	29.82	159.77	23.5	0.1334	160	60	55.8	4	Y
958	6/23/00	29.83	159.80	23.5	0.1334	165	65	62.4	4	Y
960	6/23/00	30.05	160.03	23.6	0.1084	190	80	76.6	2	Y
962	4/21/00	28.18	154.43	23.6	0.0767	168	90			N
963	4/21/00	28.30	154.32	23.6	0.0823	170	90	86.6	3	Y
964	4/21/00	28.32	154.30	23.8	0.1047	117	45	16.3	4	Y
968	4/23/00	27.93	154.52	23.8	0.1084	157	85	46.1	3	Y
975	6/17/00	27.55	160.68	23.8	0.1202	164		58.7	3	Y
978	6/19/00	27.85	161.02	23.8	0.1084	148	40	27.8	4	Y
989	6/20/00	28.08	160.67	23.8	0.0978	147	30	20.2	4	Y
991	6/10/00	27.95	161.62	24.0	0.1084	151		61.4	4	Y
994	6/16/00	27.90	160.65	24.0	0.1084	183		99.1	4	Y
998	6/14/00	27.85	161.70	24.0	0.1103	145		56.0	4	Y
999	6/10/00	28.00	161.60	24.0	0.0881	158		55.5		N
1008	5/24/00	34.07	163.03	24.0	0.0781	178	80	29.9		N
1015	5/26/00	34.25	163.17	24.0	0.1122	190	100		4	Y
1031	7/14/00	26.70	159.32	24.0	0.1047	117		16.6	2	Y
1043	7/9/00	29.77	154.30	24.1	0.0881	109		5.5	4	Y
1052	7/21/00	24.87	154.20	24.1	0.1012	124	35		4	Y
1054	6/9/00	28.78	160.35	24.1	0.1012	137	30	28.9	4	Y
1056	6/10/00	29.00	160.55	24.1	0.1012	173	70		4	Y
1059	6/11/00	28.52	160.18	24.3	0.0851	147	40	35.2		N
1062	6/16/00	29.75	159.70	24.3	0.1029	168	65	49.0	4	Y
1064	6/17/00	29.65	159.78	24.3	0.0944	184	90	65.7		N
1066	6/17/00	29.78	159.87	24.4	0.0781	132	30		2	Y
1069	6/19/00	29.52	159.68	24.4	0.0822	135	40	32.3	3	Y
1070	6/23/00	30.18	154.23	24.4	0.0881	119	20	15.3	3	Y
1085	8/16/00	23.68	155.30	24.4	0.0823	118	25	6.3	3	Y

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
1086	8/16/00	23.72	155.35	24.4	0.0881	138	50	38.1	2	Y
1087	8/16/00	23.77	155.50	24.4	0.0881	122	30	17.7	4	Y
1089	8/17/00	23.98	155.85	24.4	0.1066	152	60	31.1	4	Y
1090	8/17/00	23.92	155.78	24.4	0.1245	109	20		4	Y
1093	8/17/00	23.78	155.60	24.4	0.1245	186	80	99.3		N
1103	8/20/00	24.48	155.93	24.4	0.1245	128	30		4	Y
1107	8/9/00	26.88	161.25	24.4	0.0795	113		19.9	4	Y
1109	8/10/00	27.00	161.42	24.6	0.0822	102		6.4	4	Y
1113	8/10/00	27.02	161.32	24.6	0.0822	185		110.4	4	Y
1116	8/11/00	27.05	161.58	24.6	0.0767	165		77.2		N
1119	8/12/00	27.02	161.97	24.6	0.0767	161		80.7		N
1124	8/13/00	26.75	161.38	24.6	0.0741	97		12.0	2	Y
1130	8/14/00	26.73	161.52	24.6	0.1202	152		54.3	4	Y
1134	8/15/00	26.77	161.08	24.6	0.1142	131		24.9	3	Y
1135	8/15/00	26.78	161.08	24.6	0.0881	155		44.0	4	Y
1138	8/16/00	23.78	155.60	24.6	0.0881	175	70		3	Y
1142	9/7/00	27.00	161.23	24.6	0.0851	140		32.1	2	Y
1144	9/7/00	27.10	161.23	24.6	0.1084	183		152.5		N
1146	9/8/00	27.18	161.18	24.6	0.0851	168		74.8	4	Y
1151	9/8/00	27.18	161.18	24.8	0.0881	133		28.2	2	Y
1153	9/10/00	26.08	160.10	24.8	0.0881	134		28.9	4	Y
1155	9/10/00	26.08	160.10	24.8	0.0881	144		37.0	5	Y
1156	9/10/00	26.08	161.10	24.8	0.0881	182		101.2		N
1158	9/10/00	26.08	160.10	24.9	0.1408	135		42.1	2	Y
1166	9/11/00	25.95	160.13	24.9	0.0822	172		150.4		N
1167	9/11/00	25.95	160.13	24.9	0.1047	184		76.0		N
1171	9/13/00	25.52	160.33	24.9	0.1047	110		11.4	4	Y
1175	9/13/00	25.52	160.33	25.1	0.1245	187		165.6		N
1178	9/13/00	25.52	160.33	25.1	0.1245	113		13.3	4	Y
1179	9/13/00	25.52	160.33	25.1	0.1245	127		42.4	4	Y
1182	9/13/00	25.52	160.33	25.1	0.0881	163		81.3		N
1185	9/13/00	25.52	160.33	25.1	0.0866	109		4.4	2	Y
1195	9/14/00	25.47	160.37	25.1	0.0881	126		19.6	4	Y
1196	9/14/00	25.47	160.37	25.2	0.0768	182		76.1		N
1200	9/16/00	25.57	160.67	25.2	0.0768	120		9.5	4	Y
1202	9/16/00	25.57	160.67	25.4	0.0994	95		2.0	2	Y
1206	16/09/2000	25.57	160.33	25.4	0.0603	195				
1222	9/19/00	27.18	159.52	25.5	0.0977	172	70	55.9		N
1224	9/19/00	27.23	158.77	25.5	0.0881	110	20	14.0	6	Y
1261	9/14/00	26.80	158.33	25.5	0.0881	120	30	132.1		N
1264	9/17/00	25.65	160.68	25.7	0.0977	124		19.2	4	Y
1266	9/17/00	25.65	160.68	25.7	0.0944	168		89.0	4	Y
1273	9/17/00	25.65	160.68	25.7	0.0977	187		105.4		N
1275	9/17/00	25.65	160.68	25.9	0.1012	180		74.1	3	Y
1276	9/18/00	25.75	160.73	25.9	0.1012	177		84.6	5	Y
1277	9/17/00	25.65	160.68	25.9	0.0961	150			3	Y
1280	9/18/00	25.75	160.73	25.9	0.0881	191		149.9	2	Y
1285	9/18/00	25.75	160.73	25.9	0.0767	157			4	Y
1289	9/18/00	25.75	160.73	25.9	0.0582	131		27.6	4	Y
1290	9/18/00	25.75	160.67	25.9	0.0582	167		81.3	4	Y
1291	9/18/00	25.75	160.73	25.9	0.0572	105		8.1	4	Y
1293	9/7/00	27.00	161.30	26.0	0.1585	178		112.8	4	Y
1294	9/7/00	27.00	161.23	26.0	0.0603	193		131.3		N
1300				26.0	0.0716	188		9.7		
1301	9/7/00	27.00	161.23	26.0	0.0562	174		106.0	3	Y
1302	9/7/00	27.00	161.23	26.0	0.0572	116			3	Y
1314	9/15/00	25.32	160.40	26.0	0.0572	166		108.2		N
1322	9/12/00	25.72	160.22	26.2	0.1084	137		39.5		N
1324	9/12/00	25.72	160.22	26.2	0.1585	171		66.0		N
1334	9/14/00	25.47	160.37	26.3	0.1585	114		2.8	4	Y
1335	9/14/00	25.47	160.37	26.3	0.0978	147		44.9	2	Y
1339	9/12/00	26.72	160.22	26.3	0.0795	105		6.7	4	Y
1343	9/15/00	27.58	159.23	26.5	0.0977	124	30	15.4	2	Y
1345	9/15/00	27.68	159.37	26.5	0.0977	129	40	14.3	2	Y
1348	9/16/00	27.75	159.63	26.5	0.0767	185	90	65.9	2	Y
1353	9/16/00	26.58	156.42	26.6	0.0795	130	35	26.5	2	Y
1371	10/11/00	29.42	158.17	26.8	0.1405	130	25	127.7		N

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
1379	10/17/00	27.90	157.73	26.8	0.1405	171	70	71.4	4	Y
1385	10/11/00	27.47	157.13	26.8	0.1203	105	10		2	Y
1386	10/10/00	27.47	157.13	27.0	0.0543	188		112.4		N
1392	10/12/00	27.47	157.13	27.1	0.1454	110	20	11.1	4	Y
1394	10/12/00	27.47	157.13	27.1	0.0624	193	90	216.7	2	Y
1397	10/12/00	27.47	157.13	27.1	0.0646	121	25	16.4	4	Y
1400	10/16/00	27.67	157.62	27.4	0.0624	129	25	15.1	4	Y
1403	10/16/00	27.98	157.67	21.4	0.2317	126	25	26.8	4	Y
1435	12/4/00	24.80	154.17	21.5	0.2278	170		87.53	4	Y
1436	12/4/00	24.80	154.17	21.5	0.1225	165		166.5	4	Y
1437	12/7/00	24.42	153.50	21.6	0.1505	110		12.32	4	Y
1438	12/7/00	24.53	153.62	21.6	0.1505	173		235.9		N
1439	12/7/00	24.42	153.50	21.6	0.1429	101		10.04	4	Y
1440	12/8/00	24.23	153.57	21.7	0.1429	111		10.4	4	Y
1441	12/8/00	24.23	153.57	21.7	0.1429	102			4	Y
1444	12/8/00	24.23	153.57	21.7	0.1585	175		123.6		N
1445	12/8/00	24.23	153.57	21.8	0.1505	126		27.9	4	Y
1449	1/5/01	29.30	155.67	21.8	0.1288	123			2	Y
1454	1/6/01	28.68	154.08	21.9	0.1334	91			2	Y
1458	1/6/01	28.68	154.08	21.9	0.1288	112		34.1		N
1460	1/6/01	28.68	154.08	22.1	0.1288	82			1	Y
1461	1/7/01	28.57	154.12	22.2	0.1288	101			4	Y
1462	1/6/01	28.68	154.08	22.2	0.1288	182		153		N
1464	1/5/01	28.28	155.72	22.4	0.1122	114		7.04	4	Y
1467	1/5/01	28.28	155.72	22.8		182		132.5		N
1470	1/5/01	28.28	155.72	22.9		155		82.1	4	Y
1479	11/8/00	27.25	162.33	23.0		148		51.5	4	Y
1480	12/10/00	25.47	154.05	23.1		151	40		4	Y
1481	12/10/00	25.67	154.05	23.8	0.0897	118	25	41.3	2	Y
1482	12/11/00	25.35	154.00	24.2	0.0822	131	30		4	Y
1483	12/10/00	26.17	154.05	24.3	0.1122	170	50	189.4		N
1487	1/7/01	28.57	154.12	24.4	0.0822	164		68.5	3	Y
1488	1/7/01	28.57	154.12	24.5	0.0794	161		81.8	5	Y
1491	1/8/01	29.40	153.95	24.5	0.0794	183		269.4	4	Y
1492	12/9/00	28.90	159.25	24.9	0.0822	169	45	57.6	6	Y
1502	1/6/01	28.12	155.75	25.0	0.1084	154		115.2	3	Y
1503	1/7/01	27.85	154.58	25.0	0.1084	100		5.05	4	Y
1505	1/7/01	27.85	154.58	25.1	0.1084	113		26.26	4	Y
1508	1/9/01	27.85	154.60	25.1	0.0741	180		143.1	4	Y
1513	1/9/01	27.85	154.60	25.1	0.1084	137		31.5	4	Y
1516	1/9/01	27.85	154.60	25.1	0.0996	176		129.9		N
1517	1/6/01	28.12	155.75	25.1	0.0996	108		23.1	2	Y
1525	11/5/00	26.32	161.50	25.1	0.0996	177		270.6		N
1527	11/5/00	26.27	161.32	25.2	0.0822	173		288.7	2	Y
1529	11/6/00	26.45	161.62	25.3	0.0657	154		118.7		N
1534	11/8/00	27.27	162.40	25.3	0.0657	163		106.7	3	Y
1536	11/8/00	27.20	162.17	25.4	0.0562	157		67.9	4	Y
1540	11/12/00	27.68	163.53	25.4	0.0562	174		73.5		N
1545	01/08/2001	29.40	153.95	25.7	0.0592	173				N
1547	04/03/2001	26.77	163.37	25.7	0.0562	188		138.5	4	Y
1548	01/03/2001	27.75	155.40		0.1698	191		158.72	4	Y
1551	04/03/2001	26.52	163.22		0.1758	102		6.44	4	Y
1552					0.1758	67		1.7		
1553	06/03/2001	26.68	163.00		0.1762	172		80.4	5	Y
1558	28/02/2001	27.98	155.83		0.1917	180		130.7	4	Y
1559	28/02/2001	28.30	155.70		0.2089	98		11.41	4	Y
1560	01/03/2001	27.83	155.43		0.2239	143		24.8	4	Y
1561	04/03/2001	26.52	163.22		0.2570	160		56.6	5	Y
1562	04/03/2001	26.67	163.30		0.2616	172		103.3		N
1564	28/02/2001	28.07	155.80		0.1380	172		116.3	4	Y
1567	01/03/2001	27.83	155.43		0.1917	78		1.55	2	Y
1576	08/03/2001	26.88	162.27		0.1917	145		30.12	4	Y
1581	08/03/2001	26.88	162.27		0.1084	165		45.8	4	Y
1583	08/03/2001	26.88	162.27		0.1084	134			4	Y
1584	07/03/2001	26.77	162.80			158		46.4		N
1585	07/03/2001	26.82	162.62			137			4	Y
1588	07/03/2001	26.77	162.80			183		74.3	4	Y

Appendix 2.

Sample no.	Date	Latitude	Longitude	SST	FLR	OFL (cm)	Wt (kg)	Total gonad wt. (g)	Stage	Duct present
1589	06/03/2001	26.78	163.12			160		75.9	5	Y
1593	05/03/2001	26.55	163.85			90		2.47	4	Y
1594	06/03/2001	26.77	163.02			188		54.5	4	Y
1595	05/03/2001	26.50	163.50			129		17.15	4	Y
1601	06/03/2001	26.83	163.00			170		120.3		N
1602	05/03/2001	26.48	163.62		0.0994	120		14.1	4	Y
1605	06/03/2001	26.83	163.00		0.1142	187		98	4	Y
1608	06/01/2001	23.10	154.90		0.0729	175	50	232.6	6	Y
1609	06/01/2001	23.45	154.90		0.0741	146	40	116.7	6	Y
1610	06/01/2001	23.48	154.92			174	60	161.5		N
1611	08/01/2001	23.45	154.90			154	55	117.5	4	Y
1622	10/03/2001	27.97	155.65		0.2018	175		110.8		N
1624	11/03/2001	28.67	155.72		0.2089	155		126.4		N
1625	11/03/2001	28.60	155.70		0.2754	186				N
1627	11/03/2001	28.37	155.77		0.1641	161		139		N
1628	12/03/2001	29.00	155.77		0.1531	156		122	2	Y
1631	12/03/2001	28.80	155.73		0.0582	177				N
1633	13/03/2001	28.95	155.77		0.0582	166		182.3		N
1634	14/03/2001	29.00	155.78		0.0582	181		291.2		N

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
21-Aug-97	inshore	0.122	0.75	170		2	2	2	77.8	50	50		
21-Aug-97	inshore	0.122	0.75	170		2	3	12	33.9	10	90		
21-Aug-97	inshore	0.120	0.75	131		3	3	6	51.9	60	30		
21-Aug-97	inshore	0.141	0.75	137		5	2	1	1085.5	100			
21-Aug-97	inshore	0.120	0.75	170		5	3	14	223.8	100			
21-Aug-97	inshore	0.120	0.75	192		2	3	2	11.4		100		
22-Aug-97	inshore	0.125	0.75	124		2	3	1	17.9	100			
21-Aug-97	inshore	0.159	0.75	178		5	2	2	1188.5	100			
22-Aug-97	inshore	0.170	0.75	175		2	2	1	97.1	100			
12-Jul-97	inshore	0.202	0.5	127		2	2	1	78.5	100			
11-Jul-97	inshore	0.195	0.5	106		5	2	2	786.6		100		
13-Jul-97	inshore	0.195	0.5	141		2	3	11	1.46	60	40		
22-Aug-97	inshore	0.232	0.75	113		2	2	3	8		100		
22-Aug-97	inshore	0.232	0.75	140		2	2	1	2.4			100	
21-Aug-97	inshore	0.244	0.75	175		2	3	3	30.5	50	50		
13-Jul-97	inshore	0.216	0.5	181		2	2	3	2047.8	100			
11-Aug-98	inshore	0.216	0.5	127	F	2	3	20	22	100			
11-Aug-98	inshore	0.224	0.5	111		2	3	1	37.4	100			
10-Aug-98	inshore	0.224	0.75	116		5	2	3	1000.3		100		
12-Aug-98	inshore	0.224	0.5	87		3	3	12	96.1	2	83	15	
29-Nov-98	inshore	0.224	0.5	167		2	3	1	23.7	100			
30-Nov-98	inshore	0.224	0.75	162		5	2	3	730	100			
30-Nov-98	inshore	0.209	0.75	142	M	2	3	1	109.9	100			
29-Nov-98	inshore	0.216	0.5	167		2	3	1	85.7	100			
29-Nov-98	inshore	0.216	0.5	158		1		0	0				
29-Nov-98	inshore	0.213	0.5	139		1		0	0				
30-Nov-98	inshore	0.213	0.75	176		2	3	1	107.8	100			
30-Nov-98	inshore	0.213	0.75	122		4	1	1	651	100			
30-Nov-98	inshore	0.209	0.75	138		2	3	1	35	100			
30-Nov-98	inshore	0.209	0.75	122		1		0	0				
30-Nov-98	inshore	0.209	0.75	136		2	1	1	115.5	100			
29-Nov-98	inshore	0.209	0.5	143		2	3	1	41.9	100			
29-Nov-98	inshore	0.209	0.5	129		1		0	0				
18-Aug-99	inshore	0.232	0.5	167	M	2		0	265	40	60		
29-Nov-98	inshore	0.232	0.5	152		1		0	0				
18-Aug-99	inshore	0.232	0.5	160	F	1		0	0				
29-Nov-98	inshore	0.232	0.5	139		2	2	1	19.4	100			
18-Aug-99	inshore	0.232	0.5	137	F	2		1	66	100			
18-Aug-99	inshore	0.232	0.5	162	M	2		1	79	100			
18-Aug-99	inshore	0.232	0.5	144	F	2		1	162	100			
18-Aug-99	inshore	0.232	0.5	180	M	1		0	0				
19-Aug-99	inshore	0.232	0.5	137	M	1		0	0				
19-Aug-99	inshore	0.232	0.5	174	M	na		1	710	100			
15-Oct-97	inshore	0.232	1	165		4	2	4	1176.5	3	97		
20-Aug-99	inshore	0.224	0.5	192	M	1		0	0				
15-Oct-97	inshore	0.224	1	145		2	2	1	94.6	100			
14-Oct-97	inshore	0.224	1	205		5	2	7	1906.8	15	85		
20-Aug-99	inshore	0.224	0.5	158	F	na		0	544	100			
20-Aug-99	inshore	0.224	0.5	181	F	na		1	740	100			
15-Oct-97	inshore	0.224	1	159		5	2	3	1939.7	92	8		
20-Aug-99	inshore	0.224	0.75	158	F	na		1	1060	100			
10-Aug-98	inshore	0.224	0.5	133		2	3	5	105.9	95	4	1	
12-Aug-98	inshore	0.224	0.5	111		2	3	1	170.7		100		
20-Aug-99	inshore	0.224	0.5	156	F	na		1	1847	100			
20-Aug-99	inshore	0.224	0.5	150	M	na		2	1525	66	34		
21-Aug-99	inshore	0.248	0.5	152	F	1		0	0				
21-Aug-99	inshore	0.248	0.5	212	F	na		1	850	100			
21-Aug-99	inshore	0.248	0.5	124	F	1		0	0				
28-Mar-99	inshore	0.248	0.75	101		2	3	2	50	90	10		
21-Aug-99	inshore	0.248	0.5	177	F	na		0	655		100		
28-Mar-99	inshore	0.248	0.75	116		2	2	1	51	100			
21-Aug-99	inshore	0.248	0.5	168	F	na		1	2330	100			
28-Mar-99	inshore	0.248	0.75	110		2	3	1	110	100			
28-Mar-99	inshore	0.248	0.75	185		1		0	0				
28-Mar-99	inshore	0.248	0.75	160		4	1	2	279	100			
28-Mar-99	inshore	0.248	0.75	130		1		0	0				
28-Mar-99	inshore	0.257	0.75	99		4	1	7	79.4				
28-Mar-99	inshore	0.257	0.75	142		5	2	1	875		100		
27-Mar-99	inshore	0.101	0.75	108		2	3	1	110	100			
27-Mar-99	inshore	0.103	0.75	170		2	3	1	150	100			
27-Mar-99	inshore	0.096	0.75	117		3	3	2	185.9	100			
29-Mar-99	inshore	0.164	0.75	217		1		0	0				
29-Mar-99	inshore	0.164	0.75	104		4	1	5	275	6	94		
29-Mar-99	inshore	0.164	0.75	152		1		0	0				
12-Aug-98	inshore	0.151	0.5	111		2	3	1	24.64	100			
15-Oct-97	inshore	0.151	1	159		5	2	2	1550	100			
16-Oct-99	inshore	0.114	0.5	127	F	5	2	1	968	100			
17-Oct-99	inshore	0.112	0.5	121	F	5	2	2	951.6	6	94		
17-Oct-99	inshore	0.108	0.5	132	F	5	2	2	1047		100		
17-Oct-99	inshore	0.108	0.5	152	M	2	3	2	141	100			
17-Oct-99	inshore	0.108	0.5	140	M	2	2	2	93.86	60	40		

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
18-Oct-99	inshore	0.116	0.5	172	F	5	2	2	1314	17	83		
18-Oct-99	inshore	0.114	0.5	110	M	2	3	1	59.8	100			
18-Oct-99	inshore	0.112	0.5	109	F	4	2	2	645	10	90		
18-Oct-99	inshore	0.112	0.5	136	F	2	3	1	162	100			
18-Oct-99	inshore	0.112	0.5	201	F	5	3	3	1900	80	20		
18-Oct-99	inshore	0.112	0.5	167	F	2	3	1	135	100			
18-Oct-99	inshore	0.112	0.5	152	M	3	3	1	559	100			
19-Oct-99	inshore	0.133	0.75	126	F	1		0	0				
19-Oct-99	inshore	0.133	0.75	143	F	1		0	0				
19-Oct-99	inshore	0.133	0.75	137	F	2	3	1	103.5	100			
19-Oct-99	inshore	0.133	0.75	198	F	2	3	1	347	100			
19-Oct-99	inshore	0.129	0.75	177	F	3	3	2	370	100			
19-Oct-99	inshore	0.129	0.75	192	M	2	3	1	128	100			
19-Oct-99	inshore	0.138	0.75	148	F	2	3	2	30	100			
16-Dec-99	inshore	0.097	0.5	175	F	1		0	0				
16-Dec-99	inshore	0.097	0.5	177	F	na		2	4154	95	5		
16-Dec-99	inshore	0.097	0.5	210	M	1		0	0				
17-Dec-99	inshore	0.097	0.75	109	M	na		1	55	100			
17-Dec-99	inshore	0.097	0.75	140	F	1		0	0				
17-Dec-99	inshore	0.097	0.75	116	F	1		0	0				
17-Dec-99	inshore	0.097	0.75	189	F	na		2	1619	45	53		
17-Dec-99	inshore	0.097	0.75	156	M	na		2	2763	71	29		
17-Dec-99	inshore	0.097	0.75	150	M	1		0	0				
17-Dec-99	inshore	0.097	0.75	205	F	na		1	889	100			
17-Dec-99	inshore	0.097	0.75	156	M	1		0	0				
17-Dec-99	inshore	0.097	0.75	166	F	na		1	1039	100			
17-Dec-99	inshore	0.097	0.75	202	F	5		1	5000	100			
18-Dec-99	inshore	0.097	0.75	150	F	1		0	0				
18-Dec-99	inshore	0.097	0.75	171	F	1		0	0				
18-Dec-99	inshore	0.097	0.75	160	F	1		0	0				
18-Dec-99	inshore	0.097	0.75	157	F	na		1	283	100			
18-Dec-99	inshore	0.097	0.75	163	M	1		0	0				
18-Dec-99	inshore	0.097	0.75	195	F	na		1	539	100			
19-Dec-99	inshore	0.097	1	209	F	1		0	0				
19-Dec-99	inshore	0.097	1	131	F	na		1	1015	100			
20-Dec-99	inshore	0.082	1	206	F	1		0	0				
20-Dec-99	inshore	0.082	1	133	F	1		0	0				
20-Dec-99	inshore	0.082	1	122	F	1		0	0				
21-Dec-99	inshore	0.082	1	179	F	na		2	1498	98	2		
12-Feb-00	offshore	0.077	0.25	123	F	na		1	80		100		
12-Feb-00	offshore	0.077	0.25	193	F	1		0	0				
12-Feb-00	offshore	0.077	0.25	116	M	na		2	312	80	20		
12-Feb-00	offshore	0.077	0.25	154	F	1		0	0				
12-Feb-00	offshore	0.079	0.25	121	F			2	266	40	60		
13-Feb-00	offshore	0.108	0.5	113	F	1		0	0				
13-Feb-00	offshore	0.108	0.5	173	M	1		0	0				
13-Feb-00	offshore	0.108	0.5	177	M	2		1	250	100			
13-Feb-00	offshore	0.108	0.5	119	M	2		0	50				
13-Feb-00	offshore	0.100	0.5	103	M	2		0	50				
13-Feb-00	offshore	0.100	0.5	157	F	1		0	0				
13-Feb-00	offshore	0.100	0.5	153	M	1		0	0				
13-Feb-00	offshore	0.100	0.5	189	M	1		0	0				
13-Feb-00	offshore	0.100	0.5	165	F	2		1	500	100			
13-Feb-00	offshore	0.082	0.5	124	M	5		1	310	100			
13-Feb-00	offshore	0.074	0.5	114	M	1		0	0				
13-Feb-00	offshore	0.074	0.5	120	F	3		1	163	94		4	
14-Feb-00	offshore	0.079	0.5	147	F	5		2	1064	79	21		
14-Feb-00	offshore	0.079	0.5	233	F	3		0	2000				
14-Feb-00	offshore	0.079	0.5	162	F	2		0	200				
14-Feb-00	offshore	0.079	0.5	230	F	1		0	0				
14-Feb-00	offshore	0.079	0.5	177	M	2		1	224	100			
14-Feb-00	offshore	0.077	0.5	213	F	1		0	0				
14-Feb-00	offshore	0.077	0.5	134	F	1		0	0				
14-Feb-00	offshore	0.077	0.5	147	M	2		1	30		100		
14-Feb-00	offshore	0.077	0.5	134	F	4		2	312	90	10		
14-Feb-00	offshore	0.077	0.5	165	M	1		0	0				
14-Feb-00	offshore	0.074	0.5	162	M	1		0	0				
14-Feb-00	offshore	0.079	0.5	142	M	3		1	204	100			
14-Feb-00	offshore	0.075	0.5	109	M	1		0	0				
16-Feb-00	offshore	0.090	0.75	100	F	1		0	0				
16-Feb-00	offshore	0.090	0.75	150	M	5		1	440	100			
16-Feb-00	offshore	0.088	0.75	106	M	1		0	0				
16-Feb-00	offshore	0.088	0.75	196	F	1		0	0				
16-Feb-00	offshore	0.085	0.75	141	F	2		1	184	100			
16-Feb-00	offshore	0.085	0.75	134	F	2		1	200	100			
16-Feb-00	offshore	0.082	0.75	197	F	4		2	914	90	10		
16-Feb-00	offshore	0.082	0.75	210	F	5		1	2775	100			
16-Feb-00	offshore	0.079	0.75	232	F	2		1	207	100			
16-Feb-00	offshore	0.079	0.75	141	F	2		0	200				
16-Feb-00	offshore	0.079	0.75	100	M	2		0	100				
16-Feb-00	offshore	0.079	0.75	170	F	1		0	0				

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
17-Feb-00	offshore	0.082	1	165	M	5		2	2801	70	30		
17-Feb-00	offshore	0.082	1	122	F	1		0	0				
17-Feb-00	offshore	0.077	1	125	F	3		1	228		100		
17-Feb-00	offshore	0.077	1	102	M	1		0	0				
17-Feb-00	offshore	0.082	1	118	F	2		1	80		100		
17-Feb-00	offshore	0.082	1	116	M	1		0	0				
17-Feb-00	offshore	0.082	1	104	M	2		1	56		100		
17-Feb-00	offshore	0.082	1	107	M	2		1	113		100		
17-Feb-00	offshore	0.079	1	127	F	1		0	0				
18-Feb-00	offshore	0.082	1	190	F	1		0	0				
18-Feb-00	offshore	0.079	1	109	F	1		0	0				
18-Feb-00	offshore	0.079	1	101	M	5		2	467	73	23		
18-Feb-00	offshore	0.079	1	149	F	2		1	189	87	13		
18-Feb-00	offshore	0.079	1	219	F	2		1	284	100			
18-Feb-00	offshore	0.077	1	160	F	5		2	1550				
18-Feb-00	offshore	0.077	1	161	M	2		1	282	100			
19-Feb-00	offshore	0.079	1	176	F	2		2	411	50	50		
19-Feb-00	offshore	0.077	1	119	M	2		1	95	100			
19-Feb-00	offshore	0.078	1	130	F	2		1	813	100			
19-Feb-00	offshore	0.078	1	171	M	1		0	0				
19-Feb-00	offshore	0.077	1	177	F	5		2	2694	90	10		
19-Feb-00	offshore	0.081	1	180	F	4		0	1460				
19-Feb-00	offshore	0.077	1	167	M	1		0	0				
19-Feb-00	offshore	0.077	1	147	F	5		0	30	100			
20-Feb-00	offshore	0.088	1	162	M	1		0	0				
20-Feb-00	offshore	0.074	1	170	F	5		2	1550				
20-Feb-00	offshore	0.074	1	142	M	3		1	292	100			
20-Feb-00	offshore	0.074	1	190	F	1		0	0				
20-Feb-00	offshore	0.074	1	100	F	1		0	0				
20-Feb-00	offshore	0.074	1	131	F	2		0	100				
20-Feb-00	offshore	0.072	1	103	F	1		0	0				
20-Feb-00	offshore	0.074	1	146	F	5		1	806	100			
20-Feb-00	offshore	0.072	1	152	F	1		0	0				
21-Feb-00	offshore	0.085	1	117	M	2		1	69		100		
21-Feb-00	offshore	0.082	1	152	M	1		0	0				
21-Feb-00	offshore	0.085	1	161	F	1		0	0				
21-Feb-00	offshore	0.088	1	184	M	1		0	0				
21-Feb-00	offshore	0.088	1	152	M	1		0	0				
21-Feb-00	offshore	0.082	1	141	F	5		0	806				
21-Feb-00	offshore	0.085	1	218	F	2		2	284				
21-Feb-00	offshore	0.085	1	146	F	3		2	292				
21-Feb-00	offshore	0.085	1	131	F	2		1	100		100		
21-Feb-00	offshore	0.078	1	207	M	3		2	1027				
21-Feb-00	offshore	0.078	1	157	F	3		2	560				
21-Feb-00	offshore	0.078	1	145	F	3		0	292				
21-Feb-00	offshore	0.078	1	197	F	5		0	4057				
21-Feb-00	offshore	0.074	1	171	F	2		1	171		100		
21-Feb-00	offshore	0.074	1	161	F	1		0	0				
22-Feb-00	offshore	0.085	1	102	F	2		1	59		100		
22-Feb-00	offshore	0.088	1	106	F	1		0	0				
22-Feb-00	offshore	0.085	1	99	F	2		1	69		100		
22-Feb-00	offshore	0.088	1	212	F	4		1	3150	100			
22-Feb-00	offshore	0.088	1	157	M	1		0	0				
22-Feb-00	offshore	0.088	1	161	F	4		1	2601	100			
22-Feb-00	offshore	0.082	1	172	M	3		0	480				
22-Feb-00	offshore	0.078	1	181	F	3		2	977	50	50		
22-Feb-00	offshore	0.085	1	153	F	4		1	639	100			
22-Feb-00	offshore	0.078	1	108	M	2		1	140		100		
22-Feb-00	offshore	0.078	1	141	F	2		0	62				
22-Feb-00	offshore	0.074	1	142	F	1		0	0				
23-Feb-00	offshore	0.088	0.75	194	F	1		0	0				
23-Feb-00	offshore	0.082	0.75	141	F	1		0	0				
23-Feb-00	offshore	0.082	0.75	104	M	1		0	0				
24-Feb-00	offshore	0.074	0.75	222	F	1		0	0				
24-Feb-00	offshore	0.074	0.75	106	F	1		0	0				
24-Feb-00	offshore	0.074	0.75	194	M	2		1	598	100			
24-Feb-00	offshore	0.074	0.75	220	F	2		1	284		100		
13-Sep-00	offshore	0.216	1	123	F	3	1	2	196.7	95	5		
11-Sep-00	offshore	0.118	1	202	F	1		0	0				
10-Sep-00	offshore	0.209	0.75	176	F	5	2	3	2339.1	100			
08-Sep-00	offshore	0.240	0.75	101	F	4	2	1	348.8	100			
07-Sep-00	offshore	0.232	0.5	183	M	1		0	0				
08-Sep-00	offshore	0.240	0.75	117	F	2	2	1	58.8	100			
08-Sep-00	offshore	0.240	0.75	133	M	1		0	0				
10-Sep-00	offshore	0.209	0.75	134	M	1		0	0				
10-Sep-00	offshore	0.209	0.75	182	M	1		0	0				
10-Sep-00	offshore	0.209	0.75	109	F	1		0	0				
10-Sep-00	offshore	0.209	0.75	135	M	1		0	0				
10-Sep-00	offshore	0.209	0.75	150	F	1		0	0				
11-Sep-00	offshore	0.205	1	154	F	1		0	0				
11-Sep-00	offshore	0.205	1	136	F	2	2	1	221.1	100			

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
11-Sep-00	offshore	0.205	1	138	F	1		0	0				
11-Sep-00	offshore	0.205	1	131	F	1		0	0				
11-Sep-00	offshore	0.205	1	172	M	3	2	2	703.2	95	5		
11-Sep-00	offshore	0.205	1	184	M	2	3	1	160.7		100		
11-Sep-00	offshore	0.205	1	108	F	1		0	0				
13-Sep-00	offshore	0.188	1	190	F	1		0	0				
11-Sep-00	offshore	0.205	1	148	F	1		0	0				
13-Sep-00	offshore	0.188	1	110	M	3	2	1	206.5	100			
13-Sep-00	offshore	0.188	1	140	F	3	2	2	357.9	8	92		
13-Sep-00	offshore	0.188	1	156	F	2	2	2	203.5	40	60		
13-Sep-00	offshore	0.188	1	187	M	1		0	0				
13-Sep-00	offshore	0.188	1	155	F	1		0	0				
13-Sep-00	offshore	0.188	1	113	M	1		0	0				
13-Sep-00	offshore	0.188	1	127	M	1		0	0				
13-Sep-00	offshore	0.188	1	108	F	3	2	1	203.6	100			
13-Sep-00	offshore	0.188	1	165	F	2	2	2	149.2	95	5		
13-Sep-00	offshore	0.188	1	109	M	1		0	0				
14-Sep-00	offshore	0.164	1	190	F	3	2	2	2586.2	99	1		
13-Sep-00	offshore	0.188	1	164	F	1		0	0				
14-Sep-00	offshore	0.164	1	125	F	1		0	0				
14-Sep-00	offshore	0.164	1	156	F	1		0	0				
14-Sep-00	offshore	0.164	1	157	F	2	2	3	897.6	98	2		
14-Sep-00	offshore	0.164	1	98	F	1		0	0				
14-Sep-00	offshore	0.164	1	120	F	2		1	69	100			
14-Sep-00	offshore	0.164	1	126	M	2		1	69	100			
14-Sep-00	offshore	0.164	1	182	M	2	3	0	284				
16-Sep-00	offshore	0.170	0.75	193	F	1		0	0				
16-Sep-00	offshore	0.170	0.75	170	F	2		2	254				
11-Aug-98	inshore	0.170	0.5	112		4	2	3	531	8	92		
16-Sep-00	offshore	0.170	0.75	124	F	2		1	69		100		
16-Sep-00	offshore	0.159	0.75	232	F	3	2	2	1027	100			
16-Sep-00	offshore	0.159	0.75	195	M	2	3	1	284	100			
16-Sep-00	offshore	0.159	0.75	120	F	2	3	1	69	100			
16-Sep-00	offshore	0.159	0.75	132	F	1		0	0				
16-Sep-00	offshore	0.159	0.75	144	F	1		0	0				
16-Sep-00	offshore	0.170	0.75	176	F	4		9	1460	20	80		
16-Sep-00	offshore	0.159	0.75	198	F	1		0	0				
17-Sep-00	offshore	0.167	0.75	101	F	1		0	0				
17-Sep-00	offshore	0.167	0.75	184	F	2		1	284	100			
17-Sep-00	offshore	0.167	0.75	124	M	2		2	69	5	95		
17-Sep-00	offshore	0.167	0.75	120	F	2		1	69			100	
17-Sep-00	offshore	0.167	0.75	168	M	2		1	254	100			
17-Sep-00	offshore	0.167	0.75	162	F	1		0	0				
17-Sep-00	offshore	0.167	0.75	148	F	2		3	100				
17-Sep-00	offshore	0.167	0.75	116	F	2		1	69		100		
17-Sep-00	offshore	0.167	0.75	149	F	1		0	0				
17-Sep-00	offshore	0.167	0.75	187	M	3		1	1000	100			
17-Sep-00	offshore	0.167	0.75	178	F	3		3	750				
17-Sep-00	offshore	0.167	0.75	180	M	2	3	3	284	100			
18-Sep-00	offshore	0.170	0.75	177	M	1		0	0				
17-Sep-00	offshore	0.167	0.75	150	M	2		12	100	80			20
18-Sep-00	offshore	0.164	0.75	111	F	1		0	0				
18-Sep-00	offshore	0.170	0.75	133	F	3	1	1	292	100			
18-Sep-00	offshore	0.170	0.75	191	M	1		0	0				
18-Sep-00	offshore	0.170	0.75	173	F	1		0	0				
18-Sep-00	offshore	0.170	0.75	104	F	1		0	0				
18-Sep-00	offshore	0.170	0.75	149	F	3		6	292				
18-Sep-00	offshore	0.170	0.75	157	M	1		0	0				
18-Sep-00	offshore	0.170	0.75	122	F	2		1	69		100		
18-Sep-00	offshore	0.170	0.75	141	F	1		0	0				
18-Sep-00	offshore	0.170	0.75	181	F	1		0	0				
18-Sep-00	offshore	0.170	0.75	131	M	1		0	0				
18-Sep-00	offshore	0.170	0.75	105	M	1		0	0				
07-Sep-00	offshore	0.216	0.5	123	F	1		0	0				
07-Sep-00	offshore	0.216	0.5	178	M	1		0	0				
07-Sep-00	offshore	0.224	0.5	157	F	1		0	0				
07-Sep-00	offshore	0.224	0.5	119	F	1		0	0				
07-Sep-00	offshore	0.224	0.5	88	F	1		0	0				
07-Sep-00	offshore	0.224	0.5	174	M	1		0	0				
07-Sep-00	offshore	0.224	0.5	116	M	1		0	0				
08-Sep-00	offshore	0.240	0.75	180	F	1		0	0				
08-Sep-00	offshore	0.240	0.75	176	F	1		0	0				
08-Sep-00	offshore	0.240	0.75	117	F	1		0	0				
08-Sep-00	offshore	0.240	0.75	121	F	1		0	0				
15-Sep-00	offshore	0.164	1	178	F	3		6	1027				
15-Sep-00	offshore	0.164	1	166	M	2	3	1	254	100			
15-Sep-00	offshore	0.164	1	138	F	1		0	0				
15-Sep-00	offshore	0.164	1	201	F	1		0	0				
15-Sep-00	offshore	0.164	1	140	F	1		0	0				
15-Sep-00	offshore	0.164	1	183	F	2	2	3	995.3	20	80		
12-Sep-00	offshore	0.202	1	172	F	2	2	3	1210.9	94	6		

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
14-Sep-00	offshore	0.164	1	179	F	2	2	1	51.1		100		
12-Sep-00	offshore	0.202	1	182	F	5	2	5	2449.6	37	63		
12-Sep-00	offshore	0.202	1	132	F	2	2	3	152.14	98		1	1
12-Sep-00	offshore	0.202	1	100	F	1		0	0				
12-Sep-00	offshore	0.202	1	111	F	1		0	0				
12-Sep-00	offshore	0.202	1	127	F	1		0	0				
12-Sep-00	offshore	0.202	1	209	F	1		0	0				
12-Sep-00	offshore	0.202	1	146	F	3	2	4	1326.5	10	90		
14-Sep-00	offshore	0.164	1	114	M	3		1	175	100			
14-Sep-00	offshore	0.164	1	147	M	3	2	1	480.5	100			
14-Sep-00	offshore	0.164	1	136	F	2	2	9	110.9	100			
14-Sep-00	offshore	0.164	1	113	F	1		0	0				
14-Sep-00	offshore	0.164	1	149	F	1		0	0				
14-Sep-00	offshore	0.164	1	270	F	5	2	8	11517	100			
14-Sep-00	offshore	0.164	1	211	F	5	2	8	8860	100			
04-Dec-00	inshore	0.141	0.5	165	M	1		0	0				
07-Dec-00	inshore	0.159	0.75	110	M	1		0	0				
07-Dec-00	inshore	0.159	0.75	173	M	1		0	0				
07-Dec-00	inshore	0.159	0.75	101	M	1		0	0				
08-Dec-00	inshore	0.156	0.75	111	M	1		0	0				
08-Dec-00	inshore	0.156	0.75	102	M	1		0	0				
08-Dec-00	inshore	0.156	0.75	110	F	1		0	0				
08-Dec-00	inshore	0.156	0.75	138	F	1		0	0				
08-Dec-00	inshore	0.156	0.75	175	M	1		0	0				
08-Dec-00	inshore	0.156	0.75	126	M	5		1	806	100			
08-Dec-00	inshore	0.156	0.75	226	F	1		0	0				
08-Dec-00	inshore	0.156	0.75	213	F	2	2	1	252.9	100			
05-Jan-01	inshore	0.094	0.75	123	M	1		0	0				
05-Jan-01	inshore	0.094	0.75	123	F	1		0	0				
06-Jan-01	inshore	0.133	0.75	132	F	1		0	0				
06-Jan-01	inshore	0.133	0.75	91	M	1		0	0				
05-Jan-01	inshore	0.094	0.75	88	F	1		0	0				
05-Jan-01	inshore	0.094	0.75	177	F	2	2	1	1216.2	100			
06-Jan-01	inshore	0.133	0.75	112	M	1		0	0				
06-Jan-01	inshore	0.133	0.75	87	F	1		0	0				
06-Jan-01	inshore	0.133	0.75	82	M	1		0	0				
07-Jan-01	inshore	0.125	1	101	M	1		0	0				
07-Jan-01	inshore	0.125	1	164	M	1		0	0				
07-Jan-01	inshore	0.125	1	161	M	1		0	0				
07-Jan-01	inshore	0.103	1	157	F	1		0	0				
08-Jan-01	inshore	0.107	1	116	F	1		0	0				
08-Jan-01	inshore	0.107	1	183	M	1		0	0				
07-Jan-01	inshore	0.125	1	174	F	1		0	0				
01-Jan-01	inshore	0.125	0.25	113	M	2	2	1	18		100		
07-Jan-01	inshore	0.125	1	73	F	2	1	1	63.5	100			
08-Jan-01	inshore	0.148	1	242	F	1		0	0				
08-Jan-01	inshore	0.107	1	197	F	1		0	0				
08-Jan-01	inshore	0.107	1	189	F	1		0	0				
08-Jan-01	inshore	0.107	1	173	M	1		0	0				
01-Mar-01	inshore	0.066	0.25	110		3	1	2	278.1		100		
08-Mar-01	offshore	0.061	1	138	F	2	2	2	198.6		100		
08-Mar-01	offshore	0.058	1	165		2	3	2	162.8		100		
05-Mar-01	offshore	0.065	0.5	128	F	2	2	1	77.9		100		
01-May-99	inshore	0.123	1	182		2	3	1	258	100			
01-May-99	inshore	0.123	1	142		1		0	0				
18-Aug-99	inshore	0.230	0.5	113	F	1		0	0				
24-Jul-99	inshore	0.221	0.75	200	M	2	3	1	115	100			
24-Jul-99	inshore	0.221	0.75	170		5	3	3	1952	100			
12-Feb-00	offshore	0.077	0.25	120	M			1	61		100		
01-Aug-99	inshore	0.214	0.5	227	F	2	3	1	327	100			
17-Feb-00	offshore	0.081	1	165	F	2		1	388	100			
18-Feb-00	offshore	0.079	1	140		5		1	806	100			
20-Feb-00	offshore	0.077	1	146		5		0	806				
21-Feb-00	offshore	0.082	1	118		2		1	69		100		
21-Aug-97	inshore	0.237	0.75	180		1		0	0				
11-Aug-98	inshore	0.289	0.5	163		2	3	1	42	100			
30-Nov-98	inshore	0.102	0.75	136		2	2	1	78.6	100			
28-Mar-99	inshore	0.129	0.75	144		4	2	2	650	77	23		
01-May-99	inshore	0.123	1	151		2	3	2	192	100			
28-Feb-01	inshore	0.087	0.255	97	F	1		0	0				
28-Feb-01	inshore	0.087	0.255	135	F	2		0	100	100			
28-Feb-01	inshore	0.087	0.255	160	F	4		0	1460	75	25		
28-Feb-01	inshore	0.087	0.255	172	M	1		0	0				
01-Mar-01	inshore	0.064	0.25	136	F	4		0	556	100			
01-Mar-01	inshore	0.064	0.25	143	M	1		0	0				
01-Mar-01	inshore	0.064	0.25	191	M	3	2	1	1540.4	100			
04-Mar-01	offshore	0.057	0.5	134	F	4	f	0	556	50	50		
04-Mar-01	offshore	0.057	0.5	165	M	1		0	0				
04-Mar-01	offshore	0.057	0.5	169	F	5	f	0	1550		100		
04-Mar-01	offshore	0.057	0.5	172	M	3	d	0	560	50	50		
04-Mar-01	offshore	0.057	0.5	199	F	5	f	1	4057		100		

Appendix 3.

Date caught	Area	FLR	Moon phase	OFL (cm)	Sex	Fullness 1-5	Digest. Stage	No. prey items	Stomach mass (g)	Squid %	Fish %	Crust. %	Other%
05-Mar-01	offshore	0.064	0.5	90	J	3	f	1	20		100		
05-Mar-01	offshore	0.064	0.5	129	M	5	f	1	1200		100		
05-Mar-01	offshore	0.064	0.5	145	F	4	f	1	1200		100		
07-Mar-01	offshore	0.059	0.75	137	M	3		0	292		100		
07-Mar-01	offshore	0.059	0.75	183	M	1		0	0				
07-Mar-01	offshore	0.059	0.75	216	F	1		0	0				

Appendix 4: Distributional data from which fine scale comparisons were made between broadbill swordfish (*X. gladius*) catch and environmental variables (hooks, number of hooks from which swordfish [BBL] were caught; SST, sea surface temperature in ºC; SSS, sea surface salinity in ppt; SSF, sea surface fluorescence in µg l^{-1}, moon stage [1=new, 4=full])

Date	Hooks	BBL	SST	SSS	SSF	Moon	Lat	Long	Wind (knots)
11/07/1997	253	1	22.28	35.54	0.17	2	26.36	154.19	15
11/07/1997	253	1	22.22	35.59	0.35	2	26.36	154.19	15
11/07/1997	253	1	22.17	35.63	0.31	2	26.36	154.19	15
11/07/1997	190	3	22.00	35.65	0.26	2	26.36	154.19	15
12/07/1997	286	0	21.84	35.73	0.21	2	26.42	154.32	10
12/07/1997	214	1	21.82	35.74	0.22	2	26.42	154.32	10
13/07/1997	271	0	21.58	35.61	0.36	2	27.07	155.18	10
13/07/1997	271	2	21.63	35.65	0.26	2	27.07	155.18	10
13/07/1997	271	2	21.65	35.70	0.23	2	27.07	155.18	10
13/07/1997	271	0	21.64	35.74	0.28	2	27.07	155.18	10
13/07/1997	66	0	21.61	35.75	0.30	2	27.07	155.18	10
21/08/1997	200	4	21.33	35.64	0.14	3	26.04	155.01	15
21/08/1997	200	5	20.94	35.70	0.11	3	26.04	155.01	15
21/08/1997	200	2	20.96	35.72	0.11	3	26.04	155.01	15
21/08/1997	200	3	21.05	35.72	0.11	3	26.04	155.01	15
21/08/1997	100	1	21.06	35.72	0.17	3	26.04	155.01	15
23/08/1997	160	2	21.83	35.54	0.08	4	25.48	154.55	15
23/08/1997	160	7	21.98	35.55	0.08	4	25.48	154.55	15
23/08/1997	160	3	22.05	35.59	0.13	4	25.48	154.55	15
23/08/1997	160	6	21.58	35.64	0.19	4	25.48	154.55	15
23/08/1997	160	4	21.25	35.65	0.20	4	25.48	154.55	15
18/11/1997	318	1	25.60	35.12	0.02	3	25.5	154.41	5
18/11/1997	318	5	25.70	35.25	0.00	3	25.5	154.41	5
18/11/1997	318	4	25.80	35.19	0.00	3	25.5	154.41	5
18/11/1997	46	0	25.81	35.35	0.00	3	25.5	154.41	5
19/11/1997	310	1	25.72	35.46	0.01	3	25.48	154.37	10
19/11/1997	310	4	25.73	35.41	0.00	3	25.48	154.37	10
19/11/1997	310	2	25.72	35.49	0.00	3	25.48	154.37	10
19/11/1997	70	0	25.76	35.45	-0.01	3	25.48	154.37	10
13/09/1997	200	0	20.28	35.59	0.45	2	33.24	153.04	5
13/09/1997	200	0	19.38	35.58	1.03	2	33.24	153.04	5
13/09/1997	200	0	19.66	35.58	0.94	2	33.24	153.04	5
13/09/1997	200	0	19.99	35.58	0.45	2	33.24	153.04	5
13/09/1997	200	0	20.51	35.56	0.26	2	33.24	153.04	5
14/09/1997	222	0	21.31	35.54	0.10	3	33.23	153.16	5
14/09/1997	222	0	20.00	35.57	0.34	3	33.23	153.16	5
14/09/1997	222	0	19.83	35.58	0.42	3	33.23	153.16	5
14/09/1997	134	0	19.58	35.60	0.50	3	33.23	153.16	5
5/11/1997	288	0	23.14	35.38	0.04	2	28.48	154.18	12
5/11/1997	288	0	23.12	35.39	0.06	2	28.48	154.18	12
5/11/1997	174	0	23.09	35.39	0.08	2	28.48	154.18	12
7/11/1997	337	0	21.87	35.19	0.14	2	33.26	152.18	5
7/11/1997	213	0	21.69	35.28	0.13	2	33.26	152.18	5
15/10/1997	273	3	21.93	35.65	-0.03	4	25.6	151.30	5
15/10/1997	273	5	21.98	35.71	-0.05	4	25.6	151.30	5
15/10/1997	273	6	22.24	35.71	-0.06	4	25.6	151.30	5
15/10/1997	120	6	22.39	35.70	-0.06	4	25.6	151.30	5
16/10/1997	295	5	22.16	35.67	0.02	1	25.33	154.37	10
16/10/1997	295	1	22.25	35.67	0.00	1	25.33	154.37	10
16/10/1997	295	2	22.27	35.64	0.00	1	25.33	154.37	10
16/10/1997	115	1	22.26	35.70	-0.01	1	25.33	154.37	10
17/10/1997	295	1	22.51	35.59	0.01	1	25.43	155.06	10
17/10/1997	295	2	22.59	35.60	-0.01	1	25.43	155.06	10
17/10/1997	295	6	22.61	35.65	-0.01	1	25.43	155.06	10
17/10/1997	115	4	22.60	35.65	-0.01	1	25.43	155.06	10
14/02/1998	227	1	28.44	35.05	-0.02	3	25.24	154.05	5
14/02/1998	227	2	28.84	35.13	-0.04	3	25.24	154.05	5

Appendix 4.

Date	Hooks	BBL	SST	SSS	SSF	Moon	Lat	Long	Wind (knots)
14/02/1998	227	1	29.01	35.20	-0.04	3	25.24	154.05	5
14/02/1998	227	3	28.96	35.23	-0.04	3	25.24	154.05	5
14/02/1998	92	1	28.93	35.23	-0.03	3	25.24	154.05	5
15/02/1998	260	3	28.53	35.04	-0.01	3	25.08	154.07	8
15/02/1998	260	1	28.62	35.07	-0.03	3	25.08	154.07	8
15/02/1998	260	1	28.72	35.14	-0.03	3	25.08	154.07	8
15/02/1998	220	2	28.91	35.17	-0.03	3	25.08	154.07	8
16/02/1998	220	1	28.81	35.11	-0.02	4	25.18	154.13	5
16/02/1998	220	2	29.60	35.19	-0.03	4	25.18	154.13	5
16/02/1998	220	1	30.04	35.18	-0.04	4	25.18	154.13	5
16/02/1998	220	2	31.07	35.28	-0.04	4	25.18	154.13	5
16/02/1998	120	1	30.35	35.22	-0.04	4	25.18	154.13	5
17/02/1998	289	1	28.81	35.09	-0.02	4	25.05	154.10	2
17/02/1998	289	1	28.88	35.02	-0.03	4	25.05	154.10	2
17/02/1998	289	3	29.09	34.97	-0.04	4	25.05	154.10	2
17/02/1998	133	1	28.94	35.03	-0.04	4	25.05	154.10	2
9/06/1998	251	0	23.01	35.71	0.11	3	26.46	155.08	6
9/06/1998	251	3	23.14	35.80	0.09	3	26.46	155.08	6
9/06/1998	251	5	23.07	35.78	0.08	3	26.46	155.08	6
9/06/1998	47	0	23.06	35.81	0.08	3	26.46	155.08	6
10/06/1998	200	1	23.09	35.79	0.09	3	26.53	155.07	18
10/06/1998	200	0	23.09	35.82	0.08	3	26.53	155.07	18
10/06/1998	200	2	22.96	35.82	0.08	3	26.53	155.07	18
10/06/1998	200	3	23.22	35.82	0.10	3	26.53	155.07	18
5/11/1998	321	5	23.28	35.34	0.23	3	25.06	154.23	5
5/11/1998	321	2	23.27	35.56	0.20	3	25.06	154.23	5
5/11/1998	308	0	23.76	35.54	0.19	3	25.06	154.23	5
6/11/1998	265	4	24.45	35.46	0.21	3	24.52	154.23	5
6/11/1998	265	2	24.49	35.49	0.18	3	24.52	154.23	5
6/11/1998	265	1	24.45	35.58	0.17	3	24.52	154.23	5
6/11/1998	155	1	23.80	35.73	0.24	3	24.52	154.23	5
7/11/1998	280	1	24.16	35.66	0.25	3	25.09	154.15	5
7/11/1998	280	0	23.60	35.50	0.28	3	25.09	154.15	5
7/11/1998	280	1	23.57	35.49	0.23	3	25.09	154.15	5
7/11/1998	110	0	23.82	35.49	0.22	3	25.09	154.15	5
8/11/1998	224	3	24.30	35.62	0.20	4	25.25	154.40	5
8/11/1998	224	4	24.82	35.61	0.17	4	25.25	154.40	5
8/11/1998	224	2	24.99	35.54	0.16	4	25.25	154.40	5
8/11/1998	41	0	25.10	35.65	0.15	4	25.25	154.40	5
9/11/1998	120	3	25.10	35.64	0.19	4	25.27	155.01	2
9/11/1998	120	0	24.76	35.60	0.18	4	25.27	155.01	2
9/11/1998	120	0	24.86	35.66	0.16	4	25.27	155.01	2
9/11/1998	87	3	24.95	35.64	0.14	4	25.27	155.01	2
10/08/1998	225	0	22.13	35.68	0.49	3	26.21	154.01	20
10/08/1998	225	4	22.22	35.65	0.54	3	26.21	154.01	20
10/08/1998	225	2	22.35	35.64	0.44	3	26.21	154.01	20
10/08/1998	225	0	22.43	35.65	0.37	3	26.21	154.01	20
12/08/1998	240	1	22.70	35.51	0.21	4	25.37	154.04	1
12/08/1998	240	2	22.98	35.39	0.17	4	25.37	154.04	1
12/08/1998	240	1	23.05	35.57	0.17	4	25.37	154.04	1
12/08/1998	180	0	23.16	35.54	0.22	4	25.37	154.04	1
10/02/1998	360	0	24.42	35.66	0.12	3	36.17	150.45	10
10/02/1998	360	0	24.96	35.58	0.10	3	36.17	150.45	10
10/02/1998	230	0	25.45	35.57	0.08	3	36.17	150.45	10
11/02/1998	334	0	23.86	35.71	0.12	3	36.2	150.28	10
11/02/1998	334	0	23.32	35.73	0.11	3	36.2	150.28	10
11/02/1998	282	0	23.49	35.73	0.08	3	36.2	150.28	10
29/11/1998	260	2	23.16	35.69	0.21	2	26.57	155.07	10
29/11/1998	260	4	22.93	35.75	0.16	2	26.57	155.07	10
29/11/1998	260	1	22.91	35.76	0.15	2	26.57	155.07	10
29/11/1998	220	1	22.95	35.77	0.15	2	26.57	155.07	10
30/11/1998	198	4	25.72	35.33	0.20	2	26.04	155.03	20
30/11/1998	198	0	25.72	35.59	0.14	2	26.04	155.03	20

Appendix 4.

Date	Hooks	BBL	SST	SSS	SSF	Moon	Lat	Long	Wind (knots)
30/11/1998	198	6	25.69	35.61	0.14	2	26.04	155.03	20
30/11/1998	198	1	25.18	35.57	0.14	2	26.04	155.03	20
30/11/1998	158	0	25.21	35.70	0.12	2	26.04	155.03	20
27/03/1998	257	2	25.78	35.51	0.61	2	26.14	154.40	15
27/03/1998	257	3	25.92	35.59	0.60	2	26.14	154.40	15
27/03/1998	257	0	26.02	35.61	0.62	2	26.14	154.40	15
27/03/1998	257	3	26.11	35.59	0.64	2	26.14	154.40	15
27/03/1998	72	0	26.15	35.59	0.64	2	26.14	154.40	15
28/03/1998	203	4	26.04	35.48	0.58	2	26.09	154.45	10
28/03/1998	203	5	25.83	35.65	0.59	2	26.09	154.45	10
28/03/1998	203	2	25.99	35.66	0.61	2	26.09	154.45	10
28/03/1998	203	1	26.17	35.79	0.62	2	26.09	154.45	10
28/03/1998	203	4	26.17	35.78	0.62	2	26.09	154.45	10
28/03/1998	85	1	26.11	35.77	0.59	2	26.09	154.45	10
29/03/1998	214	3	25.82	35.64	0.58	3	26.53	154.35	20
29/03/1998	214	0	25.73	35.74	0.57	3	26.53	154.35	20
29/03/1998	214	1	25.81	35.67	0.58	3	26.53	154.35	20
29/03/1998	214	2	25.98	35.65	0.61	3	26.53	154.35	20
29/03/1998	44	0	25.83	35.72	0.61	3	26.53	154.35	20
18/08/1999	299	2	21.70	35.73	0.08	2	25.25	157.01	10
18/08/1999	296	3	21.68	35.75	0.06	2	25.25	157.01	10
18/08/1999	299	2	21.85	35.72	0.02	2	25.25	157.01	10
18/08/1999	149	1	21.71	35.76	0.07	2	25.25	157.01	10
19/08/1999	335	1	22.35	35.69	0.05	2	24.48	157.10	5
19/08/1999	335	1	22.26	35.68	0.03	2	24.48	157.10	5
19/08/1999	335	0	22.18	35.73	0.06	2	24.48	157.10	5
20/08/1999	315	4	21.57	35.75	0.09	2	25.54	158.02	5
20/08/1999	315	2	21.71	35.76	0.03	2	25.54	158.02	5
20/08/1999	313	1	21.75	35.77	0.10	2	25.54	158.02	5
20/08/1999	139	0	21.78	35.78	0.15	2	25.54	158.02	5
21/08/1999	283	3	21.11	35.80	0.08	2	26.16	157.35	5
21/08/1999	281	5	21.77	35.78	0.03	2	26.16	157.35	5
21/08/1999	281	0	21.74	35.78	0.10	2	26.16	157.35	5
21/08/1999	267	3	21.90	35.77	0.14	2	26.16	157.35	5
22/08/1999	402	2	21.17	35.81	0.06	2	26.14	158.02	1
22/08/1999	402	1	21.28	35.79	0.08	2	26.14	158.02	1
22/08/1999	295	0	21.25	35.80	0.10	2	26.14	158.02	1
16/10/1999	323	1	22.54	35.61	-0.01	2	26.19	154.56	5
16/10/1999	323	1	22.64	35.66	-0.01	2	26.19	154.56	5
16/10/1999	323	0	22.66	35.69	-0.01	2	26.19	154.56	5
16/10/1999	118	0	22.57	35.71	0.00	2	26.19	154.56	5
17/10/1999	309	3	22.70	35.59	-0.01	2	27.09	155.00	5
17/10/1999	309	3	22.81	35.72	0.00	2	27.09	155.00	5
17/10/1999	309	0	22.99	35.73	0.01	2	27.09	155.00	5
17/10/1999	147	1	23.89	35.73	0.02	2	27.09	155.00	5
18/10/1999	334	1	22.88	35.65	-0.02	2	27.21	155.05	10
18/10/1999	334	4	23.27	35.62	-0.02	2	27.21	155.05	10
18/10/1999	334	3	23.52	35.62	-0.02	2	27.21	155.05	10
18/10/1999	97	1	23.72	35.63	-0.02	2	27.21	155.05	10
19/10/1999	302	3	21.50	35.70	-0.01	2	27.41	155.52	5
19/10/1999	302	3	22.53	35.59	-0.01	2	27.41	155.52	5
19/10/1999	302	2	22.48	35.62	-0.01	2	27.41	155.52	5
19/10/1999	209	0	22.76	35.57	-0.01	2	27.41	155.52	5
20/10/1999	324	4	22.02	35.56	0.01	2	27.41	155.52	12
20/10/1999	324	3	22.24	35.57	0.00	2	27.41	155.52	12
20/10/1999	324	3	21.69	35.52	0.00	2	27.41	155.52	12
20/10/1999	302	1	21.84	35.58	0.01	2	27.41	155.52	12
21/10/1999	234	4	21.66	35.65	0.04	2	28.01	155.52	10
21/10/1999	234	3	21.67	35.64	0.04	2	28.01	155.52	10
21/10/1999	234	5	21.65	35.66	0.04	2	28.01	155.52	10
21/10/1999	234	5	21.60	35.63	0.01	2	28.01	155.52	10
21/10/1999	232	7	22.17	35.62	0.01	2	28.01	155.52	10
22/10/1999	261	7	21.67	35.69	-0.01	3	28.05	155.51	2

Appendix 4.

Date	Hooks	BBL	SST	SSS	SSF	Moon	Lat	Long	Wind (knots)
22/10/1999	261	3	21.66	35.71	-0.01	3	28.05	155.51	2
22/10/1999	261	3	21.72	35.72	-0.01	3	28.05	155.51	2
22/10/1999	261	2	21.88	35.66	0.02	3	28.05	155.51	2
22/10/1999	215	2	21.90	35.66	0.04	3	28.05	155.51	2
16/12/1999	243	2	22.62	35.70	-0.03	2	28.45	157.50	15
16/12/1999	243	3	22.70	35.69	-0.03	2	28.45	157.50	15
16/12/1999	243	4	22.89	35.68	-0.03	2	28.45	157.50	15
16/12/1999	176	1	23.07	35.68	-0.04	2	28.45	157.50	15
17/12/1999	220	3	22.74	35.68	-0.05	2	29.12	157.49	10
17/12/1999	220	6	22.84	35.69	-0.04	2	29.12	157.49	10
17/12/1999	220	4	22.99	35.69	-0.04	2	29.12	157.49	10
17/12/1999	199	2	23.07	35.62	-0.04	2	29.12	157.49	10
18/12/1999	207	2	22.89	35.68	-0.02	2	29.04	157.48	10
18/12/1999	207	4	22.96	35.68	-0.01	2	29.04	157.48	10
18/12/1999	207	2	23.05	35.68	-0.02	2	29.04	157.48	10
18/12/1999	207	2	23.06	35.68	-0.02	2	29.04	157.48	10
18/12/1999	29	0	22.95	35.62	-0.02	2	29.04	157.48	10
19/12/1999	279	1	22.74	35.20	-0.03	2	28.59	157.45	10
19/12/1999	279	2	22.83	35.32	-0.02	2	28.59	157.45	10
19/12/1999	279	2	22.97	35.39	-0.04	2	28.59	157.45	10
19/12/1999	12	0	23.05	35.51	-0.03	2	28.59	157.45	10
20/12/1999	179	1	22.77	35.64	-0.05	3	28.46	157.22	20
20/12/1999	179	1	22.89	35.58	-0.04	3	28.46	157.22	20
20/12/1999	179	1	23.13	35.57	-0.03	3	28.46	157.22	20
20/12/1999	184	2	23.21	35.58	-0.02	3	28.46	157.22	20
21/12/1999	188	0	22.90	35.72	-0.06	3	28.46	157.21	25
21/12/1999	188	3	22.96	35.72	-0.05	3	28.46	157.21	25
21/12/1999	188	1	22.95	35.72	-0.04	3	28.46	157.21	25
21/12/1999	85	1	22.91	35.73	-0.03	3	28.46	157.21	25
12/02/1999	262	4	24.74	35.64	0.00	2	27.34	160.30	12
12/02/1999	262	3	24.74	35.64	0.00	2	27.34	160.30	12
12/02/1999	262	2	24.90	35.64	-0.01	2	27.34	160.30	12
12/02/1999	168	1	24.98	35.67	-0.01	2	27.34	160.30	12
13/02/1999	258	7	25.03	35.58	0.06	2	27.13	160.33	12
12/02/1999	258	3	25.13	35.60	0.04	2	27.13	160.33	12
12/02/1999	258	1	24.94	35.66	0.04	2	27.13	160.33	12
13/02/2000	191	3	25.17	35.65	0.04	2	27.13	160.33	12
14/02/2000	213	2	24.27	35.65	-0.04	2	28.24	160.17	5
14/02/2000	213	5	24.76	35.67	-0.04	2	28.24	160.17	5
14/02/2000	213	4	24.80	35.67	-0.05	2	28.24	160.17	5
14/02/2000	213	4	24.85	35.65	-0.04	2	28.24	160.17	5
14/02/2000	92	0	24.86	35.65	-0.03	2	28.24	160.17	5
16/02/2000	220	5	23.79	35.64	-0.07	2	28.36	160.40	15
16/02/2000	220	5	23.83	35.66	-0.06	2	28.36	160.40	15
16/02/2000	220	3	24.24	35.66	-0.06	2	28.36	160.40	15
16/02/2000	220	4	24.38	35.66	-0.07	2	28.36	160.40	15
16/02/2000	33	0	24.52	35.66	-0.07	2	28.36	160.40	15
17/02/2000	245	3	24.38	35.64	-0.04	3	28.49	160.23	10
17/02/2000	245	2	24.28	35.66	-0.05	3	28.49	160.23	10
17/02/2000	245	2	24.00	35.67	-0.06	3	28.49	160.23	10
17/02/2000	180	3	24.54	35.68	-0.05	3	28.49	160.23	10
18/02/2000	191	2	24.35	35.66	-0.06	3	29.06	160.25	12
18/02/2000	191	2	24.46	35.66	-0.06	3	29.06	160.25	12
18/02/2000	191	3	24.47	35.66	-0.06	3	29.06	160.25	12
18/02/2000	191	1	24.52	35.66	-0.05	3	29.06	160.25	12
18/02/2000	162	3	24.52	35.65	-0.05	3	29.06	160.25	12
19/02/2000	249	0	24.28	35.69	-0.05	3	29.07	160.25	18
19/02/2000	249	3	24.44	35.68	-0.04	3	29.07	160.25	18
19/02/2000	249	5	24.50	35.68	-0.03	3	29.07	160.25	18
19/02/2000	175	3	24.35	35.69	-0.02	3	29.07	160.25	18
20/02/2000	255	3	24.36	35.68	-0.04	3	28.54	160.29	10
20/02/2000	255	6	24.50	35.68	-0.04	3	28.54	160.29	10
20/02/2000	255	4	24.61	35.68	-0.03	3	28.54	160.29	10

Appendix 4.

Date	Hooks	BBL	SST	SSS	SSF	Moon	Lat	Long	Wind (knots)
20/02/2000	147	1	24.66	35.68	-0.02	3	28.54	160.29	10
21/02/2000	158	5	24.47	35.71	-0.03	3	29.01	160.40	5
21/02/2000	158	3	24.42	35.70	-0.03	3	29.01	160.40	5
21/02/2000	158	6	24.47	35.69	-0.03	3	29.01	160.40	5
21/02/2000	158	5	24.51	35.70	-0.02	3	29.01	160.40	5
21/02/2000	158	5	24.58	35.70	-0.01	3	29.01	160.40	5
21/02/2000	130	1	24.51	35.71	0.00	3	29.01	160.40	5
22/02/2000	189	5	24.45	35.73	-0.03	3	28.59	160.37	18
22/02/2000	189	2	24.44	35.72	-0.03	3	28.59	160.37	18
22/02/2000	189	3	24.46	35.71	-0.03	3	28.59	160.37	18
22/02/2000	189	4	24.46	35.72	-0.02	3	28.59	160.37	18
22/02/2000	157	2	24.40	35.71	0.00	3	28.59	160.37	18
23/02/2000	186	1	24.55	35.73	0.00	3	29.04	160.11	20
23/02/2000	186	1	24.42	35.73	0.01	3	29.04	160.11	20
23/02/2000	186	4	24.36	35.73	0.01	3	29.04	160.11	20
23/02/2000	186	2	24.35	35.73	0.01	3	29.04	160.11	20
23/02/2000	166	3	24.36	35.73	0.01	3	29.04	160.11	20