SCIENTIFIC COMMITTEE
FOURTH REGULAR SESSION

11-22 August 2008
Port Moresby, Papua New Guinea

SWORDFISH CPUE TRENDS ACROSS THE SOUTHERN WCPO

WCPFC-SC4-2008/SA-IP-4

Robert Campbell[1], Martin Unwin[2], Nick Davies[2], Naozumi Miyabe[3],

[1] CSIRO Marine and Atmospheric Research, Hobart, Australia
[2] NIWA, New Zealand
[3] NRIFSF, Shimizu, Japan

Swordfish CPUE Trends across the Southern WCPO

Robert Campbell[1], Martin Unwin[2] and Nick Davies[2], Naozumi Miyabe[3]
1. *CSIRO Marine and Atmospheric Research, Australia*
2. *NIWA, New Zealand*
3. *NRIFSF, Japan*

July 2008

1. Introduction

Indices of stock abundance (or more correctly, resource availability) are an important input into most stock assessments. While fishery independent indices are preferred, in most assessments relating to high migratory species such as tunas and billfish such indices are usually not available due to practical issues of scale in undertaking the required surveys. As such, indices based on the catch and effort data obtained from the fleets catching these species are most commonly used. In particular, indices based on standardised catch–per-unit-effort (CPUE) are the most common indices used. In this paper a number of CPUE based indices relating to swordfish availability across the southern western-central Pacific Ocean (WCPO) are presented.

2. Standardised catch-rates - Australia

We use the data recorded in logbooks on catch and effort for the Australian Eastern Tuna and Billfish Fishery (ETBF) to calculate annual and quarterly time-series indexing swordfish availability to this fleet.

The ETBF has undergone several periods of development and associated changes in targeting practices since the advent of the logbook program in 1987. As a result, the consequence temporal and spatial heterogeneity of the fishery, and associated data limitations, influence the ability to formulate meaningful abundance indices.

2.1 *Temporal Limitations*

Since the inception of the logbook program in the ETBF in 1987, four different logbooks have been utilised – AL02, AL03, AL04 and AL05 (NB. AL = Australian Longline). The percentage of sets deployed in the ETBF each year covered by each of these logbooks is shown in Figure 3.1.

A range of different information on the nature of the fishing gears, baits and targeting practices associated with any single longline set has also been collected by these logbooks over the years. However, due to the fact that the types of information recorded in logbooks has changed over time, the amount and types of data available for standardizing catch rates has also changed over time. A listing of the main variables is shown in Table 3.1.

As most of the important standardising variables were not collected in the AL02 logbook, and several were missing from the AL03 logbook (which was only used for

Figure 3.1. Annual logbook coverage (as a percentage of sets) in the ETBF.

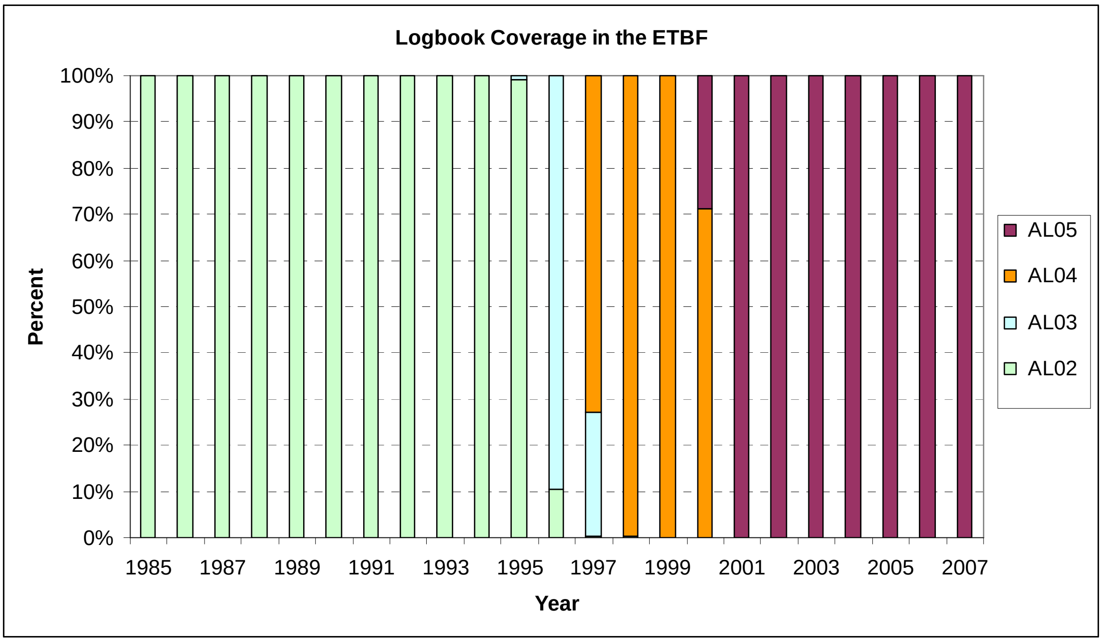


Table 3.1. List of information collected in each of the AL0x Logbooks useful for standardising CPUE.

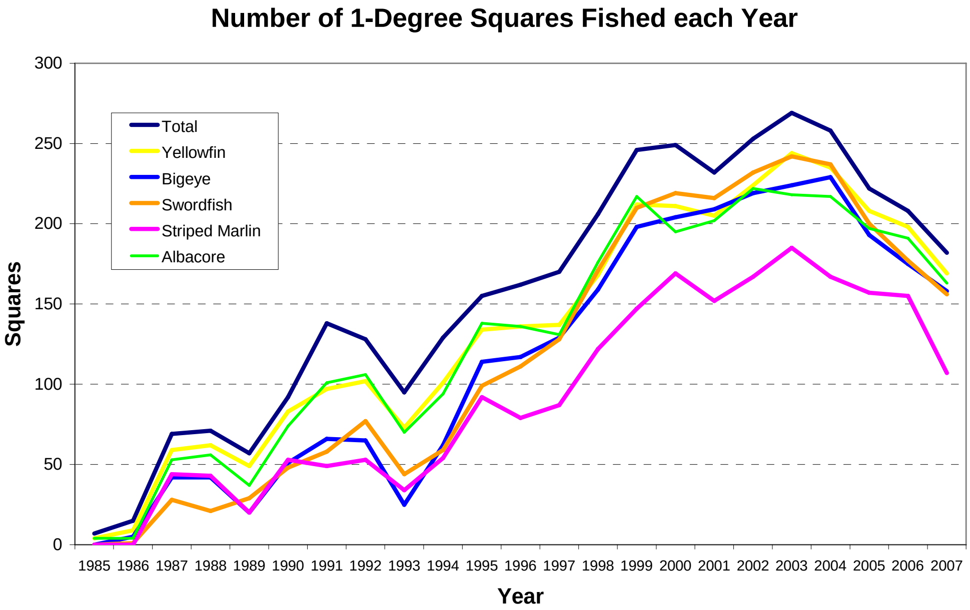
	AL02	AL03	AL04	AL05
Year	√	√	√	√
Quarter	√	√	√	√
Vessel	√	√	√	√
Hooks-per-basket	√	√	√	√
Start-time of set		√	√	√
Target Species		√	√	√
Bait-type			√	√
Number of hooks with light-sticks			√	√

a short period), all analyses outlined in this paper begin in 1997 and only makes use of the data collected in the AL04 and AL05 logbooks. (Note, as the year effect used in the standardisation corresponds to the financial year (1-July to 30 June) it is useful to note that 98.4% of sets during the second half of 1997 were covered by the AL04 logbook.)

2.2 *Spatial Limitations.*

The spatial extent of the ETBF can be usefully expressed by the number of 1x1-degreee squares of latitude and longitude fished each year and is shown in Figure 3.2. This clearly shows the spatial expansion of the fishery during the 1990s and early 2000s followed by a slight contraction in more recent years. The fishery reached its maximum extent in 2003 when 269 1x1-degree squares were fished. However, aggregated over all years, longline sets have been deployed in a total of 399 squares though many of these squares have been fished infrequently. Indeed, less than half (156) have been fished for at least 5 of the ten years between 1997 and 2006 and also have at least 5 sets deployed in any single year.

Figure 3.2. Number of 1-degree squares fished by longline vessels each year in the ETBF and the number of squares in which the five main target species were caught.



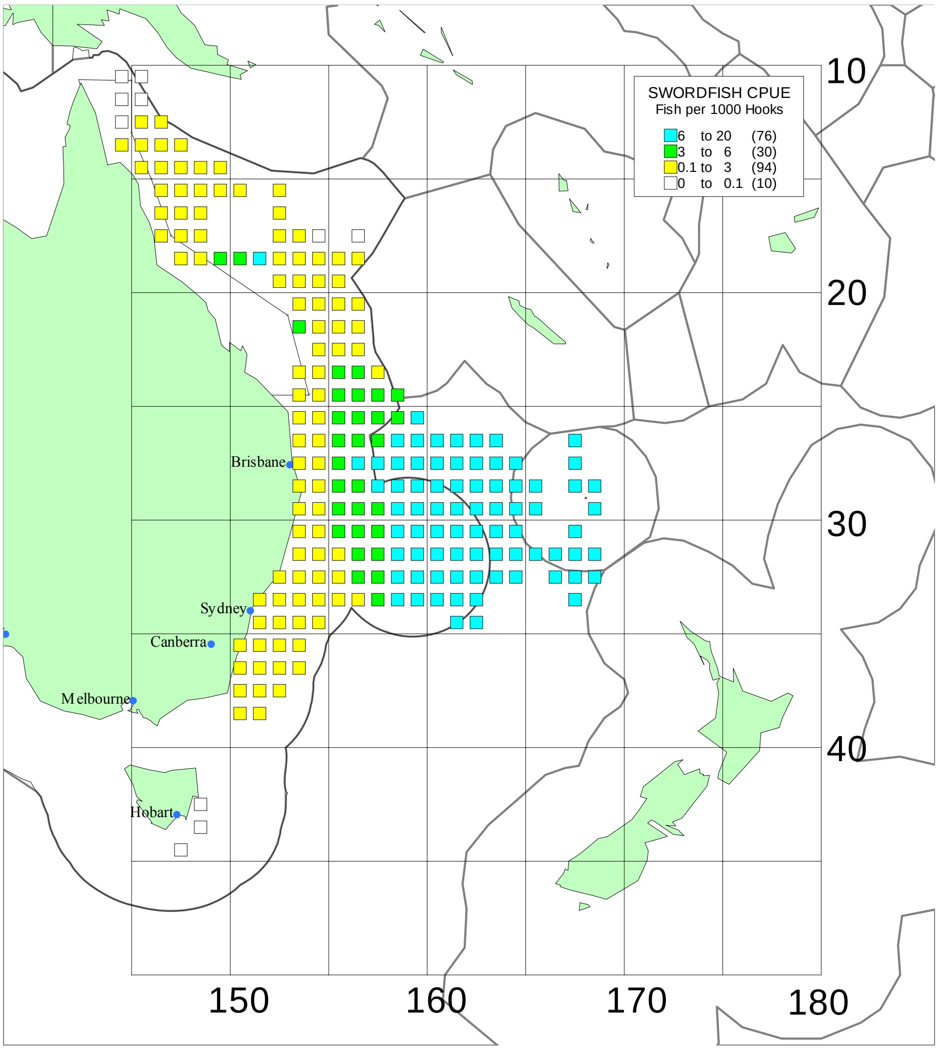
Due to the expansion of the fishery after 1997 the data coverage of many outer regions of the fishery is limited to a smaller number of years than the ten years between 1997 and 2006. This makes it difficult to estimate abundance indices at the beginning of the time series when these areas were not fished. In a similar manner, it is also difficult to estimate abundance indices in those areas which are no longer fished.

In deciding on the spatial limits to place on the data for use in the standardisations the spatial areas used in the GLM analysis were selected to match the spatial distribution of the catch rates for swordfish. In particular, the spatial distribution of nominal catch rates of swordfish within each 1-degree square (taken over the years 1997-2006 and only within 1-degree squares having greater than 4 sets over this period) is shown in Figure 3.3. Based on this distribution, three areas were identified based on combining adjacent squares with similar catch rates and only selecting consistently fished squares (each 1x1-square had to contain a least 30 fishing operations (fops) to be included). Each area for use in the GLM was defined as follows:

Area=1	Nfops>30 and cpe_swo>0.1 and cpe_swo<=3.0 latitude between -35 and -23 and longitude<157
Area =2	Nfops>30 and cpe_swo>3.0 and cpe_swo<=6.0 latitude between -35 and -23 and longitude>155
Area =3	Nfops>30 and cpe_swo>6.0 latitude between -35 and -23, longitude between 155 and 165

Of the 399 squares fishing across the entire ETBF, each area contains the following number of squares: Area 1 (33), Area 2 (27) and Area 3 (59).

Figure 3.3. Distribution of nominal swordfish CPUE (aggregated over the years 1997-2007) within 1x1-degree squares in the ETBF.



2.3 General Linear Models (GLMs)

A range of variables were available to standardize the CPUE. These variables, together with the model parameter names and category definitions, are listed in Table 3.2. The percentage of all fishing operations each year deploying various gear settings is displayed in Figures 3.4a-d. Most variables were fitted as categorical variables with a given range of values for each variable being associated with a discrete category (eg. the start times were categorized into six 4-hourly intervals of time). Only moon-phase was fitted as a continuous variable. The southern-oscillation-index variable was normalized based on the mean and standard deviation of the values across all sets included in the analysis, then categorized into one of the five categories depending on whether |z| was less than or greater than 0.3 or 1.0.

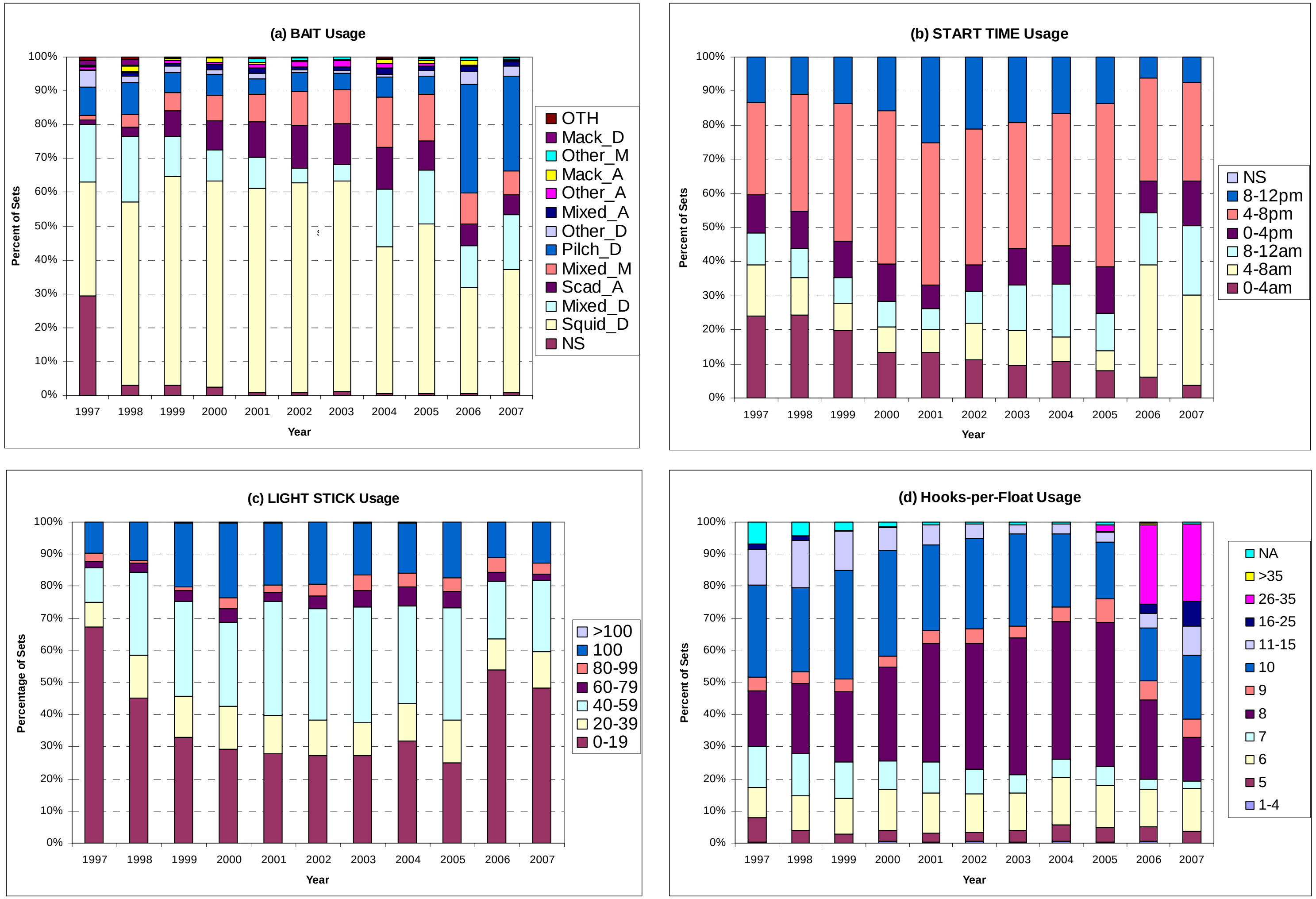
Several additional factors were also included in the analysis to help account for the influence of competitive factors between vessels on a daily and a monthly basis. These were defined as follows:

- The number of other vessels which fished in the same 1x1-degree / day strata. This was taken as a measure of the competition that day.

Table 3.2. Listing of variables, together with the model parameter names and category definitions, used to standardize CPUE.

Factor	Level	Category	Number of Sets
Year	1	1997	5147
	2	1998	6009
	3	1999	7513
	4	2000	7688
	5	2001	9294
	6	2002	9900
	7	2003	8553
	8	2004	7339
	9	2005	5772
	10	2006	4421
	11	2007	2435
Quarter	1	Jan-Mar	15908
	2	Apr-Jun	17393
	3	Jul-Sep	22381
	4	Oct-Dec	18389
Area Fished	1	Inshore	40390
	2	Middle	17490
	3	Offshore	16191
Start Time	1	before 4am	8455
	2	4am to 8am	6026
	3	8am to noon	5638
	4	noon to 4pm	6975
	5	4pm to 8pm	34488
	6	8pm to midnight	12489
Bait	1	squid, dead	47929
	2	yellowftail scad, alive	5252
	3	pilchard, dead	2676
	4	other, dead	1285
	5	other, alive	874
	6	mixed species, dead	498
	7		6853
	8		614
	9		7455
	10	mixed species, alive & dead	635
Hooks-per-Basket	1	HPB = 5 and below	2984
	2	6	9142
	3	7	6517
	4	8	29211
	5	9	3248
	6	10	14041
	7	HPB between 11 and 19	6449
	8	HPB between 20 and 40	2479
Hooks with Lights	1	0%	10940
	2	1 to 19 %	4212
	3	20 to 39 %	7556
	4	40 to 59 %	27996
	5	60 to 79 %	3797
	6	80 to 99 %	3259
	7	100%	16311
Southern Oscillation	1	soi<-1sd	11108
Index	2	:-1sd<soi<-0.3sd	16928
(standardised)	3	soi<abs(0.3sd)	17491
	4	0.3sd<soi<1sd	13935
	5	soi>1sd	14609
Moon-phase (days since full moon)	covariate	abs(cos(moon*3.14152/29))	74071
Number of other	1	0	29049
vessels fishing same	2	1	17255
1-degree square on	3	2	10302
same day	4	3	6577
	5	4	3998
	6	5	2662
	7	6	1513
	8	7 or more	2715
Number of other	1	0 to 2	14829
vessels fishing same	2	3 to 5	10858
1-degree square during	3	6 to 8	9523
same month	4	9 to 11	6986
	5	12 to 14	5819
	6	15 to 17	9681
	7	18 to 20	7586
	8	21 or more	8789
Total Sets			74071

Figure 3.4 Percentage of all fishing operations each year in the ETBF deploying various gear settings.



- The total effort (as measured by the total number of hooks) deployed by other vessels in the same 1x1-degree that month. This was taken as a measure of the competition that month.

Each variable was apportioned into a number of levels and the resulting factors fitted as categorical variables in the GLM.

Due to the inflated number of zero catch observations (30% of the 74,071 fops included in the analysis) it was considered more appropriate to standardise the CPUE data as a two stage process: the first stage being concerned with the pattern of occurrence of positive catches, and the second stage with the mean size of the positive catch rates. For both stages the means were modelled as linear combinations of the available standardising variables and then combined to give an overall mean abundance index.

A small example helps illustrate this approach. Consider a season for which there are n catch rate observations, C_i. The average catch rate can be expressed as follows:

$$\mu = \frac{1}{n}\sum_{i=1}^{n} C_i = \frac{1}{n_S + n_F}\sum_{i=1}^{n_s} C_i = \frac{n_S}{n_S + n_F}\frac{1}{n_S}\sum_{i=1}^{n_s} C_i = p_S \mu_S$$

where n_S is the number of positive or successful catch rates obtained (C_i>0), n_F is the number of zero or failed catches (C_i =0), p_S is the proportion of positive catches and μ_S is the average of the positive catch rates. This result shows that the overall mean catch rate can be expressed as the combination of the parameters from the distributions used to model the probability of a successful catch and that used to model the non-zero catch rates. A similar approach was used in the estimation of egg production based on plankton surveys (Pennington 1983, Pennington and Berrien 1984) and for estimating indices of fish abundance based on aerial spotter surveys (Lo et al 1992).

Stage 1: Prob(positive catch)

The Binominal distribution is used to model the probability of a non-zero catch where we model each observation as either a success (C_i >0) of a failure (C_i =0), with the probability of either expressed as follows:

$$\Pr(C_i > 0) = p_S \qquad \text{and} \qquad \Pr(C_i = 0) = 1 - p_S$$

Associated with each observation is a vector of covariates or explanatory variables X_j thought likely to influence the probability of a positive catch. Furthermore, we assume that the dependence of p_S occurs through a linear combination $\eta = \sum \beta_j X_j$ of the explanatory variables. In order to ensure that 0≤ p_S≤1 we use the logit link function which takes the following form:

$$\eta = \log\left(\frac{p_S}{1 - p_S}\right)$$

The inverse of this relation gives the probability of a positive sighting as a function of the explanatory variables:

$$p_S = \frac{e^\eta}{1 + e^\eta} = \frac{\exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + ...)}{1 + \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + ...)}$$

The following model was then fitted to the data using the SAS GENMOD procedure:

MODEL p_S = *year*qtr* region + hpb + clights + bait +start_time + moon_phase + soi* region + dvescat + mveseff*

/ dist=binomial link=logit

The standardised probability for a positive catch, p_S, was then calculated for each spatio-temporal strata (year, quarter and area) against a standard set of model factors.

Stage 2: Mean Size of Positive Catch Rate

Having fitted the above model to the probability of obtaining a positive catch, a separate model was fitted to the distribution of positive catch rates, μ_S. For this purpose a log-Gamma model was adopted, such that the μ_S was assumed to have a gamma distribution with a log link to the vector of covariates or explanatory variables X_j. The data fitted to the model were limited to those observations having a positive catch.

As before, the following model was then fitted to the data using the SAS GENMOD procedure:

MODEL μ_S= *year*qtr*region + hpb + lights + bait +start_time + moon_phase + soi* region + dvesn + mvesn*

/ dist=gamma link=log

A standardised mean positive catch rate, μ_S, was then calculated for each spatio-temporal strata (year, quarter and region) against a standard set of model factors.

d) Abundance Index

The above models were fitted to each of the two data-sets defined previously and the results used to calculate a relative index of abundance, *I(year)*, by taking the average across all *NQ* quarters and then taking the area-weighted sum across all *NR* regions as follows:

$$I(year) = \sum_{region=1}^{NR} \left[\frac{Area_{region}}{NQ} \sum_{qtr=1}^{NQ} p_S(\text{year}, \text{qtr}, \text{region}) * \mu_S(\text{year}, \text{qtr}, \text{region}) \right]$$

where $Area_{region}$ is the spatial size of the individual regions. Finally, for ease of comparison across all models the index was "normalized" by dividing through the average index across all years (resulting in the average of the "normalized" index being equal to 1).

2.4 Selection of Data

The data selected for analysis satisfied the following criteria:

- The location of all selected sets was within one of the three spatial regions defined previously (this area is referred to as the GLM Area),
- The date of all selected sets was between 1 July 1997 to 30 December 2007 (i.e. the data for 1997 only includes the data for the final two quarters)
- All variables used in the models were available (i.e, associated number or hooks, number of hook-per-float, bait-type, number of light-sticks, start-set-time all non-null)

- The following outliners were removed: number of hooks≤100, number of hooks-per-float>40 and CPUE>50 fish per 1000 hooks.

2.5 Results

The resulting standardised CPUE index calculated after fitting the above models is compared with the nominal CPUE (total catch/total effort) across both the entire ETBF and within the GLM Area in Figure 3.5a (annual indices) and Figure 3.5b (quarterly indices). The relative effects of each level of the variables fitted to the Binomial model in Figure 3.6a and for the Gamma model in Figure 3.6b. Finally, the Type 3 statistics for each GLM model are displayed in Table 3.3.

2.6 Comparison with 2006 Spatial Structure and 2006 Assessment

The above model was re-run using the same spatial structure used in the previous 2006 assessment. In order to compare the result with the results of the CPUE standardisation undertaken for this 2006 assessment, the analysis was confined to the data within Areas 2, 3 and 5 used in this assessment. As these three areas are larger than the three areas used in the 2008 CPUE standardisation, the total number of records fitted to the model increased to 104, 040. A comparison of the quarterly standardised index for each of the two spatial structures is given in Figure 3.7. The standardised index used in the 2006 assessment is also shown for comparison.

Figure 3.7. Comparison of the quarterly standardised index for each of the two spatial structure described in the text, together with the standardised index used in the 2006 assessment.

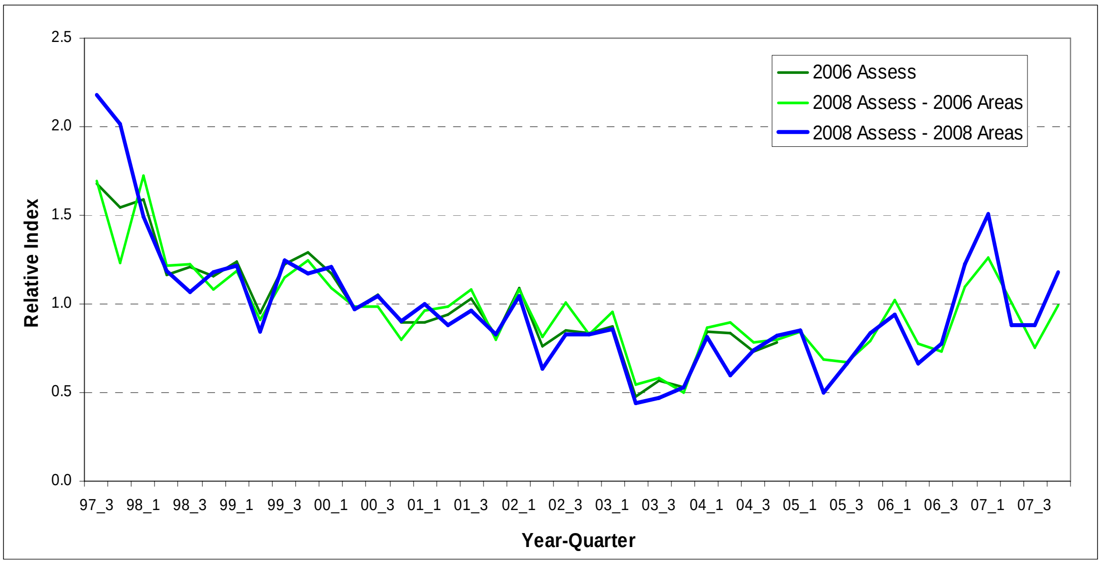


Figure 3.5a. Annual nominal and standardised CPUE indices.

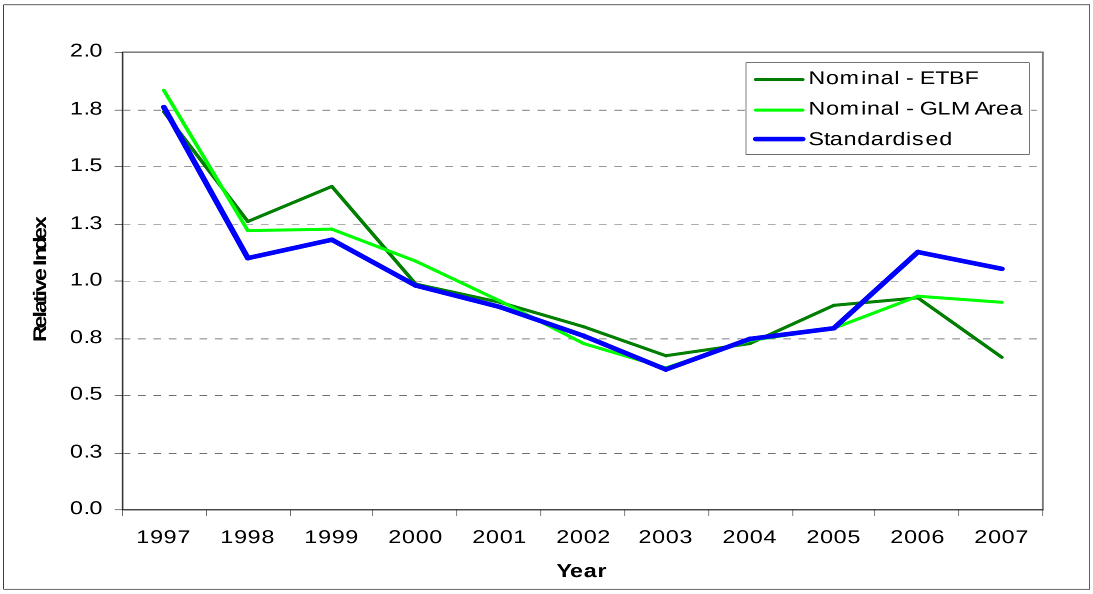


Figure 3.5b. Quarterly nominal and standardised CPUE indices.

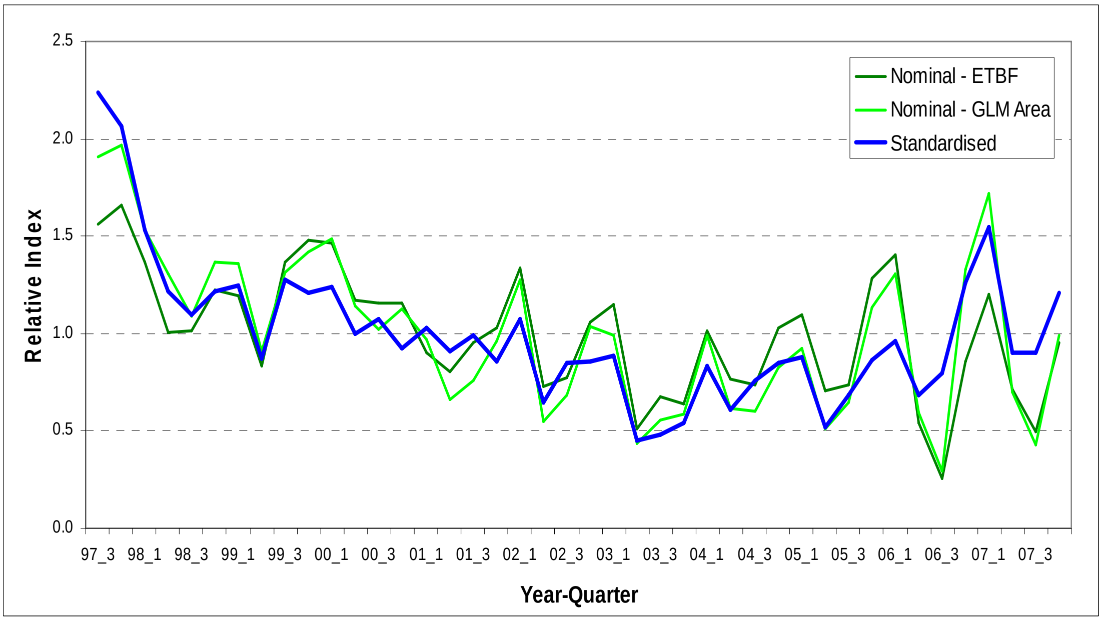


Table 3.3. Type 3 Statistics for each GLM model.

	Binominal Model			Gamma Model		
Fitted Variable	df	ChiSq	Pr>ChiSq	df	ChiSq	Pr>ChiSq
Year*Quarter*Region	123	2103.00	< 0.0001	123	7690.00	< 0.0001
Light-sticks	6	872.00	< 0.0001	6	1009.00	< 0.0001
Bait-type	9	259.00	< 0.0001	9	234.00	< 0.0001
Start Time	5	1838.00	< 0.0001	5	1263.00	< 0.0001
Hooks-per-basket	7	63.00	< 0.0001	7	775.00	< 0.0001
Daily vessel number	7	29.00	0.0001	7	30.00	< 0.0001
Monthly vessel effort	7	15.00	0.0268	7	76.00	< 0.0001
Area*SOI	12	36.00	0.0003	12	113.00	< 0.0001
MoonPhase	1	611.00	< 0.0001	1	1488.00	< 0.0001

Figure 3.6a. Relative effects of each variable fitted to the Binomial model of the probability of obtaining a swordfish catch. (Note: the standard level for each variable against which the effect of each other level is measured is that having no 95% confidence interval.)

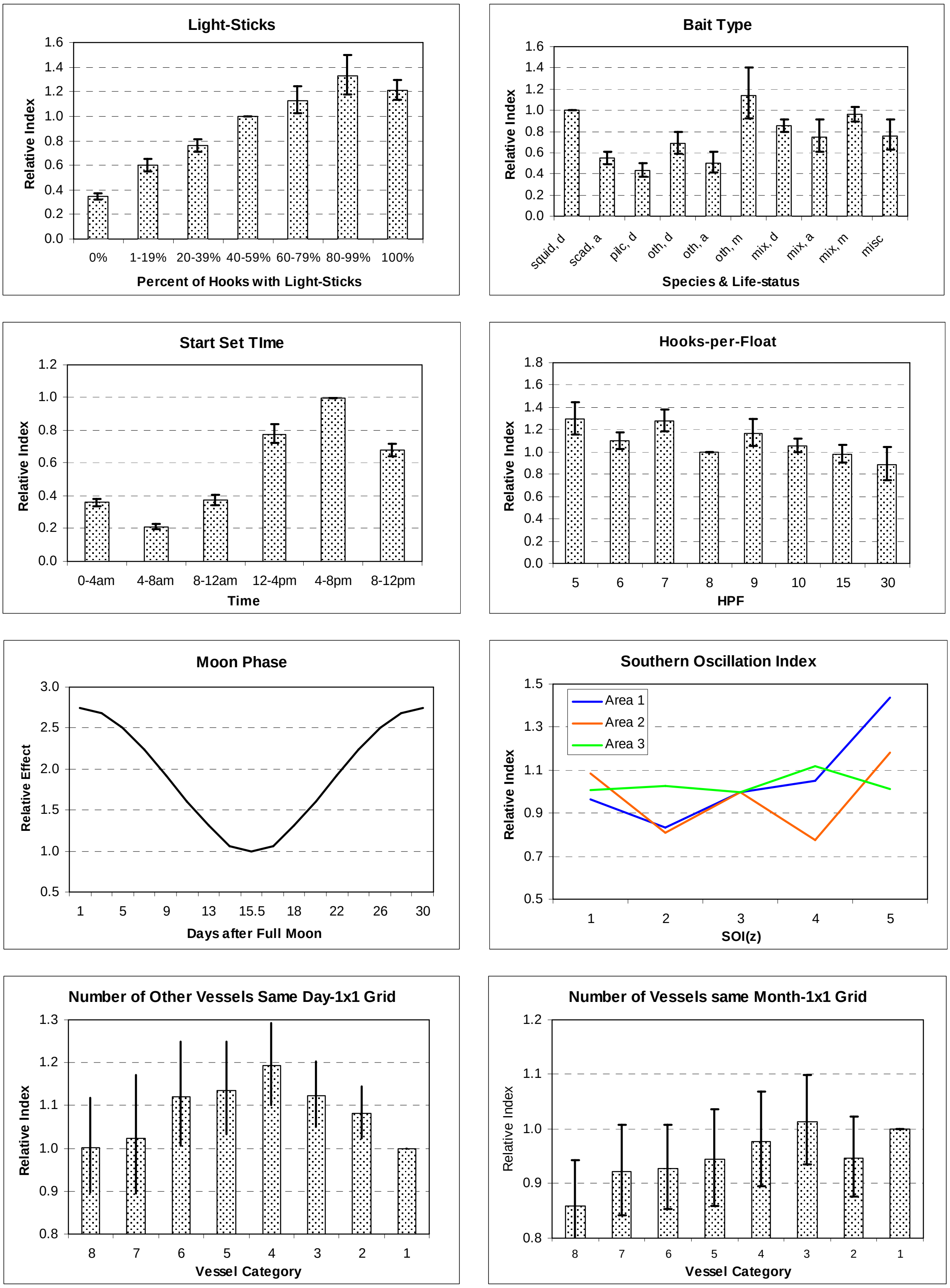
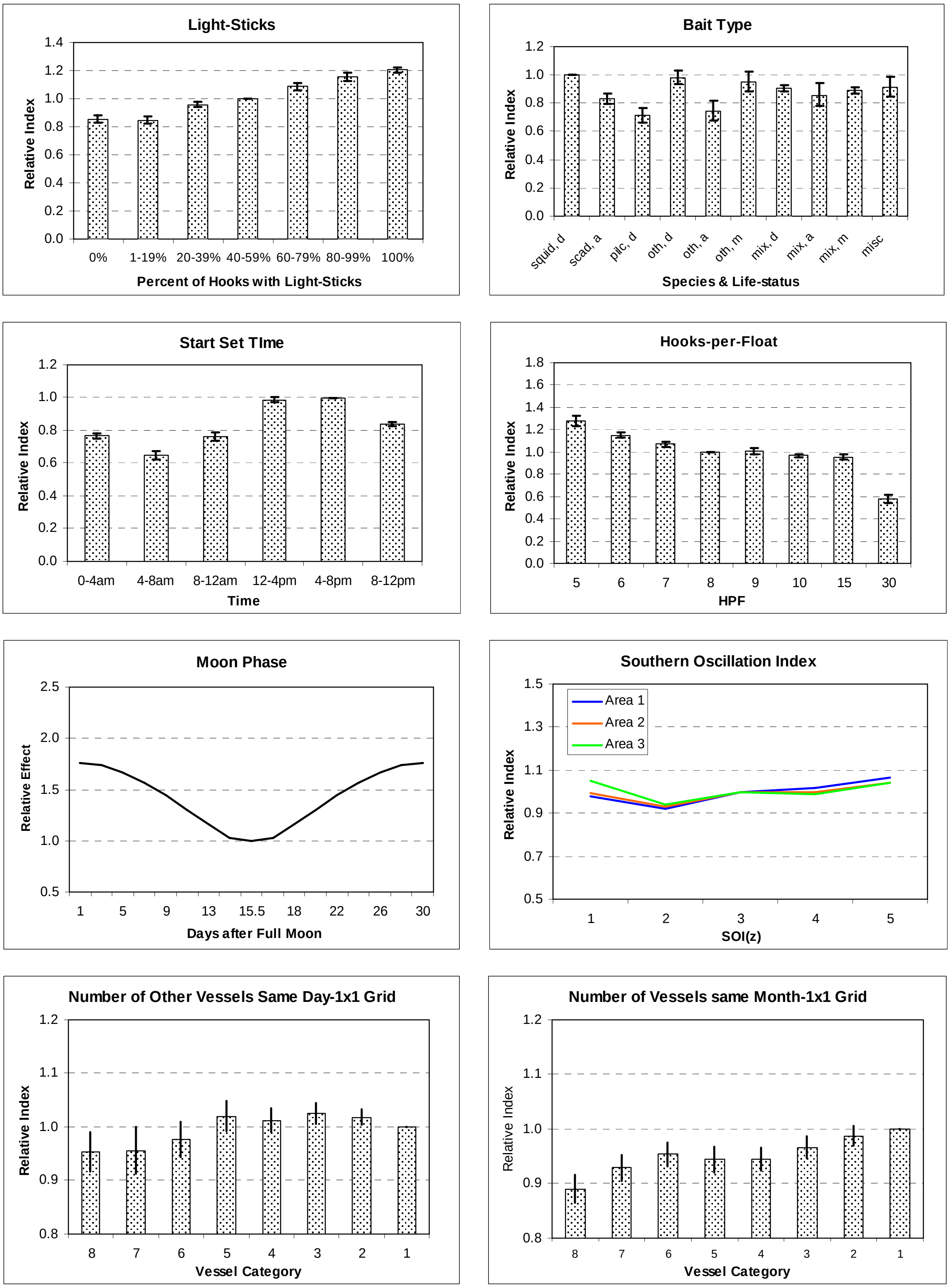


Figure 3.6b. Relative effects of each factor fitted to the Gamma model of the size of the swordfish catch given that a catch had been obtained. . (Note: the standard level for each variable against which the effect of each other level is measured is that having no 95% confidence interval.)



2.7 Standardised CPUE by Size Class

Individual weight data for swordfish caught and landed in the ETBF have been collected since mid-1997 and presently covers the ten financial years between 1997/98 and 2006/07. For this period information recorded in vessel logbooks indicates that a total of 311,888 swordfish were retained by longline vessels while during the same period 244,795 swordfish were sampled. This represents an average quarterly sampling proportion of 78.5%. Furthermore, the sampling proportion in all quarters over the period has been greater than 50 percent. As indicated by the high sampling rates, the data held are seen as being capable of representing the distributions of all size classes of swordfish caught in the fishery during this period. (For a comprehensive summary of these data, together with a number of time-series of indicators based on these data, see Campbell et al, 2007).

A histogram of the dressed weight of all swordfish measured is shown in Figure 3.8. Based on this distribution of weights three size categories were defined:

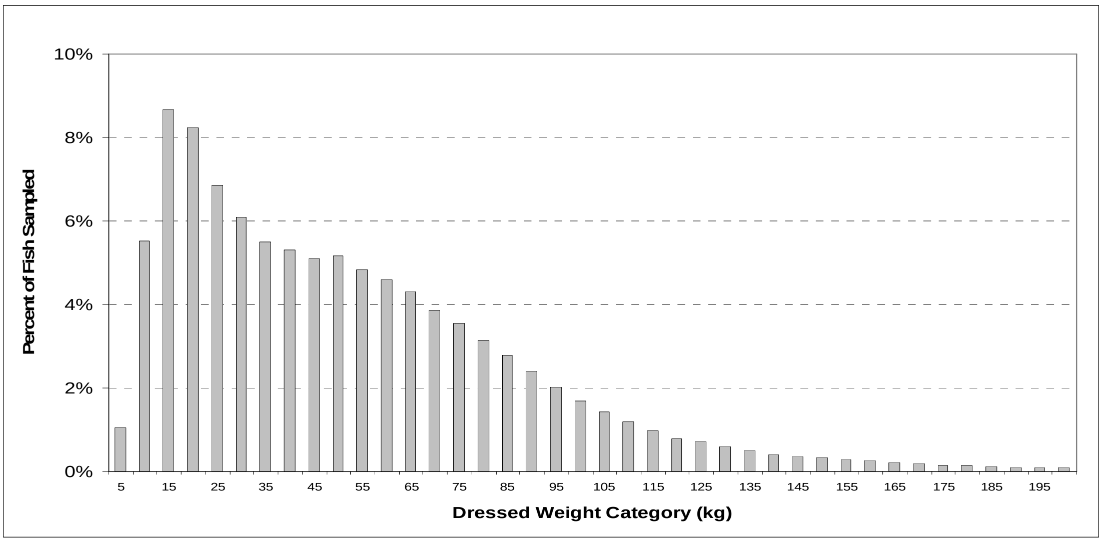
Small Fish	fish within the initial 25-percentile of the weight distribution
Large Fish	fish within the final 20-percentile of the weight distribution
Prime Fish	fish within the middle 50-55-percentile of the weight distribution

Cut-off weights were converted to whole weights using a dressed-to-whole conversion factor of 0.726 and these whole weights were rounded to the nearest five kilograms. The final selected cut-off weights, and the proportion of measured fish within each size category, are given in Table 3.4.

Table 3.4. Cut-off weights used to define three size-classes of swordfish.

Category	Dressed Weights	Whole Weights	Sample Proportion
Small Fish	< 21.78	< 30	26.2%
Prime Fish	21.78 < wt < 72.60	30.0 < wt < 100	50.9%
Large Fish	> 72.60	> 100	22.9%

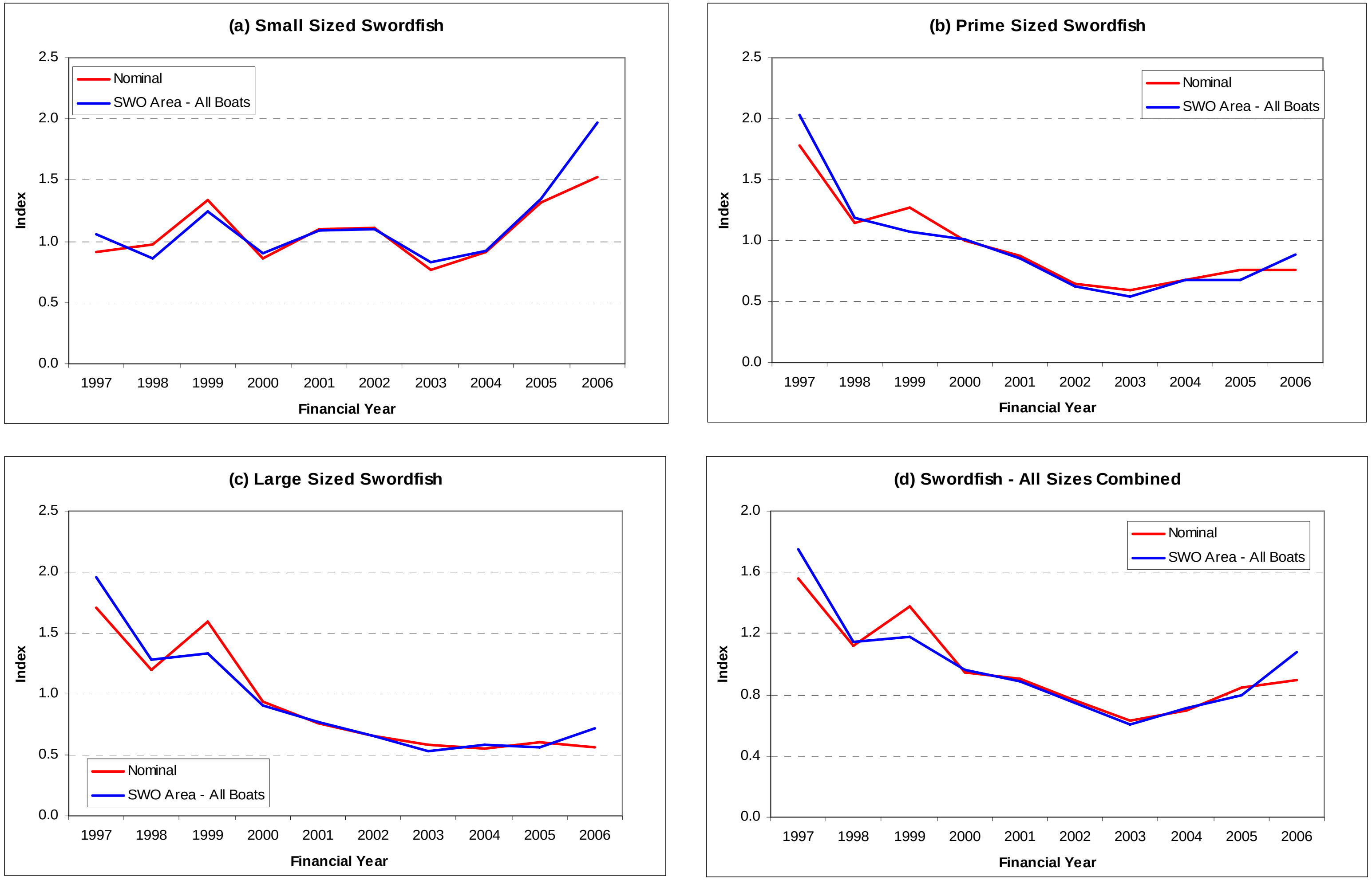
Figure 3.8. Histogram of dressed weights (to the nearest kilogram) of all swordfish sampled in the ETBF.



Using these cut-off weights the proportion of small, prime and large fish in each size sample was then calculated. As the sampling is undertaken at the processor upon unloading the fish at the end of a trip, each sample is related to the fish caught across all sets deployed during that trip. The catch associated with each individual longline fishing operation (held within a separate logbook data-set) was apportioned into each of the three size categories by matching the catch data for all sets within a trip with the associated processor data for the related trip. For those trips for which there were no processor data (or matching vessel identifier in the size data-set), the catches were apportioned using the average proportion of small, prime and large fish caught aggregated across all processor-related sets within an associated spatial-temporal strata. A hierarchical approach was used such that larger spatial-temporal strata were chosen to ensure that the number of sets in each stratum was at least 100.

Using the catch apportioned by size class, the standardised CPUE for each size class was determined by fitting the models described above. The resulting standardised indices for each size class (and the combined total) are shown in Figures 3.9a-d. (Note, these analyses include data between 1 July 1997 and 30 June 2007 only, covering the 1997 to 2006 financial years).

Figure 3.9a-d. Relative indices of (a) small, (b) prime, (c) large and (d) combined broadbill swordfish availability based on nominal and standardised CPUE.



3. Standardised catch-rates – New Zealand

Under the management system in place before 2004 the New Zealand tuna longline fleet was not allowed to target swordfish, though significant quantities (up to 1000 tonnes) of swordfish were still landed. Since the inclusion of swordfish in the Quota Management System (QMS) in October 2004, tuna longliners may target their operations for capturing swordfish. In this section, updated descriptive catch-effort analyses of the commercial fishery for swordfish within the New Zealand EEZ are summarised, and standardised CPUE indices are presented.

3.1 New Zealand catch-effort data

The New Zealand tuna longline fishery includes both chartered foreign vessels and domestically owned and operated vessels. Foreign vessels have fished in New Zealand waters since the late 1970s and were virtually the only longliners operating during the 1980s, but the domestic longline fishery has developed rapidly since 1990 and now accounts for about 90% of targeted longline effort (Griggs & Richardson 2005). Annual effort is currently about 10 million hooks (Ayers et al. 2004), having increased from about 5 million hooks in the mid 1990s with the entry of many new vessels into the fishery since 1998. The main target species are bigeye tuna (*Thunnus obesus*) and southern bluefin tuna (*T. maccoyii*), but about 10% of sets target albacore (*T. alalunga*) or other predominantly bycatch species such as yellowfin tuna (*T. albacares*) and (since October 2004) swordfish.

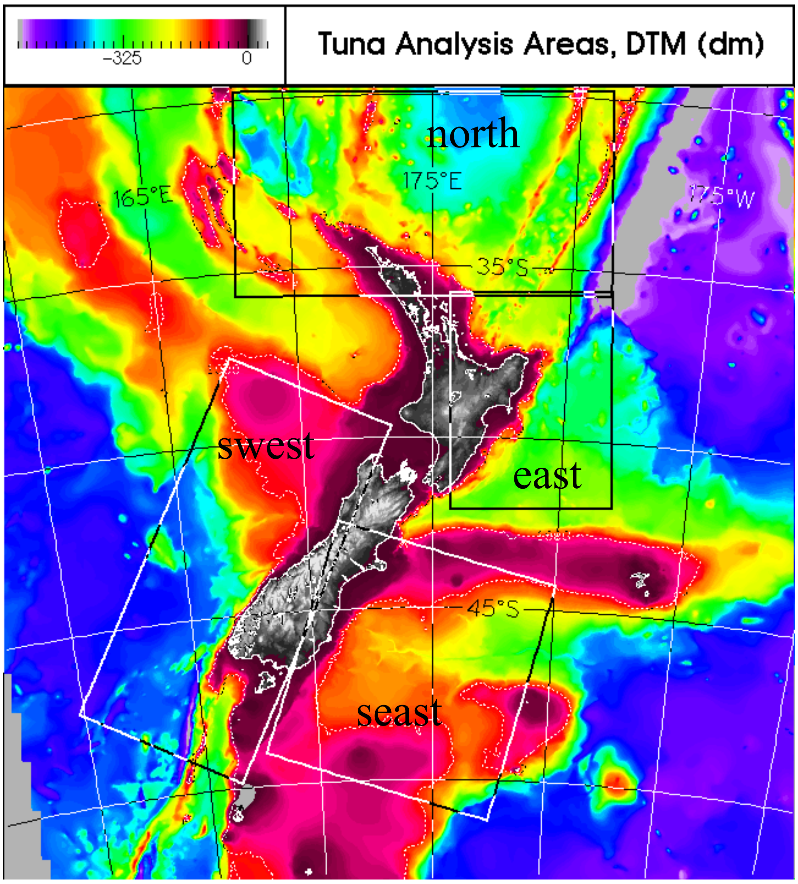
Catch and effort data for the longline fishery were derived from the Tuna Longline Catch Effort Return (TLCER) statistical forms provided by each fisher to MFish. Data recorded for each longline operation includes location and effort (e.g., date, position, set and haul times, number of hooks, line length), and catches of all QMS species. The data extracted for the analysis covered 1 January 1993 to 30 September 2007.

The descriptive analysis presented here mainly focuses on those longlining activities (operational variables) which potentially influence swordfish CPUE, including several which have become available only in the last 2-3 years. These include light stick usage and bait type, which were added to the standard statistical fishing forms used to record longline catches in 2003, and information on direct targeting of swordfish (as an alternative to the main target species, bigeye and southern bluefin), which became legal in October 2004. Thus, the updated datasets add considerably to our understanding of swordfish targeting practices, particularly with regard to trends (such as increased light stick usage).

3.2 Spatial disaggregation

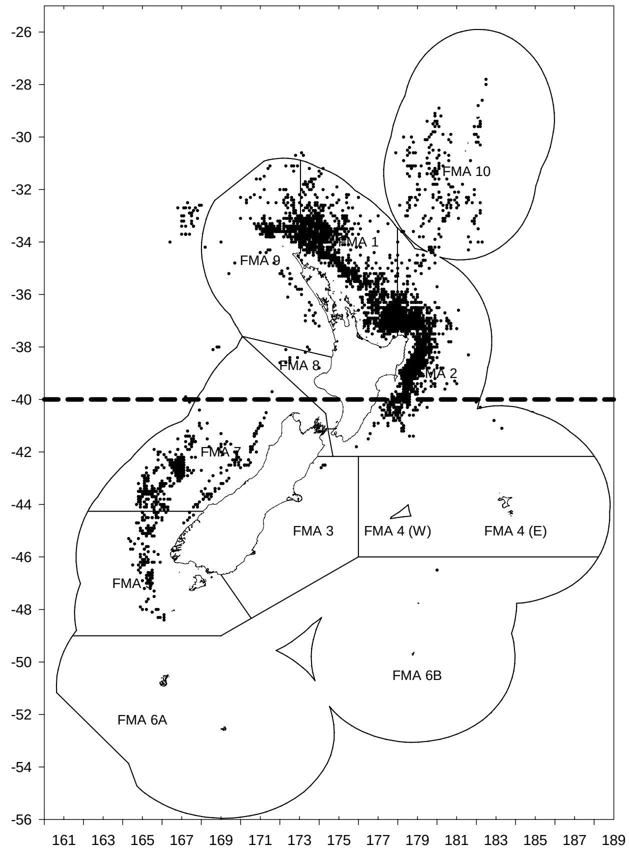
The data analysed were limited to longline sets for which the starting location lay within one of four areas which were the focus of the remote sensing programme (Figure 4.1). Conforming to these areas permitted linking each catch-effort record (each longline event) to environmental variables monitored at the event location. These four areas collectively include most of the three main longlining grounds in which significant swordfish bycatch occurs (North Cape, East Cape, and Fiordland/West Coast). For the purposes of this report, we partitioned the fishery into two disjoint areas, denoted as Area NE (the union of areas north and east), and Area SW (area swest), respectively. Sets occurring in Area seast, where swordfish are caught only rarely, were excluded from our analyses.

Figure 4.1: New Zealand and surrounding waters, showing areas used for analysis of longline CPUE within the New Zealand EEZ from 1993 to 2005. Areas used in this report are denoted Area NE (north + east), and Area SW (swest). Bathymetry ranges from 0 to 6000 m, with the 1000 m isobath shown by a dashed white line.



The Areas NE and SW correspond well with the areas defined for the spatial disaggregation of swordfish length frequency data in New Zealand, i.e., NORTH and SOUTH. These two areas also broadly correspond to the 40º S boundary that separates the CENTRAL and SOUTHERN zones under the fisheries definitions assumed in the 2008 regional swordfish assessment model (Figure 4.2). This boundary mostly subdivides the spatial distribution of the tuna longline operations in the NORTH and SOUTH areas as is evident from its position relative to the longline set locations in 2005–06 and 2006–07 (Figure 4.2).

Figure 4.2: Fisheries management areas (FMAs) making up the New Zealand EEZ, showing tuna longline set locations for 2005–06 and 2006-07 with the 40˚ S boundary used for fishery definitions in the 2008 regional swordfish assessment model.



3.3 Descriptive summaries

Total longlining effort in the NORTH Area fell steadily from 2005 to 2007, continuing a trend that has been apparent since 2002 (Table 4.1). This trend was evident in terms of number of sets, numbers of individual vessels, and total number of hooks. Average effort from 2005-2007 was only 37%-40% of the average over the three peak years of 2001-2003, and 55% - 63% of that in 2004. Despite this decline, swordfish landings were relatively high particularly in 2006 and 2007. These contrasting trends resulted in unusually high mean nominal CPUE for these two years (3.12 and 2.94 SWO per thousand hooks, respectively, in 2006 and 2007), with the 2006 figure representing an 82% increase over the highest previously recorded annual mean (1.71 in 1998; Table 4.1, Figure 4.3). Swordfish catches in the SOUTH Area totalled 313 fish over the three years from 2005 to 2007 (Table 4.2), representing 1.6% of the total landings reported in this study.

Catch and effort data were summarised with respect to tuna longline operational variables that are likely to influence swordfish catch rates. These included: target species, operation location (area), light stick usage and bait type.

Table 4.1: Summary statistics for swordfish taken by longliners in the New Zealand EEZ, 1993-2007, by analysis Area (NORTH and SOUTH). Figures shown for each Area are the total number of longline sets (Sets); number of vessels involved (Vessels); total effort (thousands of hooks); number of swordfish landed (SWO); and mean CPUE (SWO per thousand hooks).

	NORTH Area						SOUTH Area				
Year	Sets	Vessels	Hooks (x 1000)	SWO	CPUE		Sets	Vessels	Hooks (x 1000)	SWO	CPUE
1993	1 162	36	1 482	898	0.61		751	21	2 265	19	0.01
1994	1 326	44	1 115	862	0.78		363	17	909	5	0.01
1995	1 654	54	1 427	780	0.54		872	28	1 642	46	0.05
1996	1 390	54	1 177	1 207	1.07		224	15	265	49	0.22
1997	1 458	51	1 295	1 515	1.16		299	7	856	33	0.04
1998	2 406	67	2 393	3 799	1.71		210	7	625	57	0.08
1999	4 059	77	4 250	5 989	1.53		323	6	997	290	0.29
2000	4 924	98	5 422	8 955	1.69		301	8	901	207	0.25
2001	6 225	122	7 198	11 848	1.67		272	10	733	155	0.32
2002	6 683	139	7 881	10 613	1.36		491	27	1 004	178	0.27
2003	6 035	121	7 584	8 415	1.18		468	16	1 220	104	0.14
2004	3 989	91	4 630	6 962	1.52		750	35	1 620	218	0.24
2005	2 733	55	3 073	4 218	1.48		237	10	538	163	0.66
2006	2 671	52	2 911	8 847	3.12		274	7	663	117	0.40
2007	2 127	42	2 338	6 143	2.94		325	7	1 112	33	0.03

Figure 4.3: Annual longline effort (total hooks), annual catch of swordfish (SWO), and mean CPUE for swordfish in Area NE, 1993 to 2007.

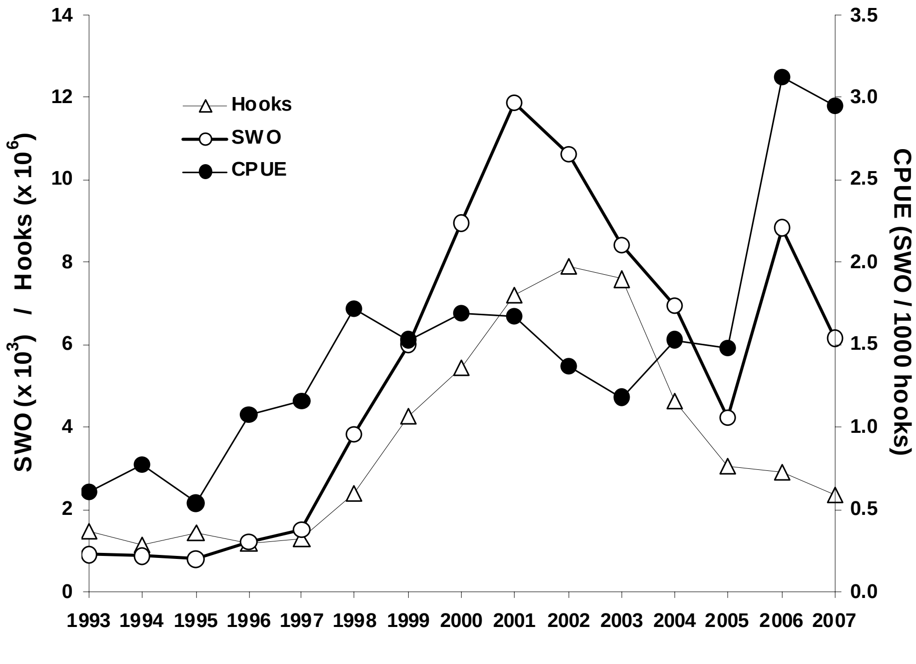


Table 4.2: Fishing effort in the NORTH Area (number of longline sets) by year and target species, 1993-2007. SWO targeting has been permissible since 2005.

Year	BIG	STN	ALB	OTH	SWO	Total
1993	790 (68.0%)	347 (29.9%)	9 (0.8%)	16 (1.4%)	-	1 162
1994	1 058 (79.8%)	163 (12.3%)	89 (6.7%)	16 (1.2%)	-	1 326
1995	1 275 (77.1%)	119 (7.2%)	209 (12.6%)	51 (3.1%)	-	1 654
1996	1 035 (74.5%)	197 (14.2%)	133 (9.6%)	25 (1.8%)	-	1 390
1997	1 111 (76.2%)	180 (12.3%)	127 (8.7%)	40 (2.7%)	-	1 458
1998	1 738 (72.2%)	225 (9.4%)	412 (17.1%)	31 (1.3%)	-	2 406
1999	3 148 (77.6%)	353 (8.7%)	492 (12.1%)	66 (1.6%)	-	4 059
2000	4 009 (81.4%)	484 (9.8%)	375 (7.6%)	56 (1.1%)	-	4 924
2001	4 905 (78.8%)	709 (11.4%)	434 (7.0%)	177 (2.8%)	-	6 225
2002	4 736 (70.9%)	1 169 (17.5%)	636 (9.5%)	142 (2.1%)	-	6 683
2003	3 431 (56.9%)	1 693 (28.1%)	793 (13.1%)	118 (2.0%)	-	6 035
2004	2 471 (61.9%)	1 064 (26.7%)	322 (8.1%)	132 (3.3%)	-	3 989
2005	1 594 (58.3%)	829 (30.3%)	120 (4.4%)	88 (3.2%)	102 (3.7%)	2 733
2006	1 637 (61.3%)	747 (28.0%)	60 (2.2%)	26 (1.0%)	201 (7.5%)	2 671
2007	1 268 (59.6%)	624 (29.3%)	16 (0.8%)	41 (1.9%)	178 (8.4%)	2 127

Table 4.3: Mean nominal catch per unit effort (swordfish per 1000 hooks) in NORTH Area by year and target species, 1993-2007. Swordfish targeting has been permissible since 2005.

Year	BIG	STN	ALB	OTH	SWO
1993	0.68	0.47	0.53	0.25	-
1994	0.89	0.33	0.30	0.54	-
1995	0.60	0.32	0.34	0.35	-
1996	1.11	0.82	0.80	2.71	-
1997	1.02	1.86	1.38	1.07	-
1998	1.61	2.31	1.88	0.94	-
1999	1.46	1.79	1.81	1.26	-
2000	1.50	2.26	2.86	2.15	-
2001	1.61	1.92	1.85	1.86	-
2002	1.32	1.33	1.68	1.71	-
2003	1.24	1.02	1.17	1.65	-
2004	1.56	1.29	1.95	1.82	-
2005	1.57	0.92	1.47	1.55	4.56
2006	3.10	1.81	1.82	5.46	8.21
2007	2.96	1.14	3.80	2.96	9.02

There has been increased targetting for swordfish since 2005 when this practice became legal following the introduction of swordfish to the NZ QMS (Table 4.2). Concurrent with this increase, there has been decreased targeting for albacore. Nominal CPUE is strongly related to target species, with operations targeting swordfish have around 100% higher catch rates than those targeting tunas (Table 4.3). Increases in CPUE are evident in 2007 over operations targeting swordfish, bigeye and albacore tuna, with the increase for swordfish target operations being substantial.

Swordfish catch rates were calculated for operations in the Fisheries Management Areas (FMAs) areas within the NORTH Area, shown in Figure 4.2. Catch rates differed between FMAs, with those in the Kermadec Islands area being up to 200% higher (Table 4.4). The number of operations in this area have increased markedly since 2004, from 4 to 80 longline sets. Although this is considerably lower effort in terms of sets the higher catch rates result in larger catches. It is evident from length frequency samples taken from trips in the Kermadecs Islands that catch size compositions differ from those in concurrent trips elsewhere in the NORTH area (Figure 4.4).

Table 4.4. Annual effort (number of longline sets) and mean swordfish CPUE in NORTH Area by year and Fisheries Management Area (FMA), 1993-2007.

	Number of longline sets				CPUE (SWO per 1000 hooks)			
Year	FMA1	FMA2	FMA9	FMA10	FMA1	FMA2	FMA9	FMA10
1993	705	381	18	25	0.65	0.54	0.52	0.66
1994	1 074	193	34	16	0.73	0.98	1.27	0.62
1995	1 320	278	19	28	0.50	0.70	0.56	0.59
1996	795	578	14	0	1.12	0.98	1.77	-
1997	1 027	396	33	0	0.99	1.54	1.82	-
1998	1 616	642	145	0	1.21	2.88	2.16	-
1999	2 854	1 012	149	39	1.00	2.79	1.65	6.66
2000	2 674	1 621	519	53	1.11	2.69	1.41	3.03
2001	3 189	2 075	799	109	1.34	2.42	0.97	1.72
2002	3 266	2 742	572	86	1.02	1.75	1.43	1.57
2003	1 658	3 685	642	40	1.14	1.24	0.78	3.18
2004	1 178	2 422	381	4	1.44	1.61	1.24	5.33
2005	1 147	1 188	382	13	1.37	1.28	2.32	3.28
2006	1 129	1 292	165	78	2.67	3.26	2.02	9.52
2007	725	1 158	164	80	2.62	2.78	3.35	7.34

Figure 4.4: Catch length compositions of landings of swordfish taken from the Kermadec Islands (Kerm) and other parts of the NORTH Area (non-Kerm) in the five quarters since 2006 quarter 3.

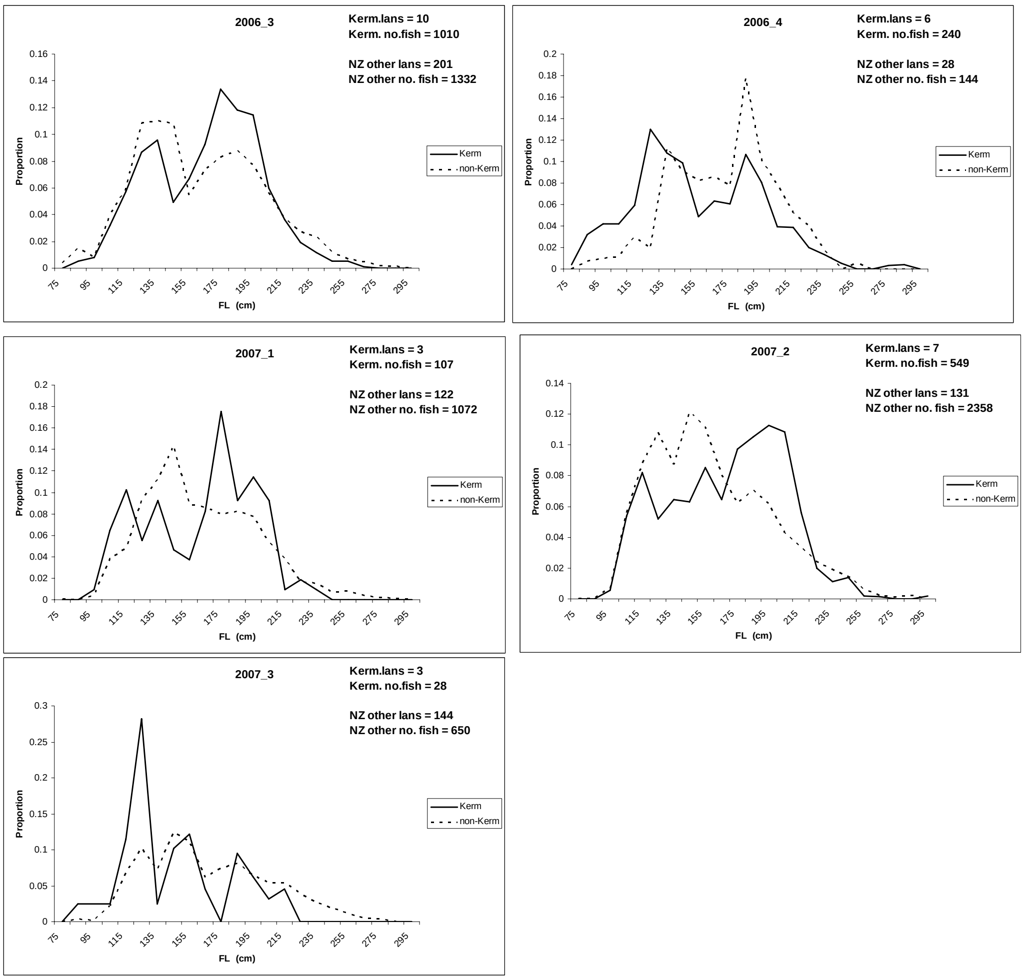


Table 4.5. Fishing effort in NORTH Area (number of longline sets) by light stick usage (light sticks per 1000 hooks) and year, 2003-2007, and by target species. Round and square brackets for light stick usage ranges denote open and closed intervals, respectively.

Light stick usage	2003	2004	2005	2006	2007
0	906 (22.0%)	427 (11.7%)	371 (14.2%)	156 (6.0%)	141 (6.8%)
(0-50]	634 (15.4%)	405 (11.1%)	115 (4.4%)	97 (3.8%)	57 (2.8%)
(50-100]	1 130 (27.4%)	1 121 (30.6%)	542 (20.7%)	407 (15.7%)	237 (11.5%)
(100-200]	1 008 (24.4%)	961 (26.2%)	657 (25.1%)	713 (27.6%)	527 (25.6%)
(200-500]	430 (10.4%)	714 (19.5%)	866 (33.1%)	1051 (40.6%)	904 (43.9%)
>500	16 (0.4%)	34 (0.9%)	63 (2.4%)	162 (6.3%)	193 (9.4%)
Total	4 124	3 662	2 614	2 586	2 059

Group	BIG	STN	ALB	OTH	SWO
0	1 014 (11.8%)	737 (15.9%)	213 (20.5%)	37 (11.7%)	0 (0.0%)
(0-50]	790 (9.2%)	374 (8.1%)	120 (11.6%)	24 (7.6%)	2 (0.4%)
(50-100]	2 127 (24.8%)	1 051 (22.7%)	198 (19.1%)	36 (11.4%)	25 (5.2%)
(100-200]	2 165 (25.2%)	1 301 (28.1%)	274 (26.4%)	74 (23.4%)	53 (11.1%)
(200-500]	2 333 (27.2%)	1 058 (22.9%)	227 (21.9%)	132 (41.8%)	215 (44.9%)
>500	163 (1.9%)	103 (2.2%)	5 (0.5%)	13 (4.1%)	184 (38.4%)
Total	8 592	4 624	1 037	316	479

Table 4.6 Fishing effort in NORTH Area (number of longline sets) by preferred bait type (% of hooks baited with squid) and year, 2003-2007, and by target species. Round and square brackets for % of squid bait ranges denote open and closed intervals, respectively.

% squid bait	2003	2004	2005	2006	2007
[0-25]	202 (4.6%)	86 (2.2%)	105 (3.9%)	41 (1.5%)	21 (1.0%)
(25-50]	2 517 (57.7%)	2 388 (60.5%)	1 421 (52.9%)	777 (29.3%)	459 (21.8%)
(50-75]	647 (14.8%)	459 (11.6%)	593 (22.1%)	711 (26.8%)	446 (21.2%)
(75-100]	996 (22.8%)	1 012 (25.7%)	569 (21.2%)	1 121 (42.3%)	1 182 (56.1%)
Total	4 362	3 945	2 688	2 650	2 108

% squid bait	BIG	STN	ALB	OTH	SWO
[0-25]	222 (2.4%)	78 (1.6%)	145 (13.6%)	5 (1.5%)	5 (1.1%)
(25-50]	4 940 (54.2%)	1 978 (41.4%)	482 (45.0%)	116 (35.4%)	48 (10.1%)
(50-75]	1 710 (18.8%)	891 (18.7%)	182 (17.0%)	33 (10.1%)	40 (8.4%)
(75-100]	2 234 (24.5%)	1 830 (38.3%)	261 (24.4%)	174 (53.0%)	383 (80.5%)
Total	9 106	4 777	1 070	328	476

The use of light sticks on tuna longlines has increased considerably since 2003 (Table 4.5), such that the percentage of operations using more than 200 light sticks per 1000 hooks has increased from less than 11% in 2003 to more than 53% in 2007. On average between 2003 and 2007, more than 83% of operations targeting swordfish employed more than 200 light sticks per 1000 hooks, compared to less than 30% for operations targeting bigeye, southern bluefin and albacore tunas. This indicates light stick usage as an important operational variable for swordfish catch rates.

Table 4.7 Number of sets and mean CPUE vs. light stick usage, hooks per basket, and usage of squid bait for longline sets targeting swordfish in Area NE, 2005-2007.

	Number of sets			Mean CPUE		
Light sticks	2005	2006	2007	2005	2006	2007
0	0 (0.0%)	0 (0.0%)	0 (0.0%)	-	-	-
(0-50]	0 (0.0%)	2 (1.0%)	0 (0.0%)	-	5.43	-
(50-100]	13 (12.9%)	3 (1.5%)	9 (5.1%)	4.18	1.61	5.40
(100-200]	15 (14.9%)	23 (11.4%)	15 (8.5%)	2.63	7.87	6.88
(200-500]	66 (65.3%)	101 (50.2%)	48 (27.1%)	4.30	8.93	8.23
>500	7 (6.9%)	72 (35.8%)	105 (59.3%)	12.23	7.66	10.08
Total	101	201	177			
Hooks per basket	2005	2006	2007	2005	2006	2007
[5-10]	28 (27.7%)	29 (14.4%)	26 (14.7%)	3.35	7.09	6.51
(10-15]	51 (50.5%)	74 (36.8%)	32 (18.1%)	3.68	7.33	8.23
(15-20]	17 (16.8%)	36 (17.9%)	16 (9%)	7.34	13.59	7.85
(20-25]	0 (0%)	5 (2.5%)	0 (0%)	NA	7.71	-
>25	5 (5%)	57 (28.4%)	103 (58.2%)	11.32	6.56	10.16
Total	101	201	177			
% squid bait	2005	2006	2007	2005	2006	2007
[0-25]	1 (1.0%)	0 (0.0%)	4 (2.2%)	8.90	-	5.80
(25-50]	28 (27.5%)	13 (6.5%)	7 (3.9%)	3.85	2.88	5.40
(50-75]	19 (18.6%)	14 (7.0%)	8 (4.5%)	3.17	3.72	6.20
(75-100]	54 (52.9%)	174 (86.6%)	159 (89.3%)	5.34	8.97	9.40
Total	102	201	178			

Similarly, the percentage of tuna longline operations using squid baits on more than 50% of hooks has increased from 37.6% in 2003 to 77.3% in 2007 (Table 4.6). Squid bait usage is an important operation variable influencing swordfish catch rates given that nearly 90% of operations targeting swordfish use squid more than 50% of the time.

A comparison of mean nominal CPUE by the operational variables: light stick usage, bait type and hooks per basket, over the period that these variables have been reported (2005 to 2007), indicates positive relationships (Table 4.7). In most years, generally higher catch rates are obtained with higher usage of light sticks and squid baits.

3.3 Standardised indices

A set of core vessels which accounted for the majority of the swordfish catch was selected for undertaking the CPUE analyses and the time series was limited to the first quarter of 1998 to the third quarter of 2007. Core vessels were identified on the basis of their fishing activity over the 10 years from 1998 to 2007, inclusive. For each individual vessel, counts were made of the number of years during they made at least one longline set within the study area during the period 1998-2007 (N9807) and the two years from 2006 to 2007 (N0607). Core vessels were those for which N9807 >= 6 and N0607 = 2.

All analyses were undertaken using a Generalised Additive Model (GAM) to which a large number of environmental variables in addition to the standard operational variables were fitted. The final predictor set consisted of the following five factors and thirteen covariates:

Factors:

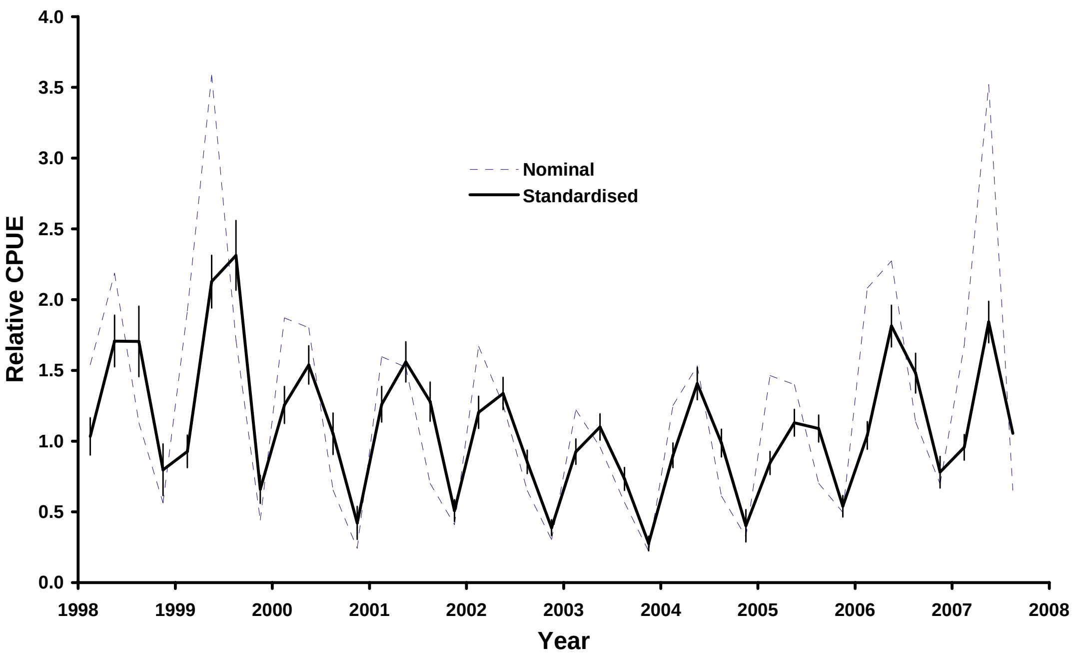
Year × Quarter interaction (39 levels)
Vessel size (small and large, based on mean longline length; 2 levels)
Vessel experience (E = experienced, N = not experienced; 2 levels)
Target species (albacore, bigeye, southern bluefin, other; 4 levels)

Covariates:

Latitude
Longitude
Depth (metres)
Depth standard deviation (metres)
Number of sets within 50 km during previous 10 days
Soak time measured from start of set to start of haul (hours)
Moon phase
Day length (hours)
Hour at start of set
Number of hooks per basket
Night fraction
Mean SST (°C)
SST anomaly (°C)

A comparison of the resulting standardised CPUE index with the corresponding nominal CPUE is shown in Figure 4.5.

Figure 4.5 Comparison of the quarterly nominal and standardised CPUE indices for the New Zealand domestic longline fleet. Standard errors are shown for the standardised time-series.



3.4 Discussion

The main points evident from the descriptive analyses are:

1. High nominal CPUE in 2006 and 2007, largely irrespective of target species;
2. Increased targeting of SWO in 2006 and 2007

3. SWO targeting mainly along shelf, but also extends well out towards Kermadecs;
4. Clear signals re CPUE vs. light stick usage and bait type;

These features must be considered in combination with historical events in the management of the swordfish fishery. Notably, that prior to its introduction to the QMS in 2004, targeting for swordfish was not legal, and was therefore not reported. The operational variables – light stick usage and bait type – have been reported by fishers on logbooks since 2005. Consequently, the three operational variables influencing swordfish catch rates are available for only part of the catch effort time series (1993 to 2007).

Despite the declining effort, swordfish landings in the NORTH Area increased markedly in 2006 and 2007, with nominal CPUE (3.12 swordfish per thousand hooks) close to double the previous record. This appears to be partly related to an increase in the proportion of vessels targeting swordfish, for which nominal CPUE was up to three times higher than for other species, but swordfish CPUE was also relatively high for vessels targeting bigeye and southern bluefin tunas. Other factors clearly associated with increased swordfish CPUE are light stick usage and the percentage of hooks set with squid bait (rather than fish bait), both of which have increased markedly in recent years irrespective of target species. Two features suggest another factor potentially affecting swordfish CPUE - heterogeneity in the population in the NORTH Area. Firstly, the marked difference in the size composition of swordfish in catches from the Kermadec Islands, compared with elsewhere in the NORTH Area. Secondly, the higher CPUE observed in catches from the Kermadec Islands area (FMA10).

It has yet to be established whether the increase in swordfish CPUE since 2005 reflects increased availability, increased targeting efficiency, or a combination of both. Either way, the fishery appears to be changing significantly. Calculation of standardised CPUE indices for the fishery aims to describe the relationships between swordfish CPUE and operational variables, but is likely to be confounded by the lack of data for bait type and light stick usage prior to 2003, and the legalisation of swordfish targeting in 2005. Strategies must be developed for modelling CPUE over the full fifteen year time series despite the absence of complete data on these potentially highly significant predictors.

4. Standardised catch-rates – Japan

Unlike the Australian and New Zealand fleets, whose fishing operations are mainly confined to regions close to home ports, the spatial coverage of fishing operations for distant water fishing nations is much more extensive and, as such, provides the opportunity to generate indices of resource availability based on standardised CPUE across several areas of the southern WCPO. Japanese fleets have recorded the number of hook-per-baskets for their associated longline fishing operations since 1975 and for the previous assessment undertaken in 2006 this data was used to generate a standardised CPUE index for swordfish within the SW Pacific. A similar set of analyses was undertaken for this assessment within each of the four regions used in the 2008 assessment. The data used for these analyses consisted of the Japanese longline catch and effort data aggregated at a 1x1-degree level of latitude and longitude and stratified by the number of hook-per-basket (HPB). This data is located at the National Research Institute for Far Seas Fisheries in Shimizu, Japan.

Within each of the four assessment areas across the southern WCPO, the analysis was limited to those zones where (i) there was a sufficient time-series of catch and effort data , and (ii) the overall CPUE was sufficiently high (relative to other zones). This eliminated all but the following areas and zones:

1) Area 1, Central zone (Area 1C)
2) Area 2, Central zone (Area 2C)
3) Area 3, Northern zone (Area 3N)
4) Area 4, Northern zone (Area 4N)

The time-series of annual effort and catch of swordfish (number of fish) for each area is provided in Figure 3.1. It is evident that there has been a significant decline in Japanese fishing effort in most areas since the early-mid 1990s and this may have a bearing on the ability to maintain sufficient spatial coverage in order to obtain a meaningful index across each area. In particular, there was little or no fishing in Area 3N from the late 1980s to the mod-1990s and as such these years were excluded from the analysis. The analysis for this area was also limited to the second and third quarters.

Within each of the above four regions, the following GLM was fitted to the data:

MODEL *Catch= Year*Quarter + Quarter*Area + HPBcat* Area*

Distribution=negative-binominal

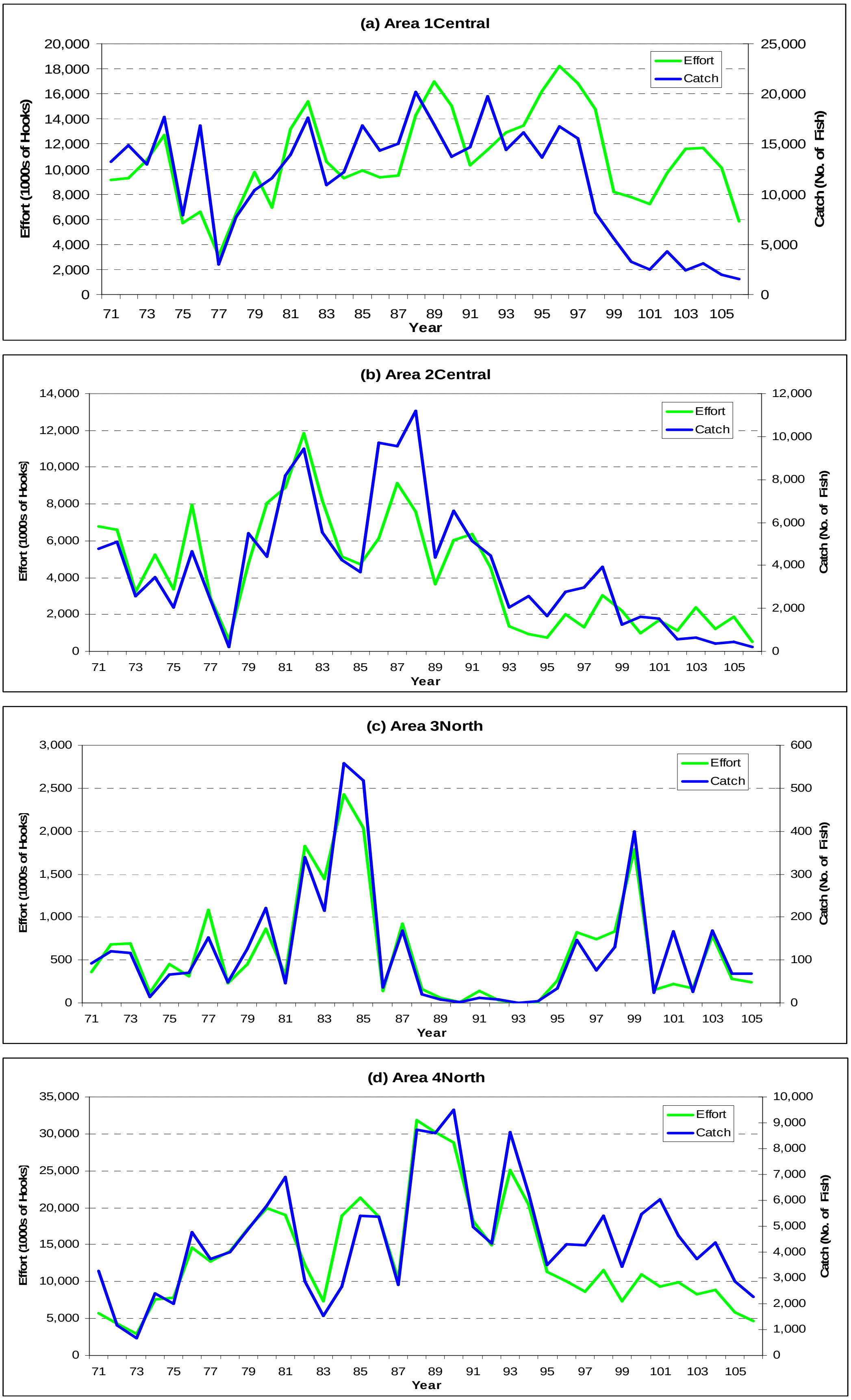
Link=*log*

Offset=*log*(*Effort*)

where the number of observations and the fitted values for each categorical variable in each region are as follows:

Area 1C	*Year*	36 levels	1971 – to 2006
(N=24,737)	*Quarter*	4 levels	1, 2, 3, 4
	Area	5 levels	refer to Figure 3.2
	HPBcat	6 levels	refer to Table 3.1
Area 2C	*Year*	36 levels	1971 – to 2006
(N=9,183)	Quarter	4 levels	1, 2, 3, 4
	Area	3 levels	refer to Figure 3.2
	HPBcat	6 levels	refer to Table 3.1
Area 3N	*Year*	29 levels	1971 – to 1988, 1996 - 2006
(N=3,349)	*Quarter*	2 levels	3, 4
	Area	4 levels	refer to Figure 3.2
	HPBcat	7 levels	refer to Table 3.1
Area 4N	*Year*	36 levels	1971 – to 2006
(N=61,318)	*Quarter*	4 levels	1, 2, 3, 4
	Area	5 levels	refer to Figure 3.2
	HPBcat	8 levels	refer to Table 3.1

Figure 3.1. Annual time-series of Japanese effort and catch of swordfish within the four main areas of the southern WCPO.



Within each area, the sub-area structure used in the GLM was based on combing 5x5-degree areas with similar nominal CPUE calculated over all years, while the HPB categories were chosen to ensure a reasonable number of observations within each category.

Table 3.1 Hook-per-Basket categories used in the GLM analyses for each region.

Areas 1C and Area 2C		Areas 3N and Area 4N	
HPB category	HPB values	HPB category	HPB values
5	≤ 5	6	≤ 6
6	6	8	7 – 8
7	7	10	9 – 10
8	8	12	11 – 12
10	9 - 10	14	13 – 14
15	> 10	16	15 – 16
		18	17 – 18
		20	>18

Figure 3.2 Schematic representation of each area indicating the sub-area structure used in the GLMs.

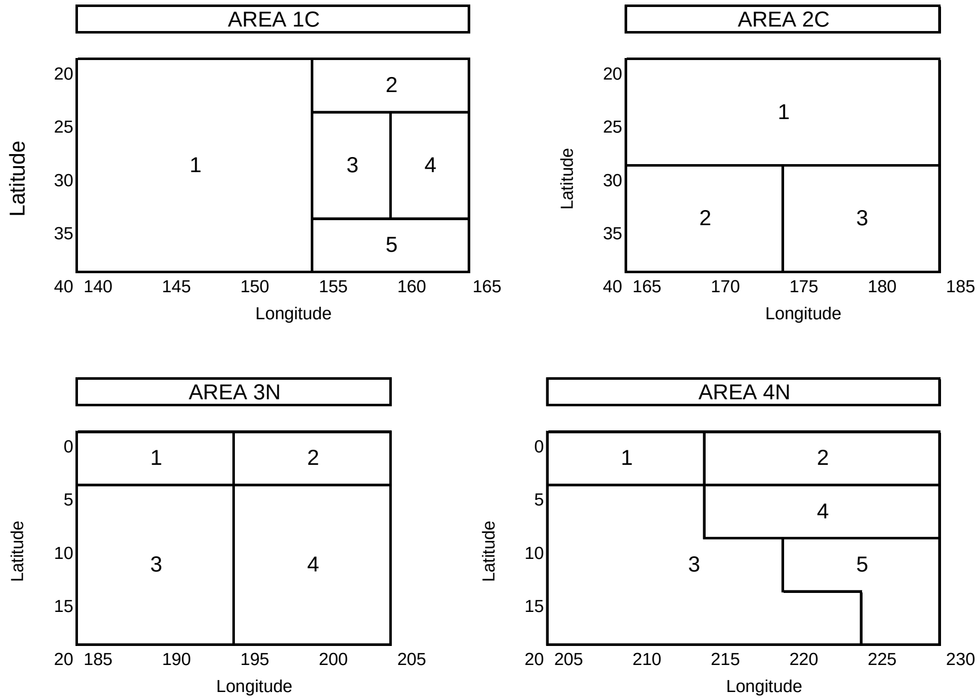


Table 3.2 Type 3 statistics associated with the GLM fitted to each area.

Area\Variable	*Year*Quarter*			*Quarter*Area*			*Area*HPBcat*		
	df	*Chi*	*Prob*	*df*	*Chi*	*Prob*	*df*	*Chi*	*Prob*
Area 1C	140	3069	<0.0001	12	443	<0.0001	25	447	<0.0001
Area 2C	130	769	<0.0001	6	135	<0.0001	15	223	<0.0001
Area 3N	56	204	<0.0001	3	7	0.0661	24	69	<0.0001
Area 4N	140	3125	<0.0001	12	1011	<0.0001	35	221	<0.0001

The resulting standardised CPUE index for each area, together with the nominal index for the data fitted, is shown in Figure 3.3. The Type 3 statistics associated with the GLM fitted to each area are also shown in Table 3.2.

Figure 3.3 The nominal and standardised swordfish CPUE indices for the Japanese fleet operating in four areas within the southern WCPO. Note, all indices are scaled such that the mean across the time-series is equal to 1.

4. Standardised catch-rates – Korea

A similar analysis to that undertaken for the Japanese fleet was also conducted using the catch and effort data for the Korean fleet in the northern zones of Areas 3 and 4. However, only aggregated 5x5-degree catch and effort data was available for this fleet and there was also no information on gear settings (i.e. hook-per-basket). Consequently, the following simplified model was fitted to the data:

MODEL *Catch= Year*Quarter + Quarter*Area*

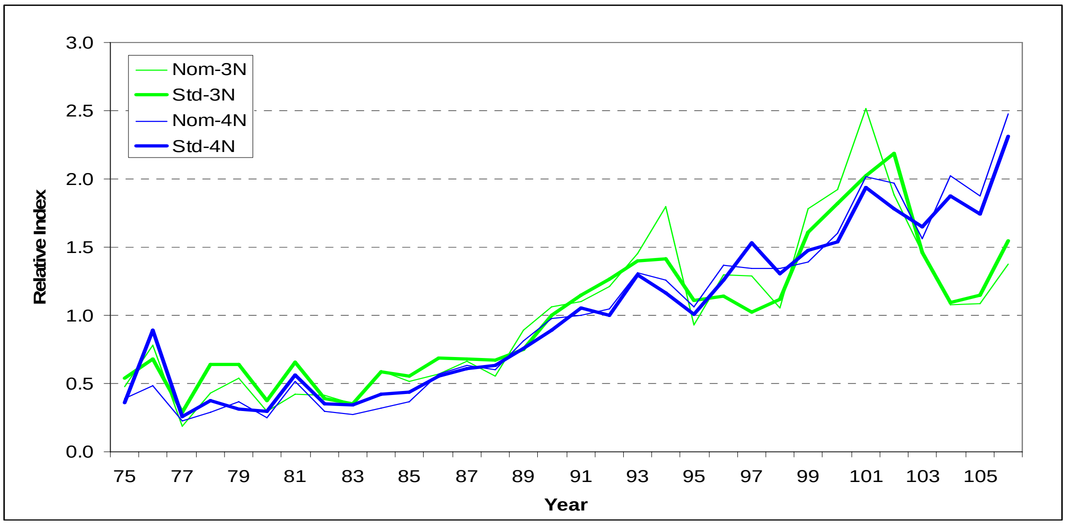
Distribution=negative-binominal

Link=*log*

Offset=*log*(*Effort*)

The results are shown in Figure 4.1.

Figure 4.1 The nominal and standardised swordfish CPUE indices for the Korean fleet operating in two areas within the southern WCPO. Note, all indices are scaled such that the mean across the time-series is equal to 1.

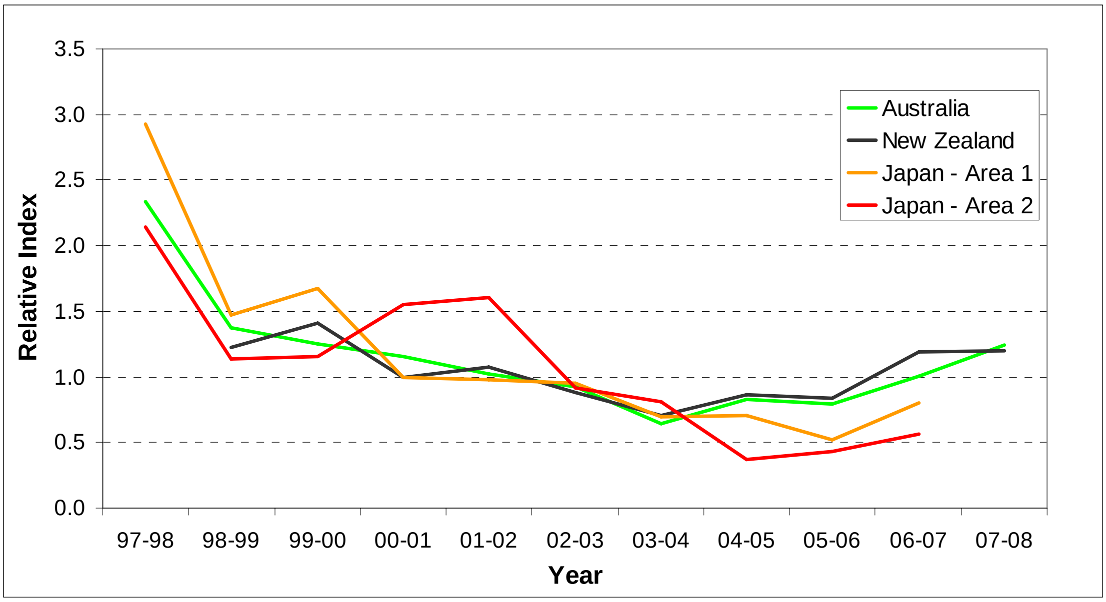


5. Comparison of Indices

5.1 Areas 1 and 2

If the swordfish resource within the Southwest Pacific (comprising Areas 1 and 2) comprises a single stock, and if the standardised CPUE indices based on the catch and effort data for different fleets fishing in this region are each considered to be approximately proportional to the size of the available swordfish population, then one would expect similar trends in the respective time-series of standardised CPUE. Such a comparison is shown in Figure 5.1 for the Australian, New Zealand and Japanese fleets. Note that the index for each annual period is based on the average of the quarterly index over the four quarters between 1-July to 30-June.

Figure 5.1 Comparison of the standardised swordfish CPUE indices for the Australian, New Zealand and Japanese fleets operating within assessment areas 1 and 2 the southern WCPO. Note, all indices are scaled such that the mean across the years 98-99 to 05-06 is equal to 1.

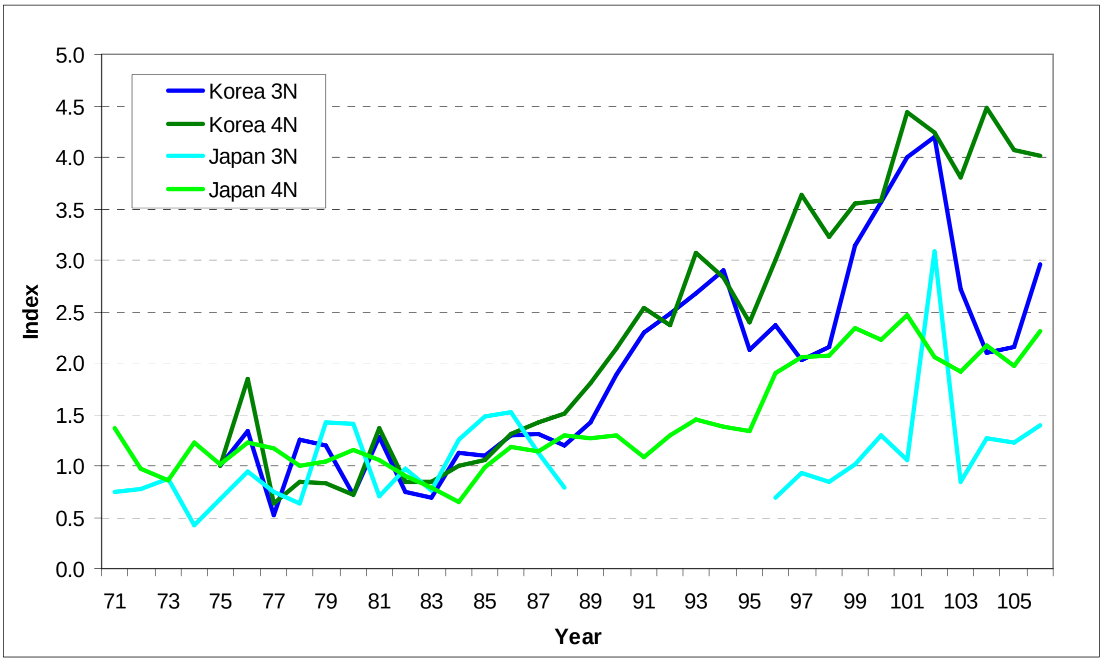


The trends for the Australian and New Zealand fleets are seen to be quite similar. This is an encouraging result as these two fleets catch the majority of the swordfish in the Southwest Pacific. Furthermore, it is for these two fleets that we have a most information on targeting and gear-setting practices required to standardise the effort. The trends for the Japanese fleet also show very similar trends to the Australian and New Zealand fleets for the first 7 years (i.e. up until 03-4) but remain below the other two indices for the remainder of the series. Nevertheless, there does appear to be an increased in the trend for the Japanese fleet at the end of the time series in line with the increasing trends since in the indices for the Australian and New Zealand fleets. Whether or not the utility of the Japanese indices in these latter years is being constrained (or at worst biased) due to the declines in overall effort in these areas remains uncertain, but the precision of the estimates will have decreased.

5.1 Areas 3 and 4

Within Areas 3 and 4 a comparison of the Japanese and Korean indices is shown in Figure 5.2. Within Area 4 both indices show a steady increase since the late 1980s, though the extent of this increase is different for the two fleets with the increase in the Korean index twice that of the Japanese index. The reason for this difference remains uncertain, though it may be due to a successive shift in targeting within the Korean fleet that has not been accounted for by the standardisation (due in part to the missing information on gear configuration). Within Area 3 the two indices are more divergent, with the Japanese index displaying little or no increase compared to a doubling in the Korean index over the past 20 years. As with the result for Area 4, this increase may be due to a shift in the targeting by the Korean fleet.

Figure 3.6 Comparison of the standardised swordfish CPUE indices for the Korean and Japanese fleets operating within assessment areas 3 and 4 the southern WCPO. Note, all indices are scaled such that the mean across the years 1975-85 is equal to 1.



References

Campbell, R, K. Williams and D. Waddingham (2007) Summary of Size Data collected from the Eastern Tuna & Billfish Fishery and associated Indicators: FY 97/98 to FY 05/06. Information paper presented to the meeting of the ETBF Resource Assessment Group, held 19-20 March 2007, Mooloolaba.

Davies, N.; Campbell, R.; Kolody, D. (2006). CASAL Stock Assessment for South-West Pacific Broadbill Swordfish 1952-2004. Methods Specialist Working Group paper presented at the 2nd meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7-16 August 2006. WCPFC-SC2 ME-WP-4.

Kolody, D.; Campbell, R.; Davies, N. (2006). Multifan-CL Stock Assessment for South-West Pacific Broadbill Swordfish 1952-2004 Methods Specialist Working Group paper presented at the 2nd meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7-16 August 2006. WCPFC-SC2 ME-WP-3.

Lo, N.C., Jacobson, L.D. and Squire, J.L. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat.Sci., 49, 2515-2526.

Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. Biometrics, 39, 281-286.

Pennington, M. and Berrien, P. 1984. Measuring the precision of estimates of total egg production based on plankton surveys. J. Plankton Res.., 6, 869-879.

Unwin, M.; Davies, N.; Richardson, K.; Griggs, L.; Wei, F. (2006). Standardised CPUE indices for swordfish (*Xiphias gladius*) from the tuna longline fishery 1992–93 to 2004–05. Final Research Report for Ministry of Fisheries Research Project SWO2004-01. 36 p.