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Port sampling of tuna longline catches for swordfish *(Xiphias gladius)* size composition in 2005–06

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Table of Contents

1. Introduction 3
2. Methods 5
2.1 Deriving a conversion relationship for processed size to FL 5
2.1.1 Predictive regression of FL from processed weight 6
2.1.2 Pilot study 6
2.2 Port sampling design 7
2.2.1 Stratification 7
2.2.2 Sampling design for each landing 8
2.2.3 Sample size 8
2.2.4 Data acquisition 9
2.3 Analysis 9
3. Results 10
3.1 Processed weight conversion relationship 10
3.2 Pilot study 11
3.3 Port sampling 12
4. Discussion 15
5. Acknowledgements 17
6. References 18

EXECUTIVE SUMMARY

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A port sampling programme for swordfish catches in New Zealand was designed and implemented. The primary aim was to derive sex-specific length distributions of swordfish in tuna longline catches from July 2005 to June 2006. This provided a valuable input to a regional stock assessment model for south-west Pacific Ocean swordfish developed and presented to the second meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission in August 2006.

Swordfish are landed in port in a processed state (headed and gutted), which prevents the measurement of whole fish fork length (FL), and sex determination. The port sampling design used entailed collecting electronically the processed weights of individual swordfish in landings from licensed fish receivers (LFRs). The excellent cooperation provided by LFRs was fundamental to the success of this study. A significant predictive relationship between processed weight and FL (an R^2 of 0.95) was used to convert port samples to estimates of catch-at-length. A non-linear function fitted to swordfish length and sex data collected by scientific observers defined swordfish length-specific sex ratios, and was projected onto the estimates of catch-at-length. Thus, sex-specific catch-at-length for swordfish was estimated.

A pilot study confirmed that processed weight is the optimum measure of swordfish size in the processed state for predicting FL. The predictive relationships for two other measures tested were less precise and the measures more variable. Although the pilot study found it feasible to sample landings directly for swordfish size composition, a more cost-effective and representative sample is obtained by acquiring individual processed weights electronically from LFRs.

Tuna longline catches of swordfish were stratified into quarterly temporal strata, and two spatial strata NORTH and SOUTH. A port sample size of 5752 fish was received from LFRs for catches from the NORTH stratum, that represented 80% of all swordfish landed in that stratum in 2005–06. Scientific observers collected sex-specific FLs for 310 fish in the NORTH stratum, which was insufficient for deriving season-specific sex ratios at length, and consequently all observer data collected since 1988 was used. The estimated function shows on average a declining proportion of males with length from 50% at 100 cm to about 10% at 265 cm. Although higher proportions of large fish were present in catches taken in the fourth quarter of 2005 (2005_4), landings in this temporal stratum accounted for only 2% of the annual catch. In contrast, landings in the second quarter of 2006 (2006_2) accounted for about 62% of the annual catch, and a high proportion (70%) of swordfish were 165 cm or less. Given the increasing proportion of females with respect to length, the port sample estimates indicate that swordfish landed in the larger length classes were predominantly females.

Samples collected by scientific observers from tuna longline catches in the SOUTH stratum were used to estimate swordfish sex-specific catch-at-length. Swordfish landings in quarters

2005_3, 2006_1 and 2006_2 were 8.3 t, 2.4 t, and 10.6 t respectively; however a sample of 37 fish was collected from quarter 2006_2 only. This represents 27% of the estimated total number of fish landed from this stratum that accounts for less than 2% of the total number of swordfish landed in New Zealand in 2005–06. Swordfish were characteristically larger compared with catches in the NORTH stratum. A high proportion of males (70%) was observed that is in contrast with the typically low sex ratio for males of about 10%. The cause of this anomaly is not clear.

Catch-at-length estimates for the NORTH and SOUTH strata were combined to produce sex-specific estimates for New Zealand, having average FLs of 147.4 cm and 163.2 cm for males and females, respectively, and 159.5 cm overall.

The port sampling design developed was cost-effective, statistically sound and achieved high coverage of swordfish landings. The sex-specific length distributions estimated are an important input to sex-structured population models that take account of the pronounced sexual dimorphism in swordfish. The design could be improved through increased coverage of swordfish catches by observers so that season-specific sex ratios at length may be estimated concurrent to port sampling. It is recommended that a bootstrap approach be developed that integrates the predictive errors in the processed weight to FL conversion relationship and the length-specific sex-ratio function into the variance estimation of sex-specific catch-at-length for swordfish.

OVERALL OBJECTIVE:
To develop methods with which to collect biological information describing highly migratory fish species from shore-based fish processing and handling facilities.

SPECIFIC OBJECTIVE 1:
To develop and implement a shore-based biological catch sampling programme for swordfish.

1. INTRODUCTION

Swordfish is a highly migratory species found throughout the Pacific Ocean (i.e. appears in longline catches) from 50º N to 50º S in the western Pacific Ocean and 45º N to 35º S in the eastern Pacific Ocean. As such the availability and abundance of swordfish in New Zealand is subject to the dynamics of a large stock of which the New Zealand waters are a relatively small part of its range. The residence time for swordfish in New Zealand waters is not known, and despite their migratory nature, it has been hypothesised that some may be resident for long periods. Genetic studies indicate that the worldwide population of swordfish is genetically structured not only between the major oceans, but also within each ocean, and that gene flow is restricted despite the absence of geographic barriers (Chow et al. 1997, Reeb et al. 2000). Examination of spatially stratified catch rates in the Australian longline fishery indicated that there were consistent declines through time and that high catch rates were maintained only by extending the grounds each year (Campbell 2002). Therefore, local depletion of swordfish may be possible and local management of fisheries affecting swordfish populations is warranted.

Swordfish catch in the south-west Pacific Ocean rapidly increased after 1994 due to the dramatic expansion of the Australian domestic longline fishery that directly targetted swordfish (Murray & Griggs, NIWA, unpublished results. A corresponding increase occurred in the New Zealand domestic longline fishery shortly after. Catches at that time were about 2000 t and 1600 t in the Australian and New Zealand longline fisheries, respectively.

The New Zealand domestic longline fishery consists of two main sectors – chartered foreign vessels, and domestically owned and operated vessels. Growth in fishing effort has been restricted to the domestic fishery. The fishery targets several tuna species, but many other species of fish are caught, including swordfish, several species of sharks, striped marlin and many other bony fishes (Francis et al. 2004). Non-target catches of some fish species are large. Swordfish catches in the domestic tuna longline fishery increased rapidly up to about 1000 t per year in 2001 and 2002, but then declined to about 350 t in 2005. Before October 2004 there was a ban on target fishing for swordfish, but no other management measures were in place. Despite this ban, reportedly there was an increased use of light sticks on longline sets and shallower sets, which are characteristic of swordfish target fishing practices. Since October 2004, when swordfish was introduced into the Quota Management System (QMS) with a TACC of 885 t, active targeting has been permitted.

Limited biological and fishery observations for south-west Pacific Ocean swordfish have limited the development of a regional assessment for this species. Despite conditioning an operating model of the south-west Pacific Ocean swordfish population on catch, effort and size data from Japanese, Australian and New Zealand fisheries, the dynamics of the model were highly uncertain (Campbell & Dowling 2003). Improving the amount and quality of available data with which to develop an assessment is a high priority.

In a sex-specific age-structured assessment for North Pacific swordfish, process error in the relationship between CPUE and abundance was found to have the greatest effect on model performance, in terms of both bias and precision. It was found that this effect could be offset by increasing the sample size of length-frequency information, particularly where there were several sources of uncertainty in fitting the assessment model (Wang et al. 2005). The length composition data derived from this study is therefore likely to be of high utility in assessing the south-west Pacific regional stock.

In this project a port sampling programme for swordfish catches in New Zealand was designed and implemented. This was available for input into a regional stock assessment model for south-west Pacific Ocean swordfish that was developed in a collaboration between CSIRO, the Ministry of Fisheries (New Zealand) and NIWA (under a separate project to the Ministry of Fisheries, SWO2004/01). This assessment was presented to the second meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission in August 2006 (Davies et al. 2006, Kolody et al. 2006).

In designing a port sampling programme for swordfish there are two main considerations:
a. the ultimate use for the estimates derived from the programme, and
b. uncertainty in measures of fish size from port samples.

Under the first consideration, account has been taken of the regional stock assessment model for the south-west Pacific swordfish population. Consequently, features of the design, such as the stratification, have been specified to ensure that catch-at-length estimates will be consistent with the structural assumptions made in the model. As such, the ultimate purpose of the swordfish length and sex catch composition estimates derived from this project is to contribute to the regional swordfish stock assessment. This underpins the aim of the sampling design of specific objective 1, which we define as:

> *To estimate the annual length, weight, and sex composition of swordfish in landings from the New Zealand tuna longline fishery.*

There is minimal swordfish catch from methods other than longline (Griggs & Richardson, 2005), with occasional small catches by troll in 2002. Therefore, only the longline fishery is specified in the aim.

For the second consideration, there is some uncertainty regarding the accuracy and precision that may be achieved for catch-at-length estimates derived from processed state measures of swordfish size. Because all swordfish are landed in a processed state, measures of fish size must be made from the processed rather than the whole fish. The measure of swordfish length that is widely applied internationally is the length from the tip of the lower jaw to the tail fork (lower jaw fork length, hereafter denoted as FL), and is used in this study. Swordfish are processed with the head removed before landing; therefore FL cannot be obtained from port samples, i.e. from direct observations of fish landed to processing facilities. The sampling design assumes that processed fish weight will suffice as a measure of the size of swordfish in the processed state, to be subsequently used as a predictor of FL. This assumption requires that a satisfactory prediction of FL is possible from the processed weight. However, there is some risk if the conversion relationship between weight and FL has sufficiently low precision that it impacts on the usefulness of catch-at-length estimates in terms of their precision. It was therefore necessary to include the collection of other measures of fish size taken in the processed state during the implementation of the design. These would be used to refine or improve the conversion relationships. This "pilot study" aspect of the design evaluates the approach used, and makes recommendations for the development of future swordfish port sampling designs.

2. METHODS

Swordfish are landed in port in a processed state (headed and gutted), which prevents the measurement of FL, and sex determination. To estimate catch length composition, a conversion relationship was derived between measures obtained for whole fish with those for fish in the processed state, and port sample estimates of catch-at-length were related to observer programme estimates of sex-specific length composition. These relationships were used to convert port sample processed size frequency distributions into estimates of the catch length composition for whole and sexed fish. Consequently there are two stages in deriving an estimate of swordfish catch length composition:

1. derive a conversion relationship between measures obtained for whole fish with those for fish in the processed state, and,
2. project scientific observer programme estimates of length-specific sex ratios onto port sample catch-at-length estimates.

2.1 Deriving a conversion relationship for processed size to FL

Measurements taken at sea of swordfish FL, processed length and processed weight by the Ministry of Fisheries (now Ministry for Primary Industries) scientific observer programme were used to derive the parameters for a conversion relationship. All historical observer data for whole/processed swordfish measurements were extracted from the observer *l_line* database and summarised with respect to sex and quarter of collection. Predictive log-log linear regression relationships were derived between fish weight in the processed state and FL. Because swordfish growth is sexually dimorphic (Young & Drake, 2004), sex-specific relationships were also derived and compared. Because the relationships are likely to be length-specific, a suitably wide size range was identified from the observer database.

Two alternative processing methods have been reported by scientific observers on different vessels. One method retains the pectoral fins and throat area (i.e. only the head is removed at the point of the operculum, denoted cut “A”), and the other method removes the head, pectoral fins and throat area (denoted “cut B”). Observer samples from fish processed using either method (464 from method A and 262 from method B) were used to derive separate predictive relationships that were compared.

Swordfish catch-at-length observations input to the regional stock assessment model are stratified into the length class intervals 0–10; 11–20; 21–30 cm etc, whereas the linear regressions predict FL as a continuous variable. To illustrate the variability of the linear regressions with respect to the length class intervals, observer samples were used to make pair-wise comparisons between the predictions in each interval with those observed. This provides an indication of the performance of the processed weight conversion in the context of the length class intervals assumed in the stock assessment model. To convert from processed weights to the class interval frequencies required applying the conversion relationship from processed weight to predicted FL, and apportioning the predictions to length class intervals. Scientific observer data was used to compare the predicted class interval frequencies with those from the actual FL observations associated with the processed weights from which the predictions were derived. The differences between the two distributions were interpreted for the level of imprecision in the predicted length for individual fish.

2.1.1 Predictive regression of FL from processed weight

The conversion relationship between the units of measure in the port samples (in this example processed fish weight) to FL was as follows:

$$L_{FL} = c({w_{proc}}^{m}) \tag{1}$$

where w_{proc} is the processed weight, m and c are parameters of the non-linear relationship estimated, and L_{FL} is FL.

2.1.2 Pilot study

The pilot study aims to address the question: is the relationship between processed weight and FL a satisfactory predictor of swordfish size for deriving estimates of catch length composition? The optimum measurement obtained for swordfish in the processed state, and used as a predictor, is that which incurs least predictive variability in FL and is readily obtained from port samples. Consequently, two aspects were included in the pilot study design:

1. a comparison of alternative predictors of FL from the processed state; and,
2. an assessment of the feasibility of collecting processed state measures directly from fish processors.

Comparison of alternative predictors of FL

Tractable measurements of swordfish in the processed state that have been identified are:

A. the length (in a straight line) from the pectoral girdle cut to the point of the caudal fin cut (or tail fork);
B. the length (in a straight line) from the posterior point of the dorsal fin cut to the point of the caudal fin cut (or tail fork); and,
C. processed weight.

The Ministry of Fisheries Observer Programme was requested to collect these processed state measurements in addition to the measurement of FL (straight line). Conversion relationships between these measures and FL were derived and compared so that the best approach in terms of the precision required for determining catch-at-length frequencies could be determined.

Feasibility assessment for collecting processed state measures directly from fish processors

An assessment was undertaken of the feasibility of collecting size frequency samples of swordfish in the processed state directly from landings at fish processing facilities. Observations were made of measures A, B, and C from swordfish landings at the major fish processors in the Auckland area. Notes were made in respect of:

- the logistics required to access an individual landing;
- accessibility to fish within each landing at the processing facility;
- disruption caused to the processing chain by obtaining samples; and,
- the resources required to obtain samples.

From this information, the feasibility of obtaining samples and the resources required were determined.

Fish processors were asked for access to landings and the landing consignment documents (measure C). They were informed of the number of landings to be sampled (and hence the number of sampling events), and the information to be collected.

2.2 Port sampling design

The port sampling design was determined on the basis of the temporal, spatial, and fleet stratification required and estimates of the required sample size in each stratum. The stratification being applied in the regional stock assessment model for the south-west Pacific swordfish population currently being developed was taken into account. This will ensure that the observations provided by New Zealand for input into the model will be consistent with the structural assumptions made in the model.

2.2.1 Stratification

An extract of TLCERs was obtained for the most recent fishing year and used to characterise the temporal and spatial characteristics of the fishery and landings. TLCER data was used because under the new format more information is provided on the processed state of the species in each landing. Recent characterisations of the tuna longline fishery were reviewed, e.g. Kendrick (2004), and Griggs & Richardson (2005), for the temporal and spatial patterns in the fishery, target species and swordfish bycatch. An LFRR extract was requested from the Ministry and was used to characterise the landings of swordfish to particular fish processors. In combination with the TLCER extract, this characterisation described where swordfish landings occur, the frequency and quantity of landings, landed states and the types of biological data that can be collected.

Temporal stratification
Swordfish catch is highest in the first and second quarters, and relatively high in the third quarter; but low in the fourth quarter (Griggs & Richardson, 2005). As the purpose of the design is to describe the annual catch length and sex composition, all seasons containing significant numbers of landings must be sampled. Therefore, the design provided for year-round sampling, as there is no season in which landings are negligible.

The temporal stratification of the south-west Pacific swordfish regional stock assessment model is quarterly (Kolody et al. 2006, Davies et al. 2006) and therefore the temporal stratification is consistent with the model, in that quarterly sex-specific length compositions are estimated.

Spatial stratification
The spatial stratification of the tuna longline fisheries was specified in a way similar to that defined by Ayers et al. (2004). Of the different regional boundaries they examined, they defined regions that best reflected spatial patterns in fish and fleet distributions when all years of data were included in the characterisation. These regions were a north (N) region, a southwest (SW) region, and a southeast (SE) region. The north region was defined as being north of latitude 39º 30′ S on the west coast, and north of 43º 45′ S on the east coast. The southwest region was defined as being west of Cook Strait, south of 39º 30′ S, and west of 169º E at the southern end of the South Island. The southeast region is the remaining area to the east of the South Island. It is reasonable to combine the two southern regions for this study, as swordfish catches are negligible in the SE region (Griggs & Richardson 2005). This stratification option is consistent with that proposed for the regional stock assessment model.

Fishery stratification
In characterisations of the tuna longline fisheries, method-specific strata are defined on the basis of the domestic and foreign charter fleets (Griggs & Richardson 2005). This may be warranted given the differences in their fishery operation (in particular the target species), and the areas in which they operate. However, the foreign-charter fleet do not land their catch into New Zealand ports, which prohibits port sampling of the swordfish component. It is only possible to undertake port sampling of swordfish from the domestic fleet. For the port sampling design, the fishery stratification was therefore excluded. Chartered vessels have 100% observer coverage, allowing the sex-specific length composition of swordfish caught by these vessels to be included in this project by analysis of the observer data collected and stored on the central Ministry database ***l_line*** administered by NIWA.

In summary the unit of sampling "population" (being the stratum for which estimates are calculated) is: quarter-area.

2.2.2 Sampling design for each landing

The selection of a landing from a processing factory was considered to be a random event with respect to the landing. It is typical for the numbers of swordfish in a landing to be rather low (fewer than 60 individuals), and measurements of the processed fish weights of all fish in a landing were obtained. Within-landing variance of landing size composition will therefore be zero because the sampling design excludes the random selection of sampling units within a landing, or random selection of fish within sampling units. Sampling within a landing will therefore be analogous to the catch sampling at sea by observers of the size composition of swordfish in the processed state.

The sampling design for each landing entailed the collection of individual processed state swordfish weights from processors (see Section 2.2.4).

2.2.3 Sample size

Typically a sample size is determined that will provide a representative sample of the population being sampled with satisfactory precision, e.g., a mean weighted coefficient of variation (c.v.) equal to or less than a maximum value such as 0.2. In conventional port sampling programmes, research technicians attend landings at fish processing facilities to physically collect a representative sample of fish from a landing, and measure all fish within the sample.

The design used in this study involves collecting swordfish size composition data directly from fish processors and therefore incurs minimal cost. A substantial proportion (up to 80%) of swordfish landings from the tuna longline fishery may be represented in the sample. Under this approach, a target sample size that maximises the cost-benefit of a sampling programme, in terms of maximum representation of the fishery and estimated precision for the least cost, is no longer relevant.

The design aims to acquire processed weights from all swordfish landings for which data was available electronically

2.2.4 Data acquisition

Data acquisition for each landing involved the collection of individual processed state swordfish weights from processors. The main processors of swordfish in the Auckland region were consulted, and their cooperation obtained to make this information available. Records of the processed weight (to the nearest kilogram) of each fish in a landing, that were retained by fish processors on individual landing consignment documents were forwarded directly to NIWA in electronic format. As such, the acquisition of data simply required the receipt of consignment records from fish processors that related to a particular vessel and landing date. Extracts of TLCER data for the landings sampled were requested of the Ministry to characterise the fishing associated with each landing (area of operation etc.).

2.3 Analysis

Estimates of FL composition in each stratum were calculated differently for the NORTH and SOUTH spatial strata. Historically, most landings in the SOUTH stratum are sampled by scientific observers who record the FL and sex of each fish directly. This data was input to the NIWA "catchatage" package directly for estimating weighted mean sex-specific catch-at-length. The estimates for the NORTH stratum were derived from a combination of port sample data (measured in the processed state) and scientific observer data. Consequently, the calculation of annual swordfish sex-specific size composition in catches in the NORTH stratum was done in two stages:

1. estimate FL frequencies in landings in each stratum;
2. estimate sex-specific length compositions from observer catch at-sea sampling in each stratum, and project the length-specific sex ratios onto port sample length frequencies.

Stratum estimates of FL compositions
Extracts of TLCER set-by-set catch and effort data were requested from the Ministry and the landings making up the sample were identified so that the temporal-spatial information for each was confirmed. The processed weights for each fish making up a landing were converted to FL, pooled into 10 cm length intervals, and the weighted mean length frequency distributions calculated over all landings using the NIWA software "catchatage" for each quarterly stratum. Estimates of proportions at length variance were calculated from 300 bootstraps with random resampling of landings, and fish within landings, with replacement.

For the SOUTH stratum, swordfish sex-specific length frequency estimates were calculated from scientific observer samples. Landing weights and the total weight of swordfish landed in each temporal stratum were obtained from TLCER extracts. The weighted mean length frequency distributions were calculated over all landings using the NIWA software "catchatage" for each quarterly stratum. Estimates of proportions at length variance were calculated from 300 bootstraps with random resampling of landings, and fish within landings, with replacement.

Sexed length-frequencies
Port sample estimates of catch length composition were made sex-specific using information collected bythe Ministry of Fisheries (now Ministry for Primary Industries) observer programme. A summary of the observer sexed length frequency data corresponding to each quarter-area stratum for the domestic fleet was produced and the sex-specific length

frequencies were expressed as length-specific sex ratios. To account for the variability between length classes, most likely due to low sample sizes, a non-linear function was estimated to predict sex ratios at length.

The function predicts the proportion of males in each length interval l, $Pr_{male,l}$, where parameter l_{50} is the length for which $Pr_{male,l}$ is 0.5, and parameter l_{to5} is the additional length such that at l_{50} + l_{to5} $Pr_{male,l}$ is 0.05.

$$\Pr_{male,l} = \frac{1}{1+19^{\frac{l-l_{50}}{l_{to5}}}} \tag{2}$$

The binomial likelihood for each length class, l, is:

$$-m_l(\log(\Pr_{male}) - (tot_l - m_l)(\log(1-\Pr_{male})) \tag{3}$$

where there are a total number of sexed fish, tot_l, of which m_l are male. Optimum parameter solutions for at l_{50} and l_{to5} were obtained by finding the minimum of the likelihood function.

This vector of sex ratios, $Pr_{male,l}$, was projected onto the port sample stratum-specific FL frequency estimates for the NORTH stratum.

NZ-wide sex-specific length composition

Numbers of swordfish caught at length by sex were aggregated over all temporal-spatial strata to produce the New Zealand-wide estimate of the sex-specific catch-at-length in 2005–06.

3. RESULTS

3.1 Processed weight conversion relationship

Observer processed weight and FL data from 1988 to 2005 were collated and only those observations identified using the “HG” processed state code were extracted. This provided a reasonably large sample size (2471 observations) over a wide size range (Table 1).

Log-log linear regressions were derived to produce a predictive relationship between processed weight and FL. A comparison was made between the predicted FLs from an inverse relationship between ln(FL) to ln(proc.wt) with the predictions from a direct relationship between ln(proc.wt.) to ln(FL). This revealed a measurable difference in the linear model depending upon the choice of dependent variable which was attributed to differences in the levels of error in the dependent or predicted variables. It was concluded that the relationship that predicts FL (dependent y-variable) from proc.wt (x-variable), using a log-log linear regression was most appropriate:

$$\ln(FL) = m(\ln(proc.wt) + c \tag{4}$$

The relationship expressed in normal space (R^2 0.95, residual standard error 0.053) is shown in Figure 1:

$$FL = 55.622(proc.wt^{0.2895}) \quad (5)$$

Further comparisons were made between predictions derived from the functional form of this regression with those from the standard form. The average percentage difference in predictions from the functional form of this regression with those from the standard form is 0.0069% (a maximum of 0.23%; minimum -0.627%). This result supports the view of McArdle (1988) that a functional form is not required for relationships having strong correlations (i.e. with R^2 greater than 0.81).

A difference is evident between the relationships derived for the two alternative methods for processing swordfish. The relationship for cut B has a slightly steeper slope (Figure 2) than for cut A. However, fewer small fish were available in the sample for cut B and there was a larger number of small and slender fish in the sample for cut A. These differences in size composition of the samples are likely to reflect spatial patterns in swordfish size composition relative to where the vessels using the different cuts were fishing. For instance, it is likely that observations of cut B were made on foreign charter vessels operating in the south-western areas where larger swordfish are more abundant. Cut A is the most prevalent processing method used in the domestic fishery and the difference in the predictions is not significant in making predictions of FL from processed weight records from the domestic fishery.

The comparison between the length frequency distribution in 10 cm length class intervals predicted from processed weights using the conversion relationship, and that derived directly from the observed FLs, indicates that there are differences for certain class intervals (Figure 3). However, the cumulative frequency distributions suggest that the distributions are largely the same. The cause of the inaccuracies in the predictions is not clear, as the observed length with respect to a weight class interval (see Figure 1) appears to be normally distributed and symmetric (Table 2).

3.2 Pilot study

Observer measurements of processed size

Scientific observers reported variation in the manner in which processing cuts A and B were made by fishers. Cut A was considered the most consistent and, therefore the most reliable morphometrically. Cut B was more variable because the dorsal fin cut lacked a clearly defined posterior point where the fin ended. It was common for the tail to be left on, with the lobes trimmed off.

The log-log linear relationship between processed weight and FL (R^2 value of 0.96) was a better predictor of fork length than either of the lengths recorded from the processed fish (Figure 4). Length A (R^2 value of 0.92) was more reliable than Length B (R^2 value of 0.86).

On the basis of this comparison, the predictive regression between processed weight and FL derived from the larger sample (2471 observations) described in Section 3.1 was applied in the analysis of port sample processed weight frequency data. A comparison made between separate regressions for males and females indicated negligible differences in predicted lengths (less than 1%).

Processing factory site visits

Observations were made at a Licensed Fish Receiver accountable for the majority of NZ swordfish landings. The processing environment was inspected to assess the feasibility of physically collecting measurements of swordfish in the processed state.

Samples of both processed weight and fish length could feasibly be collected for all swordfish making up a landing. Landings are typically stratified according to grades: large, small, and shark-damaged; with the grade for shark damaged fish not able to be sampled for individual fish sizes. It is preferable and feasible for a sample to be taken from all fish in the small and large grades in a landing. A sample made up of the processed weights for each fish is feasible, given that the individual weights of all fish are accurately recorded to the nearest 0.1 kg by factory staff while maintaining the export consignment database. This is true also for the small fish that are often packed in multiples in a single box.

A practical consideration is that the sampler be efficient in collecting the processed lengths to avoid disrupting the operation of the factory staff unloading fish from transport trucks. This is particularly important for the small fish that are packed in batches.

3.3 Port sampling

Summary of processors of swordfish landings

Extracts from the LFRR database were summarised forswordfish landings by Licensed Fish Receiver (LFR) and month for the 2003–04 and 2004–05 fishing years (Tables 3 and 4). About 80% of annual landings were processed at three LFRs with the remainder varying annually between the other LFRs. On average; 75% of the annual landings in 2003–04 and 2004–05 were processed during the first and second quarters.

Temporal and spatial stratification

Using TLCER data, a spatial examination of the distribution of swordfish catches with respect to tuna longline fishing effort from 1993 to 2005 identified two discrete areas having unique and homogeneous fishing effort and swordfish catch rates: NORTH – the northern areas of the North Island (FMAs 1,2,8,9,10); and, SOUTH – the southern areas of the NZ EEZ (FMAs 3,4,5,6,7). These areas are consistent with the spatial disaggregation of the New Zealand EEZ into the areas assumed for the swordfish regional stock assessment model. The model assumes quarterly time steps, and therefore the port sampling design assumes quarterly temporal stratification. The four quarters making up the sampling period from July 2005 to June 2006 were denoted (in chronological order): 2005_3, 2005_4, 2006_1 and 2006_2.

Data acquisition

The information on swordfish processed weights for a given landing were contained in export consignment records held by the LFRs. The information provided for this study for a vessel landing on a given landing date included the following fields:

- landing date
- species
- colour grade
- oil grade
- grade/processed state
- vessel name
- count of fish in box
- part count of total number of fish in box
- quantity of fish in box

- individual processed weight
- box number
- total weight in landing

From this information the processed weight frequency distribution for each landing was derived.

Data from the swordfish fishery in the NORTH stratum from the three largest processors of swordfish landings between July 2005 and June 2006 is summarised in Table 5. There appear to be discrepancies in the weight and number of landings suggesting that in some quarters more than 100% of the fishery was sampled (Table 5). This may be explained by fisher's inaccuracy in reporting the weight of swordfish on TLCERs, and by possible slight biases in calculating the estimated weight of a landing using the sample length frequencies in 10 cm length bins. The discrepancy in quarter 2006_1 may be due to errors in the trip end date or the processed date on TLCER and CLR records. However, the percentage sampled in terms of the estimated number of fish in the fishery appears consistent. In summary, 100% of the fishery was sampled in quarters 2005_4 and 2006_1 with about 70% being sampled in quarters 2005_3 and 2006_2, with on average about 80% of the fishery being sampled in 2005–06.

In addition to the discrepancy mentioned above, errors were found in the reported landed weights for a subset of the landings for which port samples were collected. A comparison was made between the CLR weights and those calculated using the port sample processed weights scaled up to greenweight. For 14 of the landings the CLR weights were more than twice as high as those derived from the port sample weights. It is highly unlikely that port sample data received from LFRs make up less than half of fish in the landing in these instances. For these landings the weight assumed was that derived from the port samples.

Observer data from NORTH stratum
Scientific observers on board tuna longline vessels in the NORTH stratum sampled 310 swordfish over the four quarters in 2005–06 (Table 6). The largest proportion (55.4%) of the annual catch was landed in quarter 2006_2; however only one trip was observed with only two fish sampled.

Sex-specific length frequency estimates from observer samples indicate that about 65% of fish caught in 2005–06 were in the length classes 155 cm and 185 cm (Figure 5, Appendix 1). However, this is most likely a biased result because the small sample collected in the 2006_2 quarter is not representative of catches in that stratum (Table 6). An annual length frequency was estimated that excluded temporal strata having samples with fewer than five fish, i.e., it combined data over the other quarters, and illustrated a broad distribution with two dominant modes at 125 cm and 175 cm (Figure 5). MWCVs were reasonably high, being between 44% and 68% for the total sample in the quarters sampled (Table 7), Catches contained considerably more females than males with females making up nearly 70% of the catch (Appendix 1).

Sex ratio estimates from observer data in NORTH stratum
Upon examination of the length-specific trend in sex ratio of swordfish sampled by scientific observers from tuna longline catches from the NORTH stratum in 2005–06, a reverse logistic function was fitted to the observed proportions of males at length. The binomial negative log-likelihood function implicitly took account of the sample size in each length interval.

The sex ratio functions estimated were dependent upon the total sample sizes available from the observer collections. Given the relatively low sample size over all sexes within each quarter in 2005–06, deriving a season-specific sex ratio was not considered feasible. Observations were therefore pooled over all quarters to derive an annual average sex ratio function for 2005–06. To examine season effects on length-specific sex ratios, season-specific functions were estimated using the complete scientific observer programme collection from 1988 to 2006.

In 2005–06 the estimate for l_{50} was 93.416 and for l_{to5} was 178.520, and the fitted length-specific sex ratio function indicated a higher proportion of females for the larger length intervals (Figure 6, Appendix 2). The relationship fitted to the data pooled over all years (1988 to 2006) was similar, although a higher proportion of males in the larger length class intervals was predicted (Figure 6). Although a large sample of sex-specific observations at length were available (2249 observations), the numbers in quarters 1 and 4 were low (153 and 16, respectively, Appendix 2). This most likely accounts for the large differences in the predicted sex-ratios at length for these quarters relative to those for quarters 2 and 3 (Figure 7) for which more observations are available. The estimated function for quarter 4 is implausible, and it was considered reasonable to assume the annual function derived over all quarters and years (Appendix 2) as a proxy sex-ratio function in quarter 4.

Port sample length frequencies for the NORTH stratum

The length frequency estimates converted from processed weights in port samples from the NORTH stratum and expressed in proportions and numbers caught with c.v.s are presented in Appendix 3 for each quarter and pooled over all quarters. Length frequency estimates in each temporal stratum were relatively precise, with mean weighted coefficients of variation of between 11% and 42% (Table 8). The lower precision for the estimate in quarter 2005_4 is attributable to the low numbers landed from the fishery in that quarter making up only 2% of the annual total (Table 5).

The annual total length frequency estimates of swordfish caught in the NORTH stratum derived from port samples and those from scientific observer collections appear similar(Figure 8), reflecting that samples were collected concurrently and from the same fishery. Despite a higher proportion of small fish in port samples, the similarity is a sufficient basis to assume the sex composition of the observer samples is representative of that in the port samples. The average annual sex ratio derived from the observer data may therefore be assumed for the port sample length frequency in each temporal stratum.

Sex-specific length frequencies were derived from the port sample estimates using the length-specific sex-ratio functions for each quarter derived from the complete observer sample from 1988 to 2006 (Figure 7) projected onto the port sample length frequency estimates in each quarter (Figure 9). As mentioned above the annual length-specific sex-ratio function (1988–2006) was assumed for quarter 4. Although a higher proportion of large fish were present in catches taken in the 2005_4 quarter, landings in this temporal stratum accounted for about 2% of the annual catch. In contrast landings in the 2006_2 quarter accounted for about 62% of the annual catch, and a high proportion (70%) of swordfish were 165 cm or less (Figure 9). Given the increasing proportion of females with length, the port sample estimates indicate that swordfish landed in the larger length classes were predominantly females. The average FL was 142.9 cm and 162.7 cm for males and females, respectively, and 158.3 cm overall.

Length frequency for the SOUTH stratum

Relatively few swordfish were sampled from tuna longliners in the SOUTH stratum and only from the quarter 2006_2. This reflects the low numbers of swordfish caught from this stratum (Table 9), with a total of 37 fish sampled by observers from an estimated 139 fish landed in the fishery (Appendix 5). This low sample size is reflected in the poor precision of the length frequency estimates with a MWCV for the pooled length frequency estimated at 82.6% (Table 9). The average FL was 208.8 cm and 238.2 cm for males and females, respectively, and 218.6 cm overall.

Swordfish in the SOUTH were larger than to those in the NORTH, with no fish observed less than 175 cm (Figure 10). Males were more abundant in catches than females.

New Zealand sex-specific length frequencies

Sex-specific numbers at length for the NORTH and SOUTH strata were pooled to derive an estimated length frequency distribution for swordfish in catches from the tuna longline fishery in New Zealand during 2005–06 (Figure 11). Given the insignificant catch taken from the SOUTH stratum, less than 2% of the New Zealand total catch, the length distribution is essentially identical to that of the NORTH stratum (Figure 9), with slightly more fish in the right hand tail. The average FL was 147.4 cm and 163.2 cm for males and females, respectively, and 159.5 cm overall.

4. DISCUSSION

Fundamental to the success of this study was the excellent cooperation provided by LFRs in undertaking port sampling of swordfish from tuna longline catches in 2005–06. Their provision of the processed weights of individual swordfish facilitated the monitoring of 80% of all fish landed in the NORTH stratum. This level of coverage produced high precision in the catch-at-length estimates derived from FL predicted from processed weights (with a $\mathrm{MWCV}_{2005\text{–}06}$ of 8.5%).

Also pivotal to the success of the design is the suitability of swordfish processed weight as a predictor of FL. Its superior performance as a predictor over other measures of the processed size was confirmed by the pilot study results. The predictor also performed well in a trial that compared the predicted FL distribution with that derived from the actual FLs associated with the processed weights measured by scientific observers. Although the pilot study showed that the physical collection of swordfish length and weight measurements from landings at LFRs was feasible, the sampling design used in this study is more cost-effective, statistically sound, and achieved substantial coverage of swordfish landings.

The pilot study revealed that a potential problem in sampling swordfish landings is that port samples may not be representative of all swordfish in the landings. A component of landings not captured in LFR records of individual processed weights, are swordfish damaged by sharks before being landed by fishers. Depending upon the damage inflicted, it may be possible for scientific observers to measure the FL of these fish. However, the individual processed weight is not recorded by LFRs and would not be an accurate predictor of FL. The design used in this study excludes these fish from samples of the landings and may cause bias if there is a systematic relationship between FL and instances of shark damage. Should shark damage be independent of FL, no bias will result from the design used. Also, the total landing weight is obtained independent of the port samples (being obtained from TLCERs and CLRs) and therefore the relative weight of each landing is not affected.

Deriving sex-specific FL distributions was a primary aim of this study for input into swordfish population models that take account of their pronounced sexual dimorphism. The design involves projecting length-specific sex-ratios derived from scientific observer samples of the same population, onto port sample FL distributions. This assumes that the observer samples are temporally and spatially representative of the population in port samples. Griggs & Davies (2006) show that the spatial distribution of observer samples closely coincides with that of the tuna longline fishery from which swordfish are landed. The 2005–06 FL distributions from scientific observer samples and port samples were broadly similar despite almost no observer samples having been collected in the second quarter (2006_2). Swordfish landed in this quarter were generally smaller than in other quarters and this temporal pattern accounts for differences between the two distributions, with the observer FL distribution containing more large fish. It is clear that the temporal coverage of swordfish landings by scientific observers was inadequate in quarter 2006_2, and in the fourth quarter in all years. Consequently, proxy season-specific sex-ratios were used in projecting port sample FL distributions to sex-specific estimates. The assumptions required that the temporal patterns in length-specific sex-ratios in 2005–06 were typical of the average observed since 1988, and the ratios in the fourth quarter are similar to the average annual ratios since 1988. A violation of the latter assumption is unlikely to bias estimates of the sex-specific FL distributions given that landings in the fourth quarter accounted for only 2% of swordfish landed in 2005–06. However, the former assumption is broad given that annual variation in swordfish length-specific sex ratios has been observed (Griggs & Davies 2006), and this variation is likely given environmental and fishing-related processes acting upon the population. The port sampling design would be improved by increasing observer coverage of landings in all quarters for deriving season-specific sex-ratios at length for the year in which port samples are collected.

Variance in the estimates of port sample catch-at-length distributions was calculated from bootstraps of the landings sampled and fish within each landing. This variance estimate essentially describes the within- and between-landing variability in swordfish size composition, and takes no account of the variability in the predictive relationship used to calculate FLs of individual fish from the processed weights. An indication of the level of variability in this relationship is evident from the comparative trial between actual and predicted FLs using scientific observer data. About 44% of predictions were for FLs in length class intervals either one interval above or below that of that for the actual FL (see Table 2). Also, no variance estimates for the sex-specific length distributions have been calculated to take account of variability in the length-specific sex ratio functions. Given the low sizes of the scientific observer samples in most years, the variability of season-specific functions estimated for any one year is likely to be high. In combination, these sources of variation are likely to add appreciably to the uncertainty in the port sample sex-specific FL distributions, above that estimated from the bootstraps presented here. An integrated approach is required, that includes predictive error in the processed weight conversion relationship and the length-specific sex ratio function by means of parametric bootstraps, for these components of the analysis. This integrated bootstrap entails fundamental modifications to the “catchatage” software and is beyond the scope of this study. However, it would be essential for the reporting of variance estimates of sex-specific catch-at-length of swordfish in tuna longline catches from port samples of processed weights.

In 2005–06 about 70% of swordfish in the scientific observer samples from the SOUTH stratum were males. This contrasts starkly with observer samples since 1988 where on average 10% of fish in samples from that stratum were males (Griggs 2005). The cause of this deviation from what appears to have been consistently a high ratio of females to males is not clear. The sample size is low (37 observations) relative to the NORTH stratum, and may not be representative of the sex composition of all catches from that stratum. However, the estimated total catch from the SOUTH stratum was also relatively low (139 fish, see Appendix 5). Although the implication of this atypical result upon the sex-specific FL distributions of swordfish in New Zealand catches is small, it does warrant closer examination to identify possible sources of observation error.

Size frequency data in the form of processed weights are important observations that are input into the regional stock assessments for yellowfin and bigeye tunas (Langley et al. 2006) and swordfish (Kolody et al. 2006) in the western and central Pacific Ocean. For these assessments using MULTIFAN-CL (Fournier et al. 1990), a relationship is used to convert from processed weight to whole weights and a length-weight relationship is used to derive FL. Langley et al. (2006) shows that size-specific non-linear conversion relationships may vary considerably between processing methods for large tunas, and this may be accounted for in the assessment model by applying the appropriate relationship to the various data.

The approach used for processed weight data for tunas differs from the design described here in that two steps are taken in converting from processed weight to FL. The product of a non-linear processed weight to whole weight conversion relationship, and a length-weight relationship is unlikely to differ substantially from the single-step, non-linear processed weight-FL conversion presented here. However, in deriving a single relationship there may be less measurement error in the data used because only two measurements are taken instead of four, and the predictive error in the relationship may be better defined. By including this source of error in the catch-at-length variance estimation using bootstraps, as recommended above, the calculated observation error estimates may be input directly to the objective functions used in fitting the population model. This approach may avoid, or assist with, making assumptions for observation error in the catch-at-length data that are becoming increasingly important in monitoring the substantial impacts of fishing on top predators in the Pacific Ocean (Sibert et al. 2006).

5. ACKNOWLEDGEMENTS

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Tables and Figures

Table 1: Summary of individual swordfish processed weights (headed and gutted, HG) and FL measurements made by observers from 1988 to 2005 (n = 2471).

	Minimum	Median	Mean	Maximum
Processed weight (kg)	2.0	58.0	72.1	260.0
FL (cm)	76.0	180.0	181.1	314.0

Table 2: Pair-wise comparison of the size bin for an observed FL converted to orbital fork length and assigned to a size bin, with that using the predicted FL (derived from the processed weight) converted to orbital fork length and assigned to a size bin. The proportion is shown where the predicted size bin was above or below that determined using the observed orbital fork length.

No. equivalent	1 bin below	1 bin above	2 bins below	2 bins above	3 bins below	3 bins above
1095	510	578	122	99	34	18
44%	21%	23%	5%	4%	1%	1%

Table 3: The percentage of total annual swordfish landings processed by individual licensed fish receivers (LFR) for the 2003–04 and 2004–05 fishing years. Note: a unique identifier for each LFR is shown.

LFR	2003–04	2004–05
A	31%	46%
B	37%	22%
C	12%	11%
D	5%	6%
E	2%	4%
F	0%	3%
Other	13%	7%

Table 4: The percentage of total annual swordfish landings processed in each month for the 2003–04 and 2004–05 fishing years.

Month	2003–04	2004–05	Mean
Oct	0%	1%	1%
Nov	1%	1%	1%
Dec	1%	0%	1%
Jan	1%	4%	3%
Feb	5%	8%	7%
Mar	17%	14%	15%
Apr	18%	13%	15%
May	20%	22%	21%
Jun	19%	10%	15%
Jul	9%	12%	11%
Aug	5%	11%	8%
Sep	2%	5%	3%

Table 5: Summary of swordfish landings in the tuna longline fishery in the NORTH spatial stratum, the processed weight data provided by LFRs for the third and fourth quarters of 2005 (2005_3 and 2005_4 respectively), and the first and second quarters of 2006 (2006_1 and 2006_2 respectively), and details of the percentage of the fishery sampled in terms of the weight of landings (MHR data), estimated total number of fish landed, and the number of landings (CLR data).

	2005_3	2005_4	2006_1	2006_2	**2005-06**
Fishery landed weight (t)	87.4	12.5	101.6	249.9	451.4
Weight of landings sampled	68.3	14. 5	116.1	202. 3	401.2
% fishery landings weight in sample	78.2%	115.5%	114.3%	80.9%	88.9%
Estimated number landed in fishery	1122	145	1455	4534	7256
Estimated number in landings sampled	899	173	1688	3729	6489
Processed weights sample size	779	149	1479	3345	5752
% of numbers landed in fishery in sample	69.4%	102.7%	101.6%	73.8%	79.3%
Number of landings in fishery	193	48	111	249	601
Number of landings in sample	185	48	122	234	589
% of fishery landings sampled	95.9%	100.0%	109.9%	94.0%	98.0%

Table 6: Length frequency samples collected by observers on board longline vessels in the NORTH stratum in each quarter of 2005–06.

Quarter	Males	Females	Unsexed	Total
2005_3	10	40	3	53
2005_4	36	77	30	143
2006_1	22	75	15	112
2006_2	0	1	1	2
Total	68	193	49	310

Table 7: Mean weighted coefficients of variation (MWCV) expressed as percentage for proportion at length frequency estimates of swordfish from samples collected by observers on board longline vessels in the NORTH stratum in each quarter of 2005–06 and for the length frequency pooled over all quarters. – indicates no observations in sample collected.

	2005_3	2005_4	2006_1	2006_2	Pooled
Male	74.9	69.2	106.8	-	73.5
Female	47.9	62.7	67.5	64.2	51.8
Unsexed	95.2	85	112.6	72.5	79.1
Total	44.3	45.5	56.8	68.1	53.5

Table 8: Mean weighted coefficients of variation (MWCV) expressed as percentage for proportion at length frequency estimates of swordfish from port samples of individual fish processed weights collected from landings to LFRs in the NORTH stratum in each quarter of 2005–06 and for the length frequency pooled over all quarters.

	2005_3	2005_4	2006_1	2006_2	Pooled
MWCV	21.4	42.4	15.5	11.1	8.5

Table 9: Sample details and mean weighted coefficients of variation (MWCV) expressed as percentage for proportion at length frequency estimates of swordfish from samples collected by scientific observers on board tuna longline vessels in the SOUTH stratum in 2005–06.

Quarter stratum		Male	Female	Unsexed	Pooled
2006_2	Sample size	26	7	4	37
2006_2	MWCV	89.5	150.2	122.1	82.6

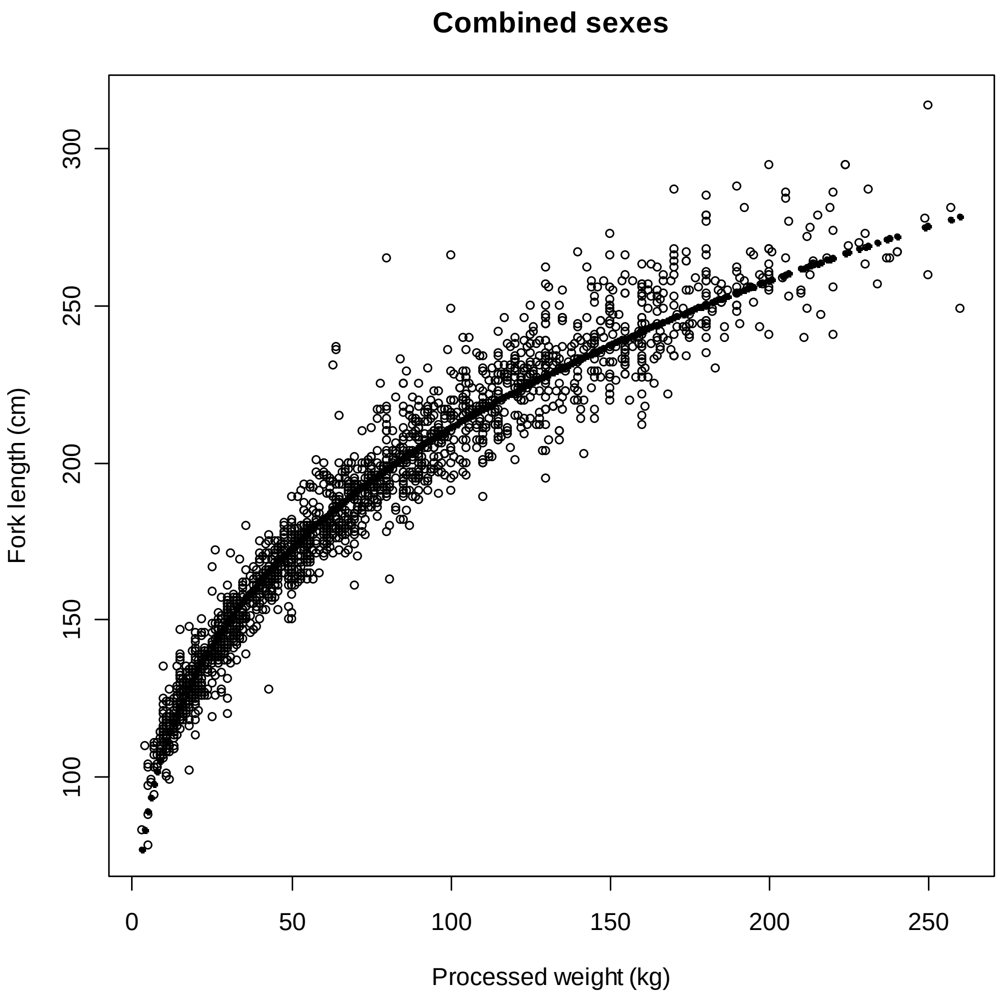


Figure 1: Predictive relationship between observed swordfish processed weights (headed and gutted, HG, open circles) and predicted fork length (solid circles) using samples taken by observers from 1988 to 2005 (n = 2471).

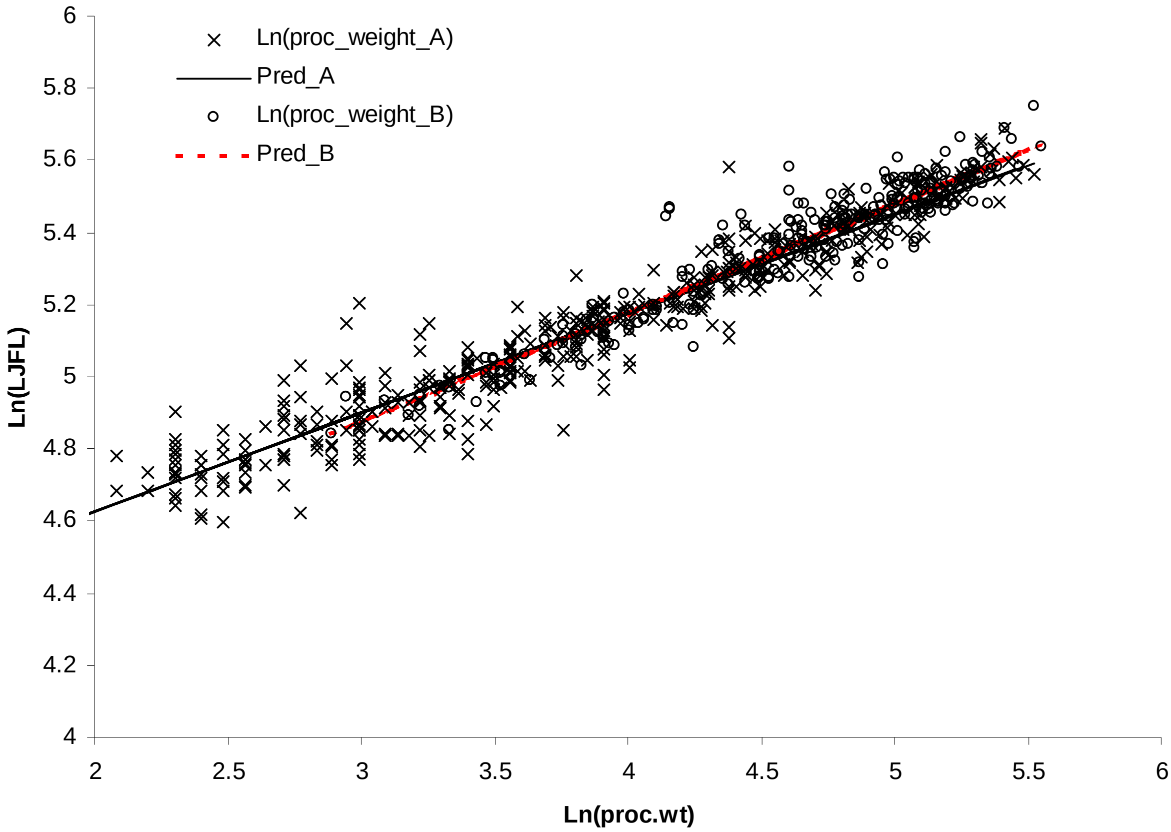


Figure 2: Comparison of ln-ln transformed predictive relationship between swordfish processed weights (headed and gutted, HG) and FL (pred-FL) using samples taken by observers for two methods of processing fish, cuts A and B, (crosses and circles respectively).

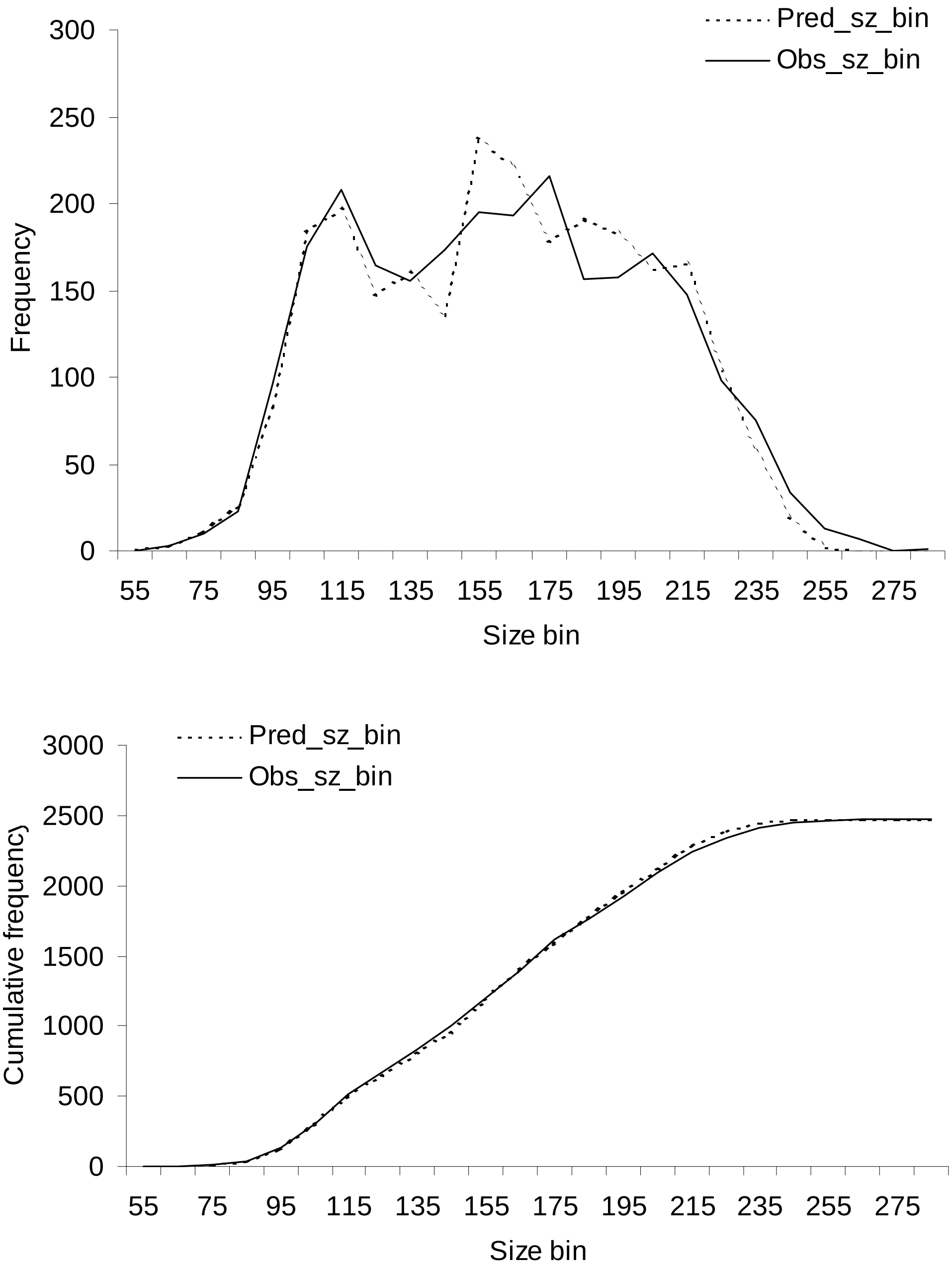


Figure 3: Comparison of the size bin frequency distributions (actual and cumulative) for observed FL converted to orbital fork length and assigned to size bins (solid line), with that using the predicted FL (from processed weight) converted to orbital fork length and assigned to size bins (dashed line).

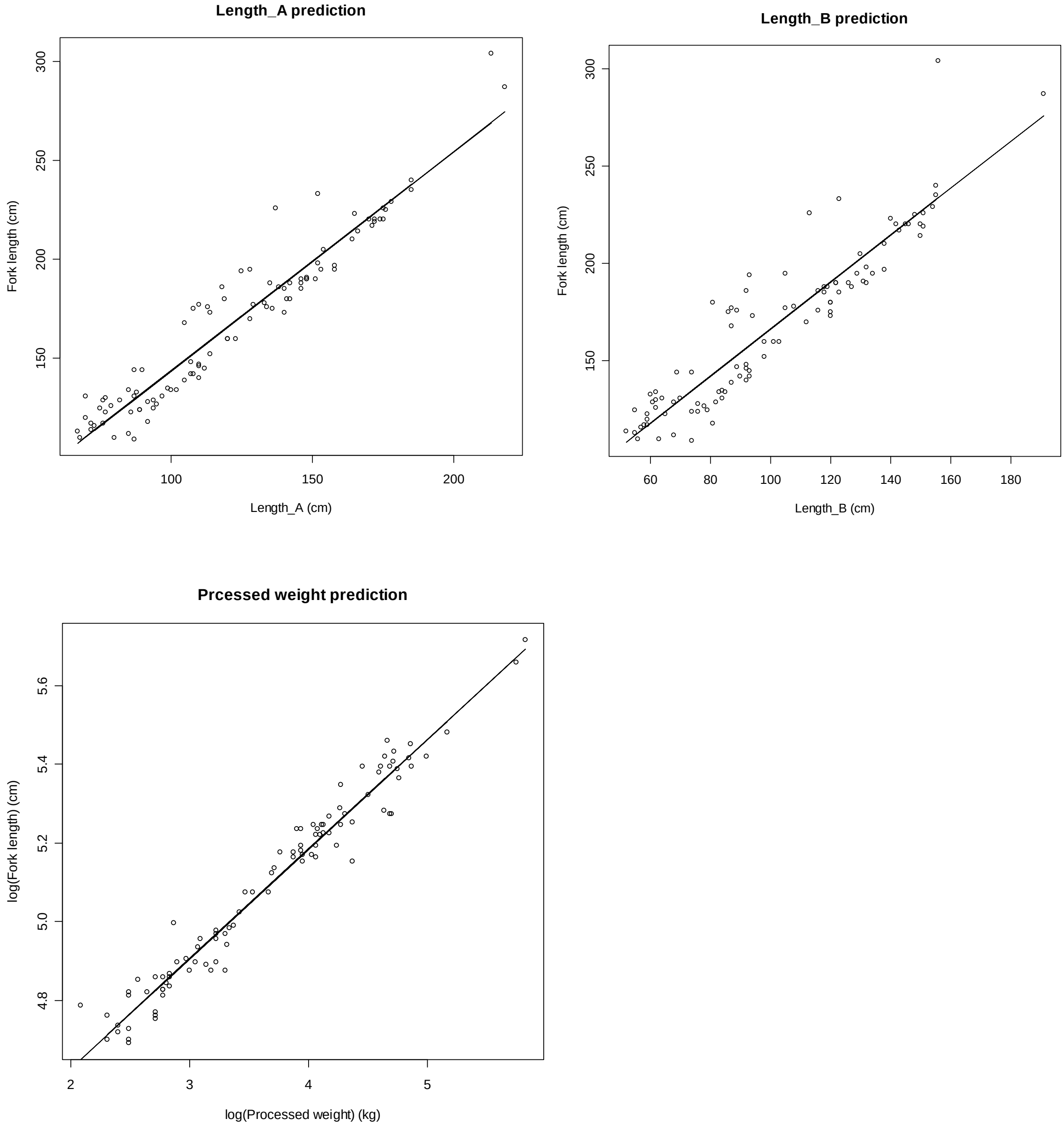
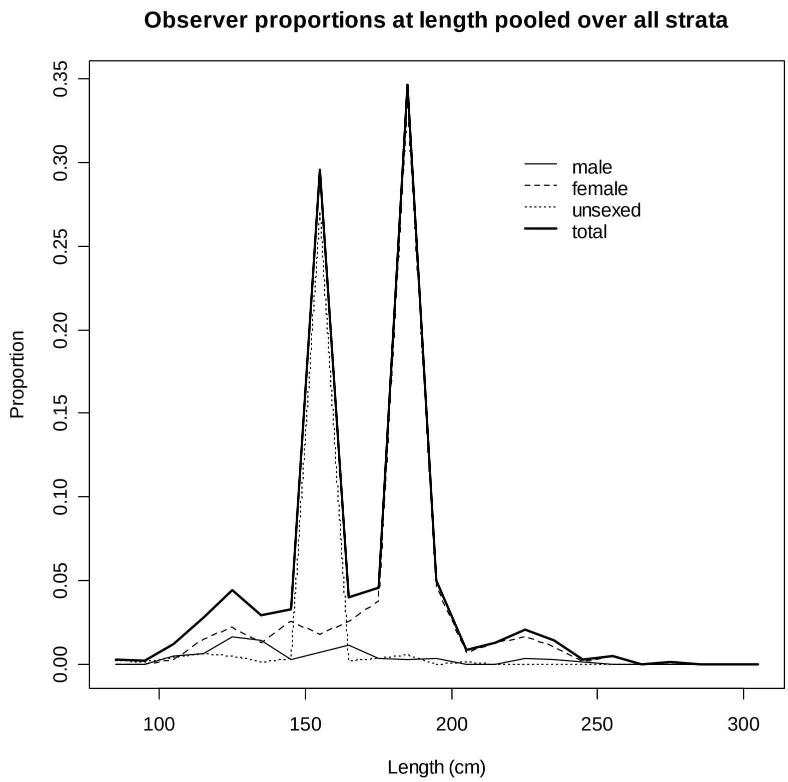


Figure 4: Comparison of alternative measures of swordfish processed size as potential predictors of fork length (FL): length A, from the anterior end of the vertebral column to the tail fork; length B, from the posterior point of the severed dorsal fin to the tail fork; and, C, the processed weight.



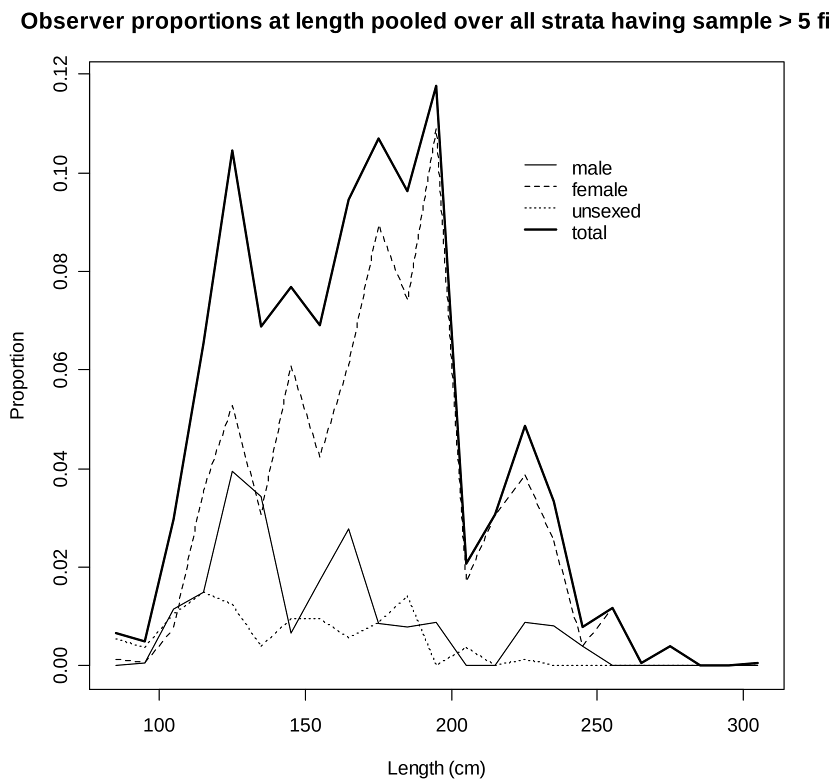


Figure 5: Sex-specific proportions at length of swordfish in tuna longline catches sampled by scientific observers from July 2005 to June 2006 in the NORTH stratum (top panel) and for those quarters in which more than 5 fish were sampled (bottom panel).

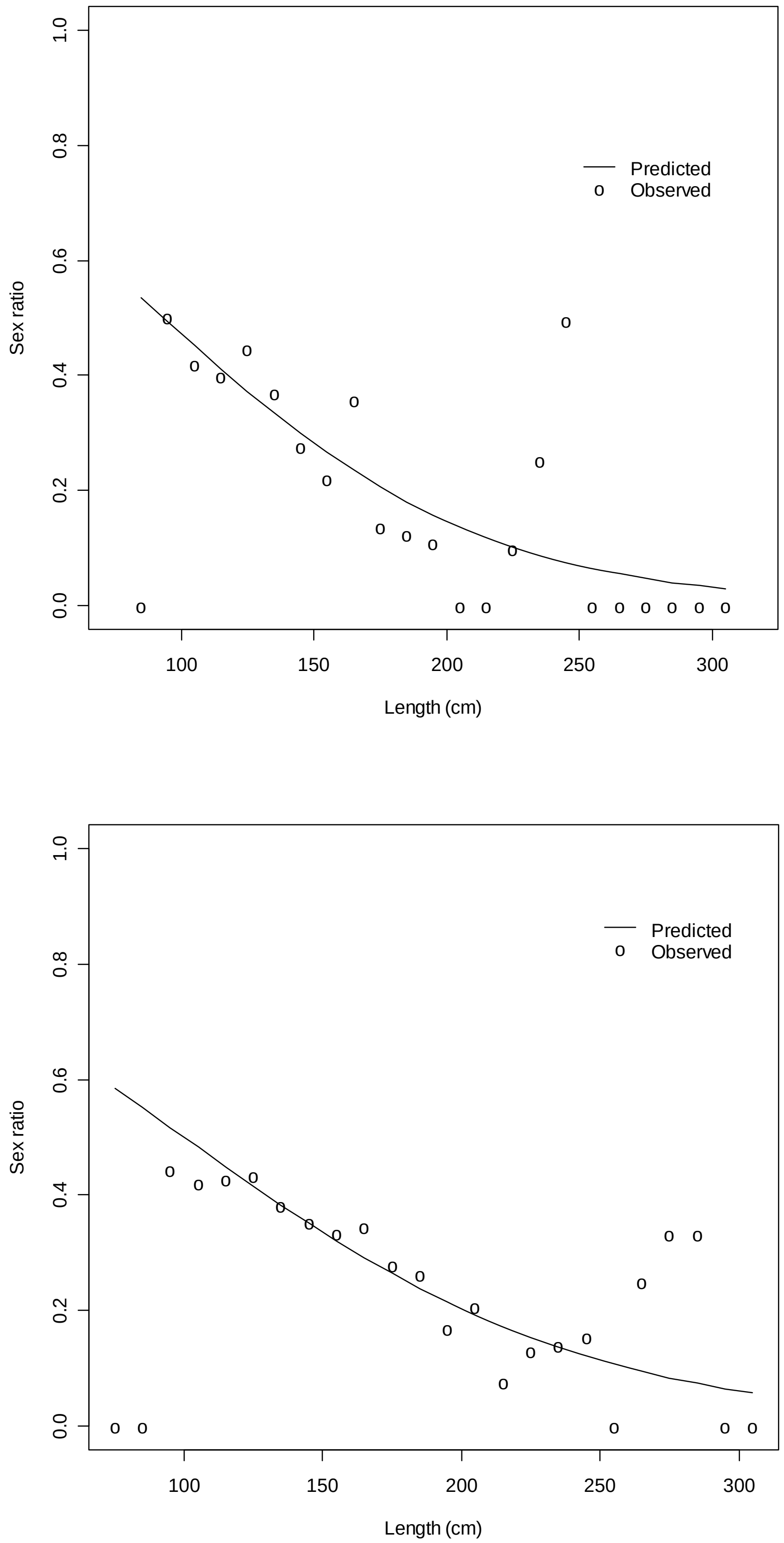


Figure 6: Length-specific sex ratios (open circles) expressed as the proportion of males in samples of swordfish catches collected by scientific observers on board tuna longline vessels in the NORTH stratum from July 2005 to June 2006 (top panel) and from 1988 to 2006 (bottom panel) with fitted reverse logistic functions (lines).

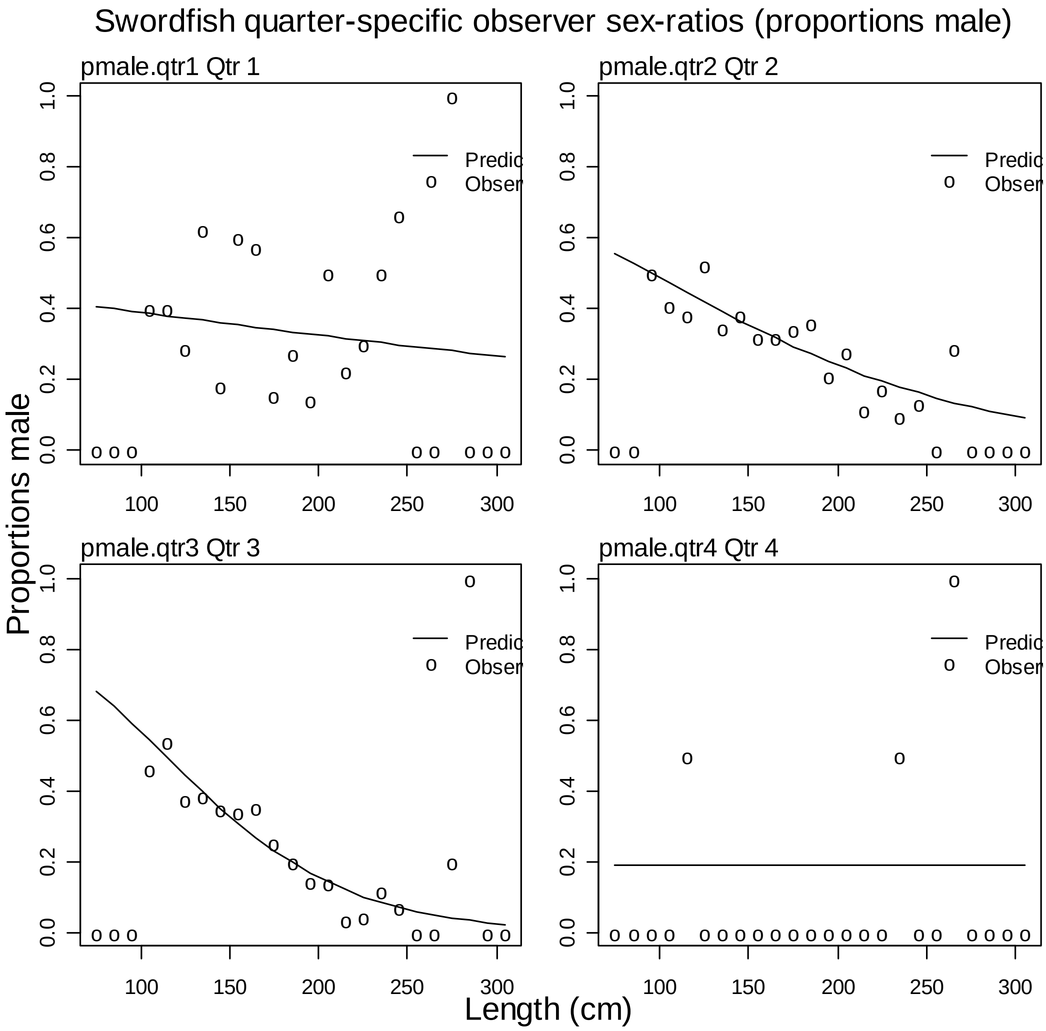


Figure 7: Length-specific sex ratios (open circles) expressed as the proportion of males in samples of swordfish catches collected by scientific observers on board tuna longline vessels for each quarter over all years from 1988 to June 2006 in the NORTH stratum with fitted reverse logistic functions (lines).

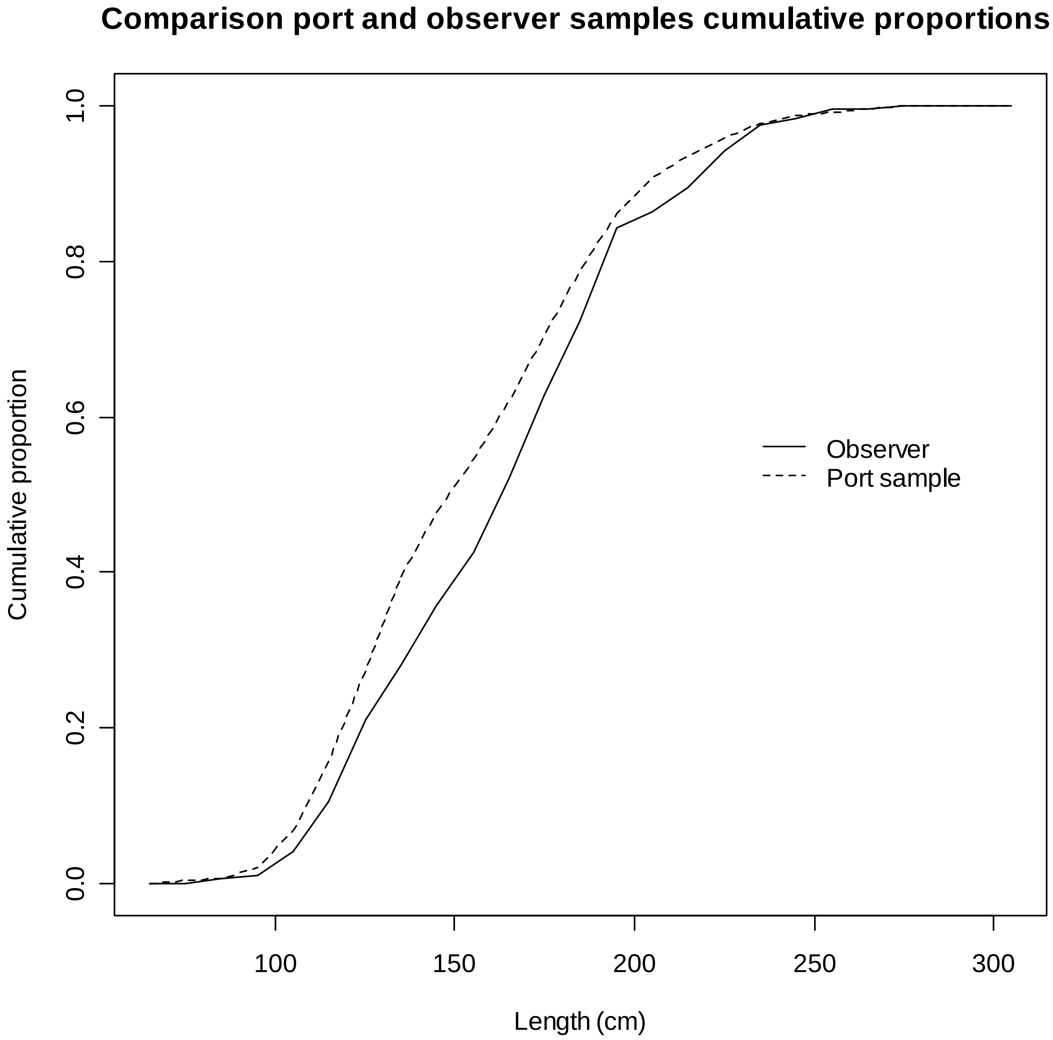


Figure 8: Comparison of the cumulative proportions at length of swordfish in tuna longline catches sampled by scientific observers and from port samples collected over the period July 2005 to June 2006 in the NORTH stratum.

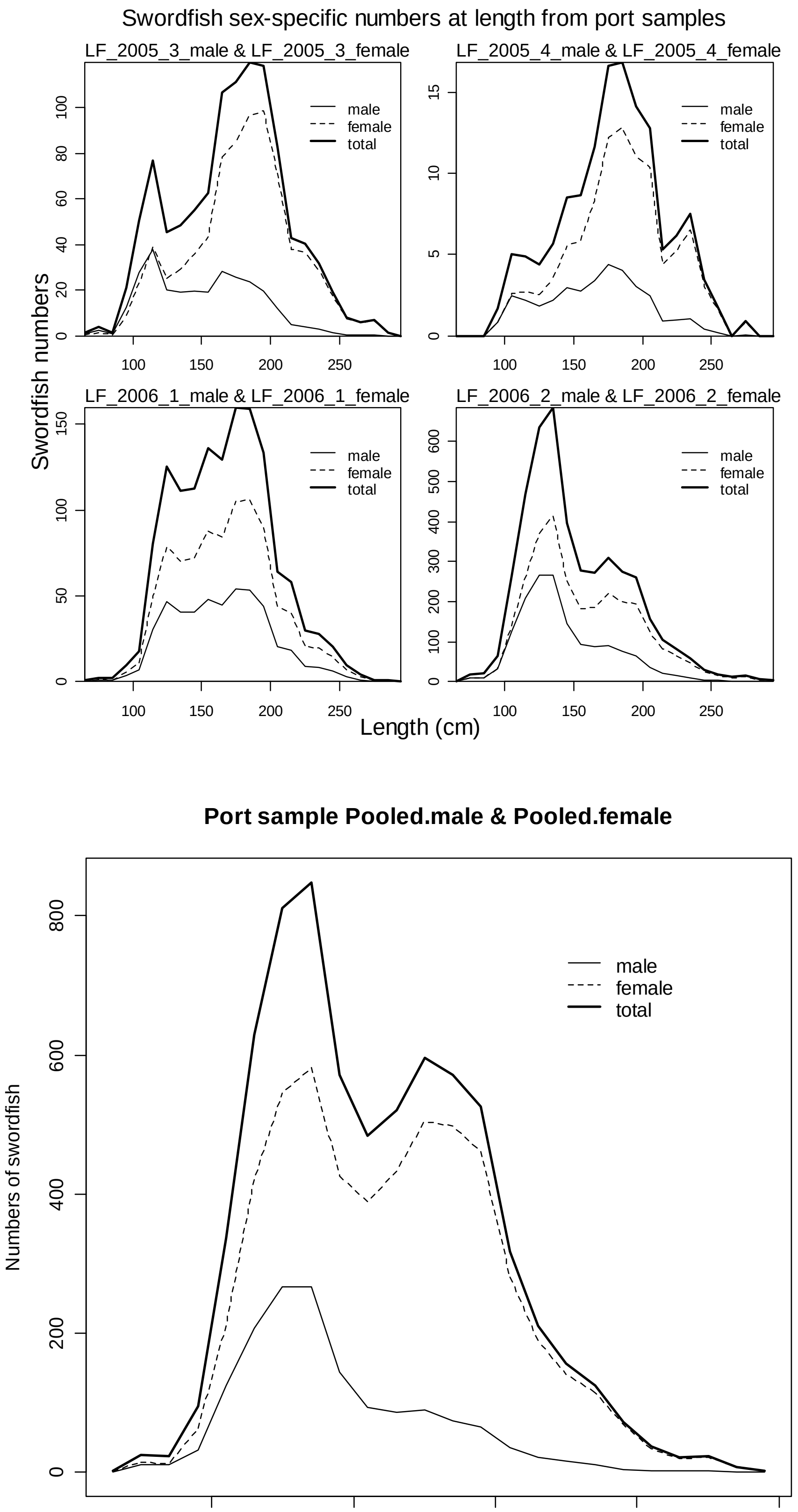


Figure 9: Sex-specific numbers at length of swordfish from port samples from tuna longline landings in each quarter from July 2005 to June 2006 (top four panels) and over all quarters (bottom panel) in the NORTH stratum.

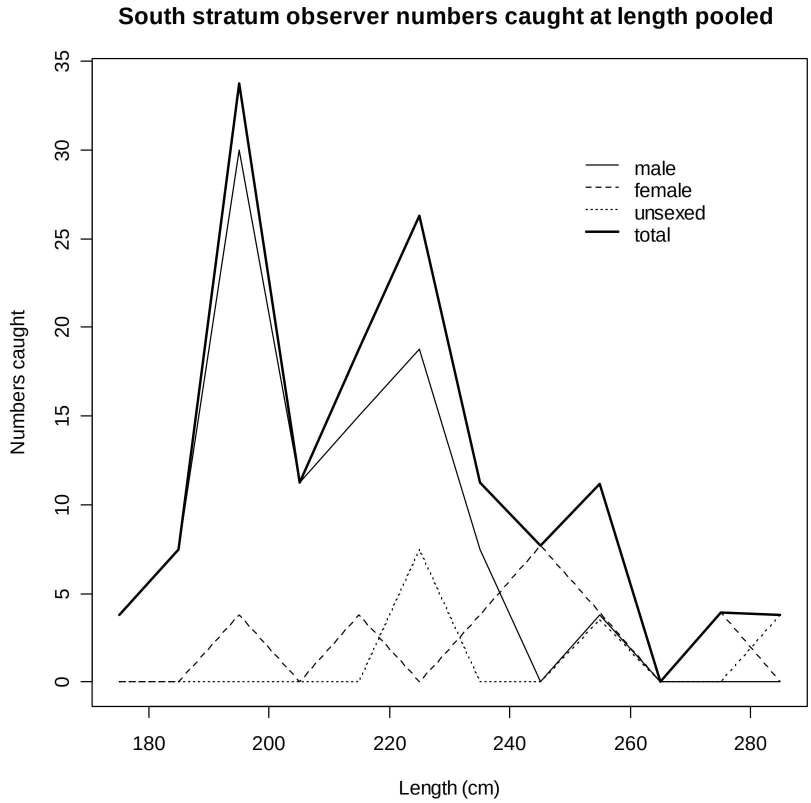


Figure 10: Sex-specific proportions at length of swordfish in tuna longline catches sampled by scientific observers from July 2005 to June 2006 in the SOUTH stratum.

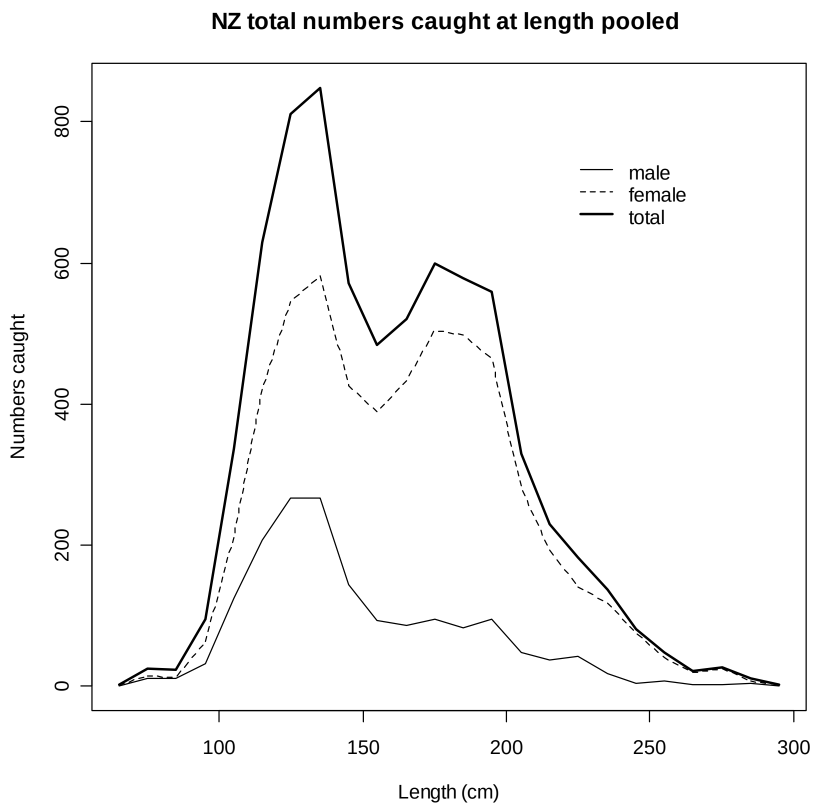


Figure 11: Sex-specific numbers at length of swordfish in New Zealand tuna longline landings from July 2005 to June 2006 estimated derived using samples from scientific observers on board tuna longliners and from port samples.

Appendix 1: Sex-specific proportions at length and coefficients of variation (c.v.) of swordfish in tuna longline catches sampled by scientific observers from July 2005 to June 2006 in the NORTH stratum.

P.j. = proportion of fish in length class, c.v. = coefficient of variation.

2005_3

Length	Male		Female		Unsexed		Total	
(cm)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.
85	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
95	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
105	0.0189	0.95	0.0000	0.00	0.0000	0.00	0.0189	0.95
115	0.0000	0.00	0.0566	0.56	0.0000	0.00	0.0566	0.56
125	0.0566	0.55	0.0755	0.49	0.0000	0.00	0.1321	0.34
135	0.0566	0.60	0.0377	0.68	0.0000	0.00	0.0943	0.44
145	0.0000	0.00	0.1132	0.41	0.0189	0.96	0.1321	0.37
155	0.0189	1.14	0.0000	0.00	0.0000	0.00	0.0189	1.14
165	0.0189	0.94	0.0377	0.67	0.0000	0.00	0.0566	0.55
175	0.0000	0.00	0.0943	0.41	0.0189	0.92	0.1132	0.36
185	0.0000	0.00	0.1132	0.37	0.0189	0.97	0.1321	0.34
195	0.0000	0.00	0.1321	0.33	0.0000	0.00	0.1321	0.33
205	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
215	0.0000	0.00	0.0377	0.72	0.0000	0.00	0.0377	0.72
225	0.0189	0.99	0.0377	0.71	0.0000	0.00	0.0566	0.57
235	0.0000	0.00	0.0189	0.95	0.0000	0.00	0.0189	0.95
245	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
255	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
265	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
275	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
285	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
295	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
305	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00

2005_4

Length	Male		Female		Unsexed		Total	
(cm)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.
85	0.0000	0.00	0.0141	0.91	0.0210	0.78	0.0351	0.63
95	0.0070	1.41	0.0070	1.32	0.0000	0.00	0.0141	0.92
105	0.0280	0.64	0.0419	0.71	0.0279	0.93	0.0977	0.56
115	0.0349	0.63	0.0561	0.47	0.0421	0.59	0.1331	0.28
125	0.0556	0.53	0.0630	0.40	0.0070	1.25	0.1256	0.32
135	0.0418	0.55	0.0979	0.40	0.0418	0.69	0.1815	0.27
145	0.0280	0.61	0.0422	0.54	0.0070	1.33	0.0772	0.34
155	0.0070	1.28	0.0279	0.71	0.0141	1.37	0.0490	0.45
165	0.0353	0.65	0.0422	0.70	0.0207	0.79	0.0981	0.45
175	0.0070	1.50	0.0210	0.77	0.0000	0.00	0.0280	0.63
185	0.0000	0.00	0.0139	1.07	0.0137	0.93	0.0277	0.76
195	0.0070	1.72	0.0490	0.59	0.0000	0.00	0.0560	0.66
205	0.0000	0.00	0.0142	0.97	0.0000	0.00	0.0142	0.97
215	0.0000	0.00	0.0140	0.84	0.0000	0.00	0.0140	0.84
225	0.0000	0.00	0.0140	0.85	0.0139	1.11	0.0280	0.71
235	0.0000	0.00	0.0070	1.27	0.0000	0.00	0.0070	1.27
245	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
255	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
265	0.0000	0.00	0.0070	1.29	0.0000	0.00	0.0070	1.29
275	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
285	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
295	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
305	0.0000	0.00	0.0070	1.20	0.0000	0.00	0.0070	1.20

Appendix 1 cont.

P.j. = proportion of fish in length class, c.v. = coefficient of variation.

2006_1

Length	Male		Female		Unsexed		Total	
(cm)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.
85	0.0000	0.00	0.0000	0.00	0.0077	1.28	0.0077	1.28
95	0.0000	0.00	0.0000	0.00	0.0085	1.75	0.0085	1.75
105	0.0000	0.00	0.0086	1.71	0.0182	0.99	0.0268	0.95
115	0.0267	1.07	0.0090	1.32	0.0251	0.85	0.0609	0.61
125	0.0177	1.15	0.0265	0.81	0.0269	0.77	0.0711	0.62
135	0.0090	1.23	0.0091	1.63	0.0000	0.00	0.0180	0.99
145	0.0090	1.29	0.0090	1.23	0.0000	0.00	0.0180	1.06
155	0.0181	1.06	0.0902	0.43	0.0185	1.26	0.1268	0.45
165	0.0359	0.83	0.0897	0.72	0.0086	1.68	0.1342	0.41
175	0.0180	0.93	0.0987	0.56	0.0000	0.00	0.1168	0.48
185	0.0180	0.98	0.0451	0.55	0.0093	1.55	0.0724	0.45
195	0.0183	1.12	0.0971	0.41	0.0000	0.00	0.1154	0.32
205	0.0000	0.00	0.0359	0.67	0.0084	1.27	0.0443	0.61
215	0.0000	0.00	0.0268	0.75	0.0000	0.00	0.0268	0.75
225	0.0000	0.00	0.0447	0.63	0.0000	0.00	0.0447	0.63
235	0.0181	1.21	0.0359	0.92	0.0000	0.00	0.0541	0.60
245	0.0088	1.51	0.0090	1.21	0.0000	0.00	0.0178	0.85
255	0.0000	0.00	0.0267	0.94	0.0000	0.00	0.0267	0.94
265	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
275	0.0000	0.00	0.0093	1.44	0.0000	0.00	0.0093	1.44
285	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
295	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
305	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00

2006_2

Length	Male		Female		Unsexed		Total	
(cm)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.
85	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
95	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
105	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
115	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
125	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
135	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
145	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
155	0.0000	0.00	0.0000	0.00	0.4657	0.72	0.4657	0.72
165	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
175	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
185	0.0000	0.00	0.5343	0.64	0.0000	0.00	0.5343	0.64
195	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
205	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
215	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
225	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
235	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
245	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
255	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
265	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
275	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
285	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
295	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
305	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00

Appendix 1 cont.

P.j. = proportion of fish in length class, c.v. = coefficient of variation.

Length (cm)	Male *P.j.*	Male c.v.	Female *P.j.*	Female c.v.	Unsexed *P.j.*	Unsexed c.v.	Total *P.j.*	Total c.v.
							Year 2005-06	
85	0.0000	0.00	0.0006	1.03	0.0023	1.58	0.0028	1.39
95	0.0003	1.63	0.0003	1.44	0.0016	2.80	0.0022	2.33
105	0.0049	0.80	0.0033	1.23	0.0045	0.85	0.0127	0.52
115	0.0064	0.97	0.0153	0.48	0.0064	0.65	0.0281	0.42
125	0.0169	0.50	0.0226	0.38	0.0053	0.83	0.0449	0.33
135	0.0147	0.49	0.0132	0.48	0.0017	0.73	0.0295	0.34
145	0.0028	0.82	0.0261	0.38	0.0041	1.02	0.0329	0.35
155	0.0075	0.70	0.0181	0.47	0.2701	0.79	0.2957	0.72
165	0.0120	0.54	0.0261	0.52	0.0024	1.09	0.0405	0.34
175	0.0037	0.90	0.0384	0.37	0.0038	1.00	0.0458	0.32
185	0.0034	0.97	0.3370	0.63	0.0061	0.81	0.3465	0.62
195	0.0037	0.99	0.0467	0.27	0.0000	0.00	0.0505	0.24
205	0.0000	0.00	0.0073	0.75	0.0016	1.39	0.0089	0.67
215	0.0000	0.00	0.0132	0.50	0.0000	0.00	0.0132	0.50
225	0.0038	1.04	0.0166	0.46	0.0006	1.08	0.0209	0.41
235	0.0034	1.26	0.0108	0.70	0.0000	0.00	0.0143	0.51
245	0.0017	1.34	0.0017	1.33	0.0000	0.00	0.0034	0.88
255	0.0000	0.00	0.0050	0.85	0.0000	0.00	0.0050	0.85
265	0.0000	0.00	0.0003	1.30	0.0000	0.00	0.0003	1.30
275	0.0000	0.00	0.0017	1.48	0.0000	0.00	0.0017	1.48
285	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
295	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
305	0.0000	0.00	0.0003	1.25	0.0000	0.00	0.0003	1.25

Pooled proportions for strata with sample size > 5 fish Year 2005-06

Length (cm)	Male *P.j.*	Male c.v.	Female *P.j.*	Female c.v.	Unsexed *P.j.*	Unsexed c.v.	Total *P.j.*	Total c.v.
85	0.0000	-	0.0013	-	0.0053	-	0.0066	-
95	0.0006	-	0.0006	-	0.0037	-	0.0050	-
105	0.0114	-	0.0076	-	0.0106	-	0.0296	-
115	0.0150	-	0.0356	-	0.0149	-	0.0655	-
125	0.0394	-	0.0528	-	0.0125	-	0.1046	-
135	0.0343	-	0.0307	-	0.0039	-	0.0688	-
145	0.0065	-	0.0608	-	0.0095	-	0.0768	-
155	0.0174	-	0.0422	-	0.0094	-	0.0691	-
165	0.0279	-	0.0610	-	0.0057	-	0.0945	-
175	0.0086	-	0.0895	-	0.0088	-	0.1069	-
185	0.0079	-	0.0741	-	0.0142	-	0.0962	-
195	0.0087	-	0.1090	-	0.0000	-	0.1177	-
205	0.0000	-	0.0171	-	0.0037	-	0.0208	-
215	0.0000	-	0.0307	-	0.0000	-	0.0307	-
225	0.0088	-	0.0386	-	0.0013	-	0.0487	-
235	0.0080	-	0.0253	-	0.0000	-	0.0332	-
245	0.0039	-	0.0040	-	0.0000	-	0.0078	-
255	0.0000	-	0.0117	-	0.0000	-	0.0117	-
265	0.0000	-	0.0006	-	0.0000	-	0.0006	-
275	0.0000	-	0.0041	-	0.0000	-	0.0041	-
285	0.0000	-	0.0000	-	0.0000	-	0.0000	-
295	0.0000	-	0.0000	-	0.0000	-	0.0000	-
305	0.0000	-	0.0006	-	0.0000	-	0.0006	-

Appendix 2: Predicted swordfish length-specific sex ratios derived from a reverse logistic function expressed as the proportion of males at length ($Pr_{male,l}$) and parameters from fitted functions to observations collected by scientific observers on board tuna longline vessels in the NORTH stratum from July 2005 to June 2006, and for each quarter from 1988 to June 2006. Sample size = *n*.

Length	Pooled					1988-06
	2005-06	Qtr1	Qtr2	Qtr3	Qtr4	Annual
65	0.615	0.414	0.581	0.724	0.187	0.617
75	0.575	0.407	0.554	0.683	0.187	0.584
85	0.535	0.400	0.527	0.639	0.187	0.551
95	0.493	0.393	0.499	0.592	0.187	0.517
105	0.452	0.386	0.472	0.544	0.187	0.483
115	0.412	0.380	0.445	0.494	0.187	0.449
125	0.373	0.373	0.418	0.445	0.187	0.415
135	0.335	0.367	0.391	0.397	0.187	0.383
145	0.299	0.360	0.365	0.351	0.187	0.351
155	0.266	0.353	0.340	0.307	0.187	0.321
165	0.235	0.347	0.316	0.267	0.187	0.292
175	0.207	0.341	0.293	0.230	0.187	0.264
185	0.181	0.334	0.271	0.197	0.187	0.239
195	0.158	0.328	0.250	0.167	0.187	0.215
205	0.137	0.322	0.230	0.142	0.187	0.193
215	0.119	0.316	0.211	0.119	0.187	0.172
225	0.102	0.310	0.193	0.100	0.187	0.154
235	0.088	0.304	0.177	0.084	0.187	0.137
245	0.076	0.298	0.161	0.070	0.187	0.122
255	0.065	0.292	0.147	0.058	0.187	0.108
265	0.056	0.286	0.134	0.048	0.187	0.095
275	0.048	0.280	0.121	0.040	0.187	0.084
285	0.041	0.275	0.110	0.033	0.187	0.074
295	0.035	0.269	0.100	0.027	0.187	0.065
305	0.030	0.263	0.090	0.022	0.187	0.058
l_{50}	93.42	-58.29	94.73	113.85	-1.53E+09	99.94
l_{to5}	178.52	1040.07	268.24	148.91	3.08E+09	215.98
n	310	153	997	1083	16	2249

Appendix 3: Proportions at length and coefficients of variation (c.v.) of swordfish in tuna longline catches from July 2005 to June 2006 in the NORTH stratum estimated from port samples by quarter and pooled over all quarters.

P.j. = proportion of fish in length class, *N.j.* = number of fish in length class, c.v.(*P.j.*) and c.v.(*N.j.*) = coefficients of variation.

Length (cm)	2005_3 *P.j.*	c.v.(*P.j*)	*N.j.*	c.v.(*N.j.*)	2005_4 *P.j.*	c.v.(*P.j*)	*N.j.*	c.v.(*N.j.*)
65	0.0011	1.00	1.2	1.00	0.0000	0.00	0.0	0.00
75	0.0035	0.88	3.7	0.89	0.0000	0.00	0.0	0.00
85	0.0012	1.49	1.3	1.50	0.0000	0.00	0.0	0.00
95	0.0197	0.40	20.8	0.41	0.0122	1.11	1.7	1.20
105	0.0476	0.28	50.5	0.30	0.0371	0.65	5.0	0.72
115	0.0724	0.21	76.7	0.23	0.0359	0.66	4.9	0.69
125	0.0426	0.26	45.2	0.28	0.0321	0.66	4.4	0.69
135	0.0459	0.27	48.6	0.28	0.0418	0.55	5.7	0.57
145	0.0520	0.22	55.1	0.23	0.0623	0.50	8.5	0.53
155	0.0591	0.20	62.6	0.20	0.0635	0.39	8.6	0.38
165	0.1005	0.16	106.5	0.16	0.0858	0.38	11.7	0.40
175	0.1048	0.15	111.0	0.15	0.1223	0.31	16.6	0.31
185	0.1132	0.14	119.9	0.14	0.1240	0.27	16.9	0.26
195	0.1114	0.15	118.0	0.14	0.1039	0.31	14.1	0.30
205	0.0782	0.18	82.8	0.16	0.0942	0.30	12.8	0.27
215	0.0402	0.24	42.6	0.23	0.0389	0.52	5.3	0.51
225	0.0381	0.26	40.3	0.25	0.0455	0.42	6.2	0.41
235	0.0298	0.30	31.5	0.29	0.0555	0.42	7.5	0.40
245	0.0178	0.34	18.9	0.32	0.0254	0.57	3.5	0.56
255	0.0076	0.56	8.0	0.55	0.0130	0.90	1.8	0.88
265	0.0057	0.65	6.1	0.65	0.0000	0.00	0.0	0.00
275	0.0064	0.52	6.8	0.52	0.0066	1.28	0.9	1.26
285	0.0013	1.24	1.3	1.23	0.0000	0.00	0.0	0.00
295	0.0000	0.00	0.0	0.00	0.0000	0.00	0.0	0.00

Length (cm)	2006_1 *P.j.*	c.v.(*P.j*)	*N.j.*	c.v.(*N.j.*)	2006_2 *P.j.*	c.v.(*P.j*)	*N.j.*	c.v.(*N.j.*)
65	0.0008	1.47	1.1	1.48	0.0000	0.00	0.0	0.00
75	0.0015	1.26	2.2	1.26	0.0044	0.46	19.5	0.47
85	0.0014	1.09	2.0	1.10	0.0046	0.39	20.3	0.40
95	0.0068	0.70	9.4	0.71	0.0142	0.24	62.9	0.25
105	0.0125	0.37	17.5	0.38	0.0596	0.11	263.5	0.13
115	0.0576	0.18	80.4	0.21	0.1055	0.11	466.7	0.13
125	0.0900	0.15	125.6	0.17	0.1438	0.07	636.3	0.09
135	0.0795	0.15	111.0	0.16	0.1544	0.07	683.2	0.09
145	0.0807	0.14	112.5	0.15	0.0892	0.09	394.6	0.09
155	0.0975	0.13	136.0	0.13	0.0625	0.10	276.4	0.10
165	0.0927	0.10	129.3	0.11	0.0616	0.11	272.5	0.11
175	0.1142	0.10	159.3	0.10	0.0699	0.10	309.1	0.09
185	0.1141	0.10	159.1	0.09	0.0623	0.10	275.6	0.09
195	0.0957	0.13	133.4	0.11	0.0588	0.12	260.0	0.10
205	0.0461	0.17	64.3	0.16	0.0356	0.13	157.7	0.12
215	0.0416	0.20	58.0	0.19	0.0238	0.16	105.2	0.15
225	0.0212	0.23	29.5	0.23	0.0182	0.19	80.5	0.18
235	0.0200	0.26	27.9	0.24	0.0131	0.21	58.0	0.20
245	0.0148	0.32	20.7	0.30	0.0068	0.29	30.1	0.28
255	0.0069	0.42	9.7	0.41	0.0040	0.37	17.8	0.36
265	0.0030	0.68	4.2	0.67	0.0027	0.46	11.9	0.46
275	0.0007	1.36	0.9	1.35	0.0033	0.41	14.7	0.41
285	0.0007	1.41	1.0	1.41	0.0012	0.67	5.2	0.67
295	0.0000	0.00	0.0	0.00	0.0006	0.92	2.6	0.91

Appendix 3 cont.

Length (cm)	Year 2005-06			
	P.j.	c.v.(*P.j*)	*N.j.*	c.v.(*N.j.*)
65	0.0003	0.90	2.3	0.90
75	0.0036	0.40	25.3	0.40
85	0.0034	0.36	23.5	0.36
95	0.0135	0.19	94.8	0.20
105	0.0480	0.10	336.5	0.12
115	0.0896	0.09	628.7	0.11
125	0.1157	0.07	811.4	0.08
135	0.1209	0.07	848.4	0.08
145	0.0814	0.07	570.8	0.08
155	0.0689	0.07	483.6	0.07
165	0.0741	0.07	519.9	0.07
175	0.0850	0.06	596.1	0.06
185	0.0815	0.06	571.5	0.06
195	0.0749	0.08	525.6	0.07
205	0.0453	0.09	317.7	0.08
215	0.0301	0.11	211.2	0.10
225	0.0223	0.13	156.5	0.12
235	0.0178	0.14	125.0	0.13
245	0.0104	0.18	73.1	0.18
255	0.0053	0.24	37.3	0.23
265	0.0032	0.34	22.1	0.34
275	0.0033	0.31	23.3	0.30
285	0.0011	0.53	7.6	0.53
295	0.0004	0.92	2.6	0.91

Appendix 4: Estimated sex-specific numbers at length for swordfish in tuna longline catches in NORTH stratum in 2005–06 from port samples by quarter and pooled over all quarters.

Length	2005_3		2005_4		2006_1		2006_2		Year 2005-06	
(cm)	male	female	male	female	male	female	male	female	male	female
65	0.9	0.3	0.0	0.0	0.4	0.6	0.0	0.0	0.0	2.3
75	2.5	1.2	0.0	0.0	0.9	1.3	10.8	8.7	10.8	14.5
85	0.8	0.5	0.0	0.0	0.8	1.2	10.7	9.6	10.7	12.8
95	12.3	8.5	0.9	0.8	3.7	5.7	31.4	31.5	31.4	63.4
105	27.4	23.0	2.4	2.6	6.8	10.7	124.3	139.2	124.3	212.2
115	37.9	38.8	2.2	2.7	30.5	49.9	207.5	259.2	207.5	421.2
125	20.1	25.1	1.8	2.5	46.8	78.7	265.8	370.5	265.8	545.6
135	19.3	29.3	2.2	3.5	40.7	70.3	267.3	415.9	267.3	581.1
145	19.3	35.8	3.0	5.5	40.5	72.0	144.2	250.4	144.2	426.5
155	19.2	43.4	2.8	5.9	48.1	87.9	94.1	182.3	94.1	389.5
165	28.4	78.1	3.4	8.3	44.9	84.4	86.1	186.3	86.1	433.7
175	25.5	85.5	4.4	12.2	54.3	105.0	90.6	218.6	90.6	505.5
185	23.6	96.3	4.0	12.8	53.2	105.9	74.6	201.0	74.6	496.9
195	19.8	98.3	3.0	11.1	43.8	89.7	64.9	195.1	64.9	460.7
205	11.7	71.1	2.5	10.3	20.7	43.6	36.2	121.5	36.2	281.4
215	5.1	37.6	0.9	4.4	18.3	39.7	22.2	83.0	22.2	189.0
225	4.0	36.3	1.0	5.2	9.1	20.4	15.5	65.0	15.5	141.0
235	2.6	28.9	1.0	6.5	8.5	19.5	10.2	47.8	10.2	114.8
245	1.3	17.6	0.4	3.0	6.2	14.5	4.8	25.2	4.8	68.3
255	0.5	7.6	0.2	1.6	2.8	6.8	2.6	15.2	2.6	34.7
265	0.3	5.8	0.0	0.0	1.2	3.0	1.6	10.3	1.6	20.5
275	0.3	6.5	0.1	0.8	0.3	0.7	1.8	12.9	1.8	21.5
285	0.0	1.3	0.0	0.0	0.3	0.7	0.6	4.7	0.6	7.0
295	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.4	0.3	2.4

Appendix 5: Estimated seasonal proportion at length, c.v.s and numbers of swordfish caught in tuna longline catches in SOUTH stratum in 2005–06 from samples taken by scientific observers on board vessels.

P.j. = proportion of fish in length class, *N.j.* = number of fish in length class,
c.v. = coefficient of variation.

2006_2

Length	Male		Female		Unsexed		Total		
(cm)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*N.j.*
175	0.0270	1.15	0.0000	0.00	0.0000	0.00	0.0270	1.1540	3.75
185	0.0540	0.96	0.0000	0.00	0.0000	0.00	0.0540	0.9625	7.50
195	0.2158	0.78	0.0271	1.56	0.0000	0.00	0.2429	0.4888	33.77
205	0.0809	0.94	0.0000	0.00	0.0000	0.00	0.0809	0.9381	11.25
215	0.1079	0.90	0.0271	1.63	0.0000	0.00	0.1350	0.6879	18.76
225	0.1349	0.85	0.0000	0.00	0.0540	1.01	0.1888	0.8120	26.25
235	0.0540	1.01	0.0271	1.73	0.0000	0.00	0.0810	0.9245	11.26
245	0.0000	0.00	0.0551	1.17	0.0000	0.00	0.0551	1.1739	7.66
255	0.0270	1.27	0.0281	1.68	0.0251	1.64	0.0802	1.0566	11.16
265	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.0000	0.00
275	0.0000	0.00	0.0281	1.56	0.0000	0.00	0.0281	1.5642	3.91
285	0.0000	0.00	0.0000	0.00	0.0270	1.24	0.0270	1.2432	3.75

Appendix 6: Estimated sex-specific numbers at length for swordfish in tuna longline catches in NORTH and SOUTH strata, and the NZ pooled estimates in 2005–06 from port samples and scientific observer collections.

Length	NORTH			SOUTH			pooled NZ		
(cm)	male	female	total	male	female	total	male	female	total
65	0.0	2.3	2.3	0.0	0.0	0.0	0.0	2.3	2.3
75	10.8	14.5	25.3	0.0	0.0	0.0	10.8	14.5	25.3
85	10.7	12.8	23.5	0.0	0.0	0.0	10.7	12.8	23.5
95	31.4	63.4	94.8	0.0	0.0	0.0	31.4	63.4	94.8
105	124.3	212.2	336.5	0.0	0.0	0.0	124.3	212.2	336.5
115	207.5	421.2	628.7	0.0	0.0	0.0	207.5	421.2	628.7
125	265.8	545.6	811.4	0.0	0.0	0.0	265.8	545.6	811.4
135	267.3	581.1	848.4	0.0	0.0	0.0	267.3	581.1	848.4
145	144.2	426.5	570.8	0.0	0.0	0.0	144.2	426.5	570.8
155	94.1	389.5	483.6	0.0	0.0	0.0	94.1	389.5	483.6
165	86.1	433.7	519.9	0.0	0.0	0.0	86.1	433.7	519.9
175	90.6	505.5	596.1	3.8	0.0	3.8	94.3	505.5	599.9
185	74.6	496.9	571.5	7.5	0.0	7.5	82.1	496.9	579.0
195	64.9	460.7	525.6	30.0	3.8	33.8	94.9	464.5	559.4
205	36.2	281.4	317.7	11.3	0.0	11.3	47.5	281.4	328.9
215	22.2	189.0	211.2	15.0	3.8	18.8	37.2	192.8	229.9
225	15.5	141.0	156.5	26.3	0.0	26.3	41.8	141.0	182.8
235	10.2	114.8	125.0	7.5	3.8	11.3	17.7	118.5	136.3
245	4.8	68.3	73.1	0.0	7.7	7.7	4.8	75.9	80.8
255	2.6	34.7	37.3	5.5	5.7	11.2	8.1	40.4	48.4
265	1.6	20.5	22.1	0.0	0.0	0.0	1.6	20.5	22.1
275	1.8	21.5	23.3	0.0	3.9	3.9	1.8	25.4	27.2
285	0.6	7.0	7.6	2.9	0.8	3.8	3.5	7.8	11.3
295	0.3	2.4	2.6	0.0	0.0	0.0	0.3	2.4	2.6