SCIENTIFIC COMMITTEE
THIRD REGULAR SESSION

13-24 August 2007
Honolulu, United States of America

ANALYSIS OF YELLOWFIN AND BIGEYE CATCH AND EFFORT DATA FROM THE JAPANESE AND KOREAN LONGLINE FLEET COLLECTED FROM REGIONAL LOGSHEETS

WCPFC-SC3-SA SWG/WP-6

Adam Langley[1]

[1] Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia

1 Introduction

Catch and effort data from the Japanese distant-water longline fleet are a key input in the assessment of yellowfin and bigeye tuna stocks in the WCPFC (Hampton et al. 2006a, 2006b). These data are used to derive standardised CPUE indices for each of the six regions included in the two species assessments. Within the assessment models, the temporal trends in the standardised CPUE indices are assumed to be proportional to the longline exploitable biomass.

The Japanese distant-water longline data used to derive the standardised CPUE indices are available in an aggregated format only; these data represent the summation of the total fleet catch and effort data grouped by year, month, hooks-between-float (HBF) category, and degree of latitude and longitude. No information is available regarding the operation of individual vessels within the fleet.

During previous deliberations of the Scientific Committee of the WCPFC, concerns were expressed regarding the potential biases that may result in the application of aggregated catch and effort data in the derivation of key abundance indices for the stocks. For example, the aggregated nature of the data may obscure long-term changes in the operation of the fleet that could result in “hyperstability” of the CPUE index and, thereby, compromise the assumption of proportionality between the CPUE index and stock abundance.

More recently, a technical meeting was held to discuss issues related to the analysis of catch and effort data, principally the determination of the key standardised CPUE indices (reference). The meeting also identified the need to more thoroughly analyse the available operational level data and identified a number of specific analyses that could be undertaken.

Foreign longline vessels, principally the fleets of Japan, Korea, and Taiwan, are required to furnish operational level catch and effort reports for recording fishing activity in the waters of national jurisdiction of Pacific Island countries. This information is reported via the South Pacific Regional Longline Logsheet form (see Appendix 1) which records vessel details, date and time of set, gear configuration (number of hooks and hooks-between-floats), and the catch (number and weight) of the main species caught (albacore, bigeye, yellowfin, striped marlin, blue marlin, and black marlin and sharks and other species).

These logsheet forms are completed as a condition of the longline fishing license and submitted to the fisheries agency of the country where fishing occurred. Copies of the logsheets are provided to the Statistics and Monitoring Section of the Oceanic Fisheries Programme (OFP) and the Secretariat of the Pacific Community (SPC). These data are entered in the regional fisheries database held by OFP.

There are six principal foreign longline fleets that account for most of the in zone fishing activity and, hence, represent the main sources of logsheet data.

1. Japanese distant-water longline vessels, principally fishing in the western equatorial waters of the WCPO, including Federated States of Micronesia (FSM), Republic of the Marshall Islands (RMI), Palau and Solomon Islands.
2. Japanese offshore longline vessels (principally based in Guam) mainly fishing in FSM and Palau waters.
3. Korean distant-water longline vessels, principally fishing in the equatorial waters of the WCPO east of 170°E, including Tuvalu, Kiribati waters (Gilbert Islands, Phoenix Islands and Line Islands) and international waters.
4. The Taiwanese longline fleet operating in the south Pacific and principally catching albacore, within the national waters of Fiji, and Vanuatu and international waters.

5. The Taiwanese longline fleet operating in the eastern WCPO and principally catching bigeye within the national waters of Kiribati and international waters.
6. Taiwanese longline fleet operating in the western WCPO, within the national waters of FSM, RMI, Palau and Solomon Islands.

These data sets provide substantially greater spatial and temporal resolution than the aggregated catch and effort data generally available for the foreign longline fleets (typically aggregated by month and either one or five degree latitude/longitude squares).

This report presents the results of a number of analyses of the logsheet data, principally focussing on the Japanese longline fleets operating within the western area of the WCPO (Region 3 of the six-region MFCL models for yellowfin and bigeye). The specific analysis and the rationale for these analyses are outlined below.

Analysis	**Data set(s)**	**Rationale**
Comparison of trends in bigeye and yellowfin CPUE from various Japanese data sets from Region 3.	JP 5*5, month. JP DW 1*1, month. JP DW 5*5, month. JP DW logsheet. JP offshore logsheet.	• Examine consistency of CPUE trend between data sets. • Potential to utilise logsheet data to extend CPUE time-series (2005 and 2006).
Comparison of trends in bigeye and yellowfin CPUE from Korean and Japanese data sets from Region 4.	JP DW 1*1, month. KR 5*5, month. KR logsheet	• Examine consistency of CPUE trend between data sets. • Potential to augment JP CPUE data with data from the Korean fleet to develop a composite CPUE time-series.
Standardised CPUE analysis of Japanese logsheet data from Region 3.	JP DW logsheet. JP offshore logsheet. Oceanographic data.	• Comparison of indices derived from various data sets. • Examine influence of operational variables in CPUE index (e.g. time of day). • Examine influence of oceanographic variables in CPUE index.
Standardised CPUE analysis of Korean logsheet data from Region 4.	KR DW logsheet. Oceanographic data.	• Comparison of indices derived from various data sets. • Examine influence of operational variables in CPUE index (e.g. time of day). • Examine influence of oceanographic variables in CPUE index.
Cluster analysis of logsheet data based on composition of the non-target catch.	JP DW logsheet. JP offshore logsheet.	• Use cluster analysis to distinguish between different types of fishing operation (related to target activity) as defined by catch composition. • Comparison of CPUE indices derived from different clusters.
Cluster analysis of logsheet data based on oceanographic conditions where fishing occurred.	JP DW logsheet. JP offshore logsheet. Oceanographic data.	• Use cluster analysis to distinguish between different "habitats" (related to target activity) as defined by oceanographic data. • Comparison of CPUE indices derived from different clusters. • Identification of key "habitat" for principal species.
Spatial analysis	JP DW logsheet.	• Computation of a range of spatial statistics that summarise operation details of fishing operation. • Determination of patchiness of fishing operation. • Comparison of CPUE trends from different modes of fishing.

2 Summary of logsheet data sets

2.1 Japanese longline data sets, Region 3

The logsheet data from the Japanese distant-water fleet represents a significant proportion (generally 50–70%) of the total longline fishing effort by this fleet within Region 3 (Table 1). Since 1980, there has been a steady decline in the number of vessels and fishing effort (total sets and hooks) within the logsheet data set. This is broadly consistent with the overall decline in longline effort by the Japanese distant-water fleet in Region 3, although there has also been a decline in logsheet coverage in recent years (to about 30%) (Table 1).

Table 1. Summary of the logsheet data from the Japanese distant-water fleet for vessels fishing within Region 3 of the yellowfin/bigeye MFCL assessment area. Limited data are also available from 1978 and 1979. The proportion of total effort is the proportion of total fishing effort (number of hooks) reported by the Japanese distant-water fleet (aggregated dataset).

Year	Number			Prop. of records		Prop. total effort
	Vessels	sets	Hooks (m)	Start time	HBF	
1980	588	20,896	40.88	-	0.853	0.394
1981	621	28,444	55.86	-	0.899	0.485
1982	447	26,221	51.90	-	0.994	0.545
1983	317	16,090	32.29	-	0.996	0.533
1984	394	24,043	50.74	-	0.996	0.767
1985	351	23,883	54.38	-	0.998	0.712
1986	238	13,093	31.11	-	0.998	0.691
1987	188	10,859	25.30	-	0.979	0.757
1988	196	10,407	24.61	-	0.993	0.581
1989	205	13,084	31.19	-	0.992	0.588
1990	196	11,918	28.70	-	0.990	0.541
1991	152	9,283	22.84	-	0.994	0.523
1992	216	10,636	26.09	-	0.993	0.657
1993	189	10,385	25.54	-	0.990	0.626
1994	167	8,071	20.22	-	0.996	0.481
1995	166	11,257	27.68	-	0.984	0.640
1996	115	6,123	14.49	-	0.975	0.618
1997	86	4,075	9.86	-	0.971	0.482
1998	86	3,821	9.17	-	0.989	0.418
1999	103	6,994	17.13	0.143	0.851	0.669
2000	100	4,185	10.03	0.663	0.324	0.354
2001	72	2,943	7.25	0.252	0.925	0.276
2002	82	3,111	8.23	0.325	0.875	0.286
2003	95	6,256	16.02	0.440	0.916	0.579
2004	60	2,461	5.81	0.737	0.843	0.272
2005	54	2,623	6.25	0.949	0.922	-
2006	43	1,450	3.11	0.974	0.763	-

Most of the logsheet records from the Japanese distant-water fleet include information regarding the gear configuration (HBF). Since 1999, time of set has been recorded on logsheets, following the introduction of a revised logsheet form, and this field has been recorded for almost all sets in the most recent years (Table 1).

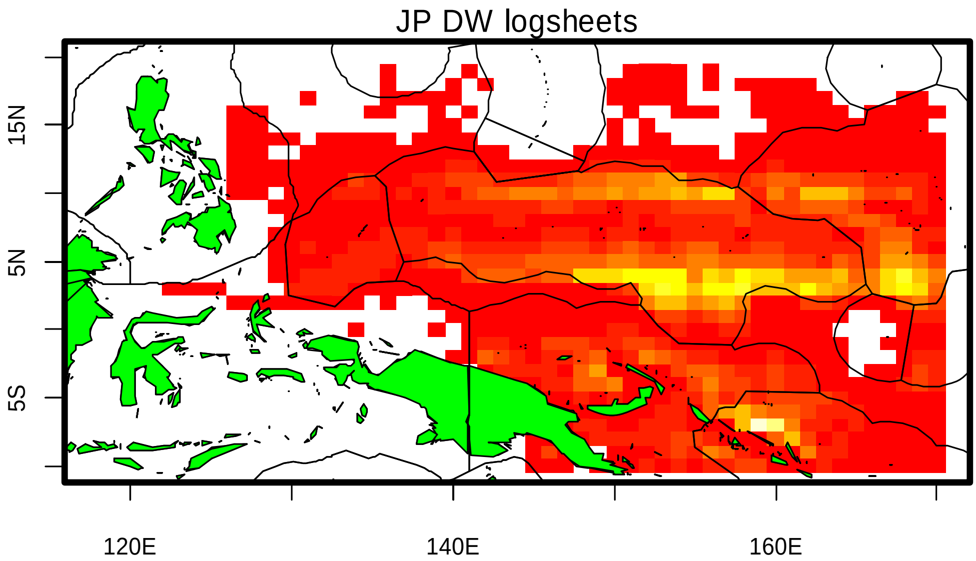
Logsheet data from the offshore (Guam-based) Japanese longline fleet is considered represent almost complete coverage of this fleet (Peter Williams, pers. comm.) (Table 2). The fleet represents about 40–70 vessels and, with the decline of the Japanese distant-water fleet, represents an increasingly significant component of the total Japanese longline fishing activity within Region 3; in the last decade the fleet has represented about 30% of total Japanese longline effort in area.

As with the distant-water logsheet data, HBF has routinely recorded on most logsheets and since 2000 almost all records have recorded the time of the set (Table 2).

Table 2. Summary of the logsheet data from the Japanese offshore (Guam-based) fleet for vessels fishing within Region 3 of the yellowfin/bigeye MFCL assessment area. The proportion of total effort is the proportion of total fishing effort (number of hooks) reported by the Japanese offshore fleet (aggregated dataset). For this fleet, logsheet coverage rates are assumed to be 100%.

Year	Number			Prop. of records		Prop. total effort
	Vessels	sets	Hooks (m)	Start time	HBF	
1987	30	1,091	2.04	-	0.796	0.999
1988	48	2,458	4.63	-	0.747	1.001
1989	93	6,189	11.94	-	0.745	1.000
1990	92	6,642	13.64	-	0.951	1.000
1991	91	6,894	14.33	-	0.982	1.000
1992	64	3,760	8.14	-	0.945	1.001
1993	61	4,686	9.91	-	0.971	1.001
1994	59	4,275	8.72	-	0.930	1.009
1995	64	7,626	15.94	-	0.985	1.006
1996	71	7,512	15.76	-	0.964	1.002
1997	62	6,413	13.44	-	0.977	1.000
1998	60	5,892	12.55	-	0.956	1.000
1999	65	6,805	15.02	0.266	0.788	1.000
2000	67	6,748	15.18	0.929	0.661	1.000
2001	51	3,536	8.20	0.977	0.777	1.000
2002	32	1,548	3.61	0.919	0.884	0.999
2003	52	4,421	10.19	0.935	0.864	1.001
2004	42	5,580	12.61	0.870	0.669	1.000
2005	52	4,314	9.98	0.948	0.890	0.999
2006	48	3,470	7.76	0.962	0.770	1.001

The spatial distribution of fishing effort within Region 3 differs between the two fleets (Figure 1). The offshore fleet has concentrated fishing activity within FSM generally south of Guam. The main area of fishing effort occurs in two latitudinal bands, at about 5°N and 10°N. Fishing effort by the distant-water fleet also tends to be concentrated along the same latitudinal bands, although the fleet generally operates eastward of the offshore fleet (Figure 1). The distant-water fleet has operated over a wider area of Region 3 with fishing activity also concentrated in the RMI EEZ, Solomon Islands and, historically, within PNG waters.



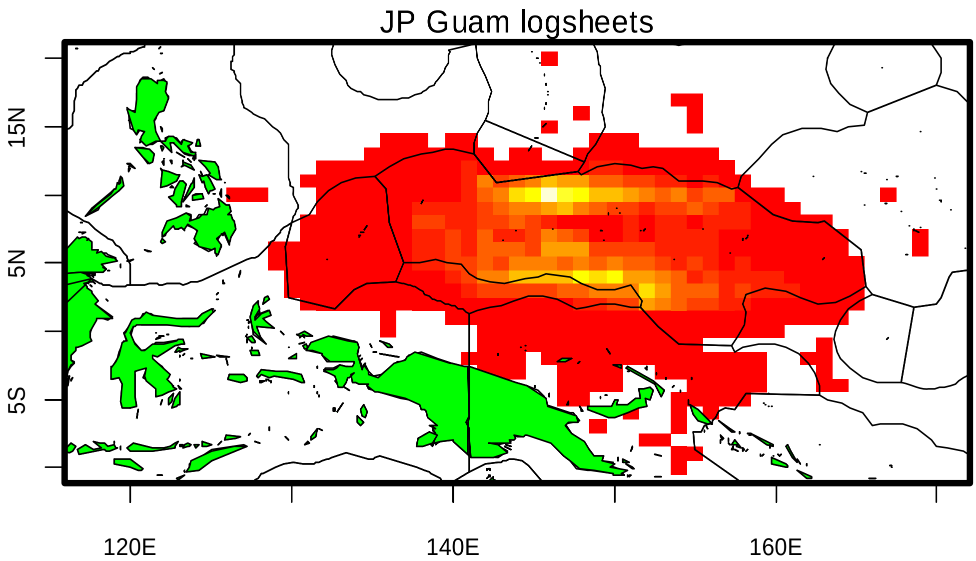


Figure 1. Spatial distribution of logsheet sets, by one degree square, for the Japanese distant-water fleet (top) and the Japanese offshore (Guam-based) fleet (bottom) operating within Region 3, all years combined. The intensity of effort is depicted by colour; increasing from red to orange to yellow, white represents no effort. The scales differ between the two plots.

2.2 Longline data sets, Region 4

A long time-series of catch and effort data is available from the Korean longline fleet fishing within Region 4 of the WCPO. Fishing effort by this fleet increased from the early 1990s to recent years. This contrasts with the decline in Japanese longline fishing activity in the area; during the last 15 years, the overall magnitude of effort and the seasonal variation in the level of effort which was lower than during the preceding period (Figure 2).

Over the last decade, fishing effort in Region 4 by the Korean longline fleet has greatly exceeded the effort by the Japanese distant-water fleet. There is the potential to combine the Japanese and Korean longline data set to derive a composite CPUE index for yellowfin and bigeye within Region 4. However, the aggregated catch and effort data available from the Korean fleet (aggregated by 5*5 and month) are at a coarser spatial resolution than the Japanese longline data (aggregated by 1*1, month, and HBF) and do not include information regarding gear configuration.

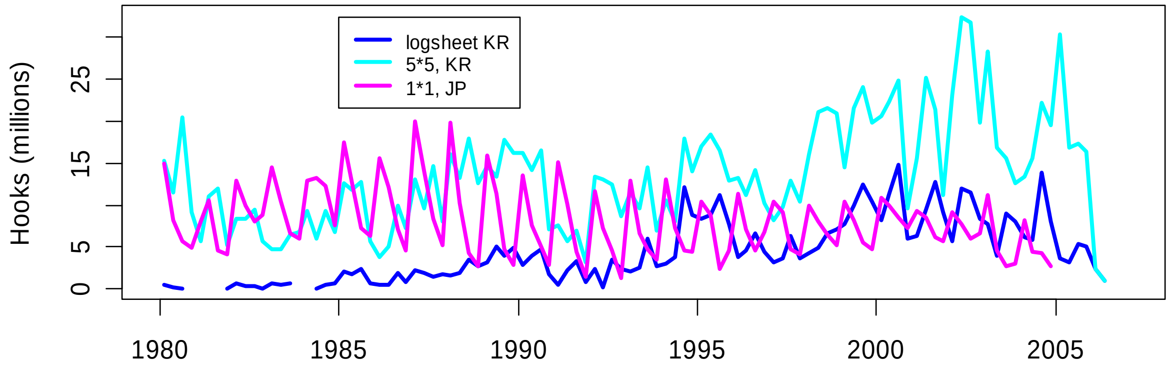


Figure 2. Quarterly longline effort (millions of hooks) from various sources of Korean and Japanese longline data from Region 4 of the yellowfin/bigeye MFCL assessments, 1980 to 2006. Data held by OFP databases (as at 3 April 2007).

Nevertheless, information regarding gear configuration is available for the majority of logsheet records provided by the Korean longline fleet (Table 3). Prior to 1989, less than 20% of Korean longline fishing activity within Region 4 was reported on regional logsheets. However, over the last decade logsheets have accounted for 40–50% of total longline effort, documenting fishing activity of 120–150 individual longline vessels (Table 3).

Overall, the spatial distribution of Korean logsheet data is broadly consistent with the distribution of total reported fishing effort within Region 4 (Figure 3).

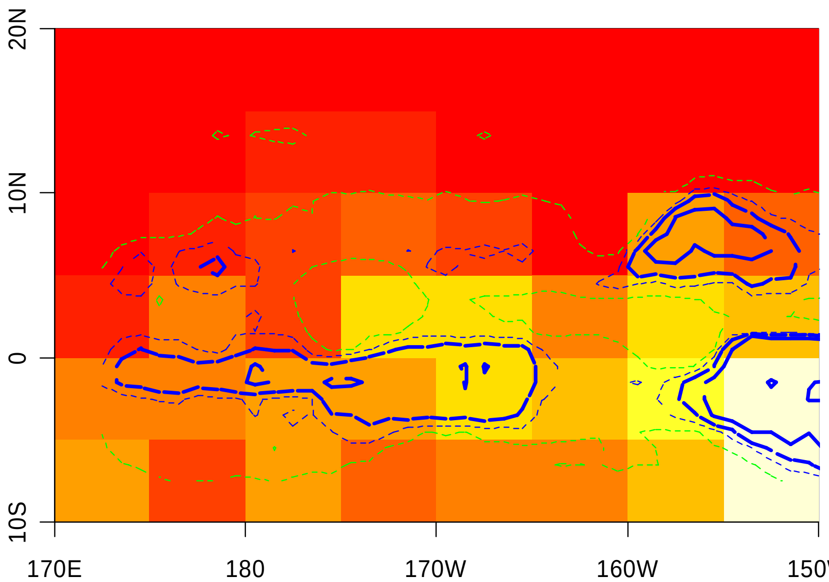


Figure 3. A comparison of the distribution of aggregated 5 degree Korean longline effort data (heat map) and logsheet data (contour lines) from Region 4 of the yellowfin/bigeye MFCL assessments, 1980 to 2006. Data held by OFP databases (as at 3 April 2007). The contour lines represent low (green), medium (blue dashed), high, and very high (solid blue) levels of effort from logsheet data. The relative level of effort for the 5 degree aggregated data set increases from red (low) to orange (medium) to yellow (high).

Table 3. Summary of the logsheet data from the Korean distant-water fleet for vessels fishing within Region 4 of the yellowfin/bigeye MFCL assessment area. The proportion of total effort is the proportion of total fishing effort (number of hooks) reported by the Korean distant-water fleet (aggregated dataset).

Year	Number			Prop. of records		Prop. total effort
	Vessels	sets	Hooks (m)	Start time	HBF	
1980	12	216	0.65	-	-	0.012
1981	1	10	0.03	-	-	0.001
1982	19	558	1.33	-	0.272	0.042
1983	13	673	1.75	-	0.814	0.077
1984	23	500	1.40	-	0.932	0.045
1985	47	2,376	6.97	-	0.935	0.163
1986	46	1,270	3.75	-	0.976	0.144
1987	61	2,629	7.43	-	0.971	0.164
1988	87	3,475	9.83	-	0.929	0.164
1989	97	6,365	17.11	-	0.892	0.276
1990	126	5,087	13.25	-	0.842	0.246
1991	84	2,833	6.94	-	0.793	0.296
1992	102	3,514	8.56	-	0.853	0.180
1993	91	5,622	13.44	-	0.824	0.315
1994	118	11,747	27.74	-	0.774	0.551
1995	157	15,477	36.05	-	0.833	0.558
1996	107	8,268	19.45	-	0.775	0.398
1997	79	6,793	16.87	-	0.690	0.409
1998	122	8,698	22.96	0.000	0.761	0.289
1999	156	15,650	40.40	0.000	0.792	0.506
2000	148	15,322	40.37	0.034	0.813	0.523
2001	148	13,891	37.59	0.031	0.766	0.513
2002	144	13,663	37.44	0.049	0.757	0.349
2003	144	10,254	28.54	0.505	0.740	0.390
2004	126	12,111	33.99	0.886	0.803	0.482
2005	92	6,149	17.24	0.957	0.751	0.214
2006	32	1,278	3.38	0.894	0.895	-

3 Comparison of catch and effort data sets

3.1 Japanese longline data sets, Region 3

OFP databases include five different sets of longline data from the Japanese fleets operating within Region 3. Four of these data sets are a subset of the total data set which includes all fishing effort (and associated catch) aggregated by 5 degree latitude/longitude squares (5*5, all) (Figure 4).

The total data set is comprised of two distinct subsets: the total 5*5 data for the distant-water fleet (5*5, DW) and the offshore fleet (vessels unloading in ports other than in Japan). The latter is equivalent to the logsheet data from the offshore fleet (logsheet Guam) given the assumption of complete logsheet coverage.

The distant-water data sets are available at three levels of spatial resolution: aggregated at 5 degree lat/long, aggregated at 1 degree lat/long, and operational level logsheet. The 1 degree and logsheet data sets represent about 80% and 50% of the total distant-water effort (5*5, DW), respectively (Figure 4).

Overall, since the mid 1980s, there has been a steady decline in total Japanese longline effort in Region 3, largely driven by a decline in the activity of the operation of the distant-water fleet (Figure 4). Total effort for the distant-water fleet and the entire Japanese fleet was only available up to the end of 2004, although logsheet data for both fleets were available until mid 2006.

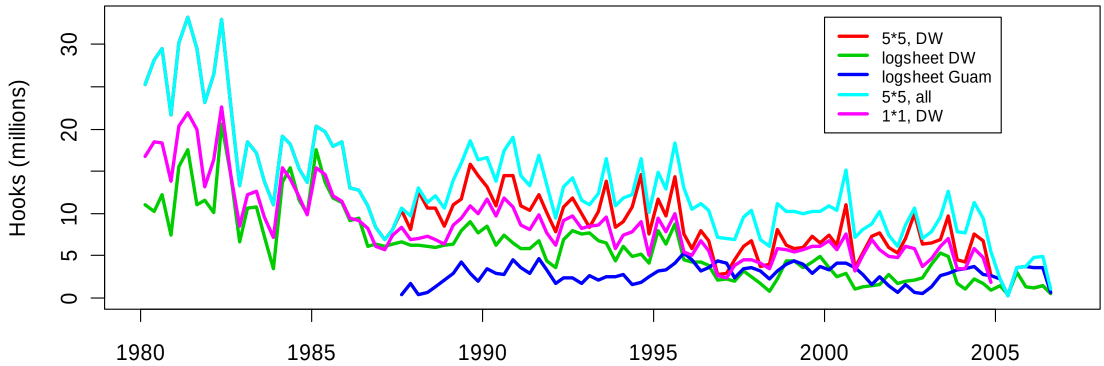


Figure 4. Quarterly longline effort (millions of hooks) from various sources of Japanese longline data from Region 3 of the yellowfin/bigeye MFCL assessments, 1980 to 2006. Data held by OFP databases (as at 3 April 2007). Total effort data for the distant-water fleet were available up to the end of 2004.

Trends in the nominal catch rate (number of fish per 100 hooks) of yellowfin are very similar for the three sets of data available from the distant-water longline fleet (5*5 DW, 1*1 DW, and DW logsheet) with a steady decline in CPUE from 1985 to 2000 and relatively low CPUE in the subsequent period (Figure 5). The logsheet data from the offshore fleet (logsheet Guam) reveals a similar declining trend from the late 1980s, although the overall magnitude of the CPUE is considerably lower than the distant-water fleet (Figure 5).

For the distant-water fleet, trends in nominal CPUE of bigeye are virtually identical for the three data sets (5*5 DW, 1*1 DW, and DW logsheet) (Figure 5). Quarterly nominal CPUE indices derived from the offshore (Guam) logsheet data are very similar from the late 1980s to 2000, but deviate from the distant-water fleet in the subsequent years, tending to decline slightly rather than exhibiting the periods of high CPUE recorded by the distant-water fleet in 2001 and 2004.

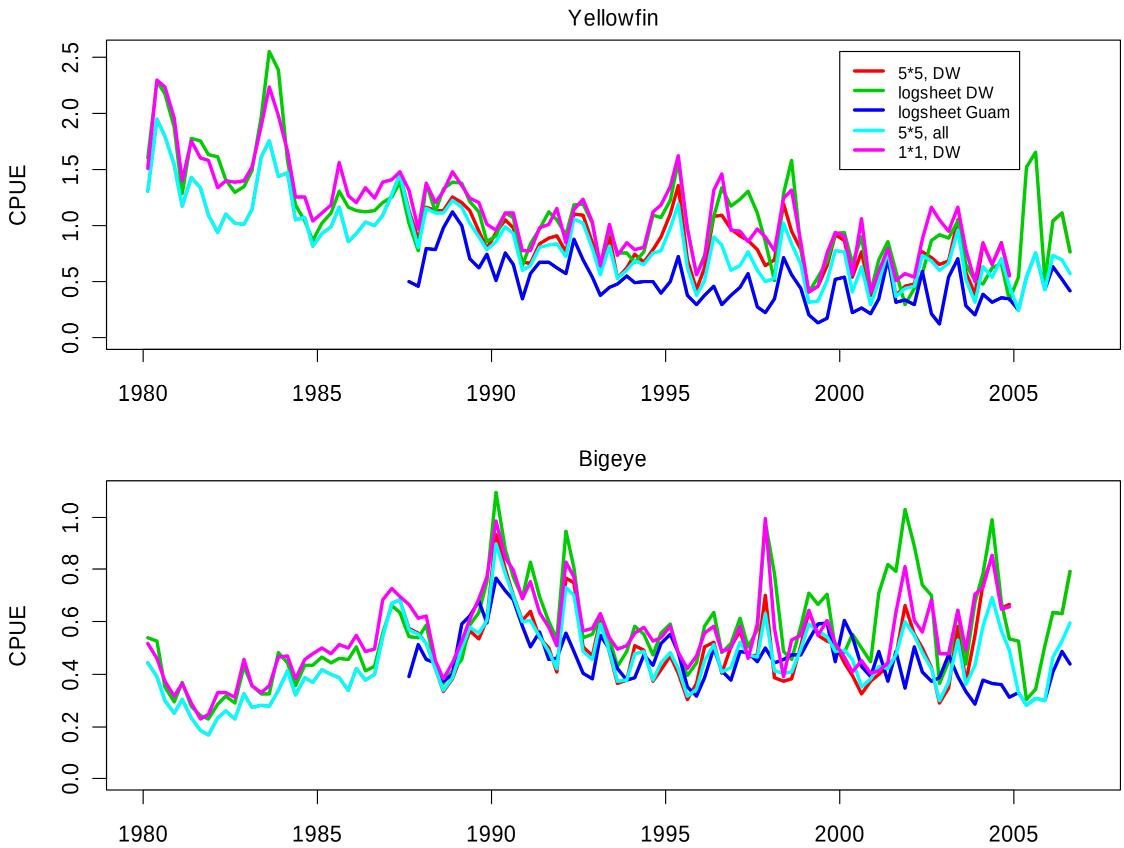


Figure 5. Quarterly nominal yellowfin and bigeye CPUE (number of fish per 100 hooks) from various sources of Japanese longline data from Region 3 of the yellowfin/bigeye MFCL assessments, 1980 to 2006. Data held by OFP databases (as at 3 April 2007).

3.2 Longline data sets, Region 4

Trends in nominal longline catch rates of yellowfin tuna within Region 4 are very similar for the two sets of data available from the Korean longline fleet: a) the aggregated monthly, 5*5 lat/long data submitted by the Korean fisheries agency and b) the data submitted on regional logsheets by Korean longline vessels (Figure 6). The magnitude and the trend in the nominal CPUE from the Korean fleet are also comparable to nominal CPUE from the Japanese longline data (aggregated by month, HBF, and lat/long) (Figure 6).

For bigeye tuna, trends in nominal CPUE are comparable for the two sets of Korean data (aggregated and logsheet). The trend in nominal CPUE is also comparable to the Japanese longline data during the 1990s, but deviates from Japanese CPUE trend during the 1980s and over the last five years (Figure 6). In both periods, Korean longline CPUE was considerably lower than the nominal CPUE from the Japanese fleet.

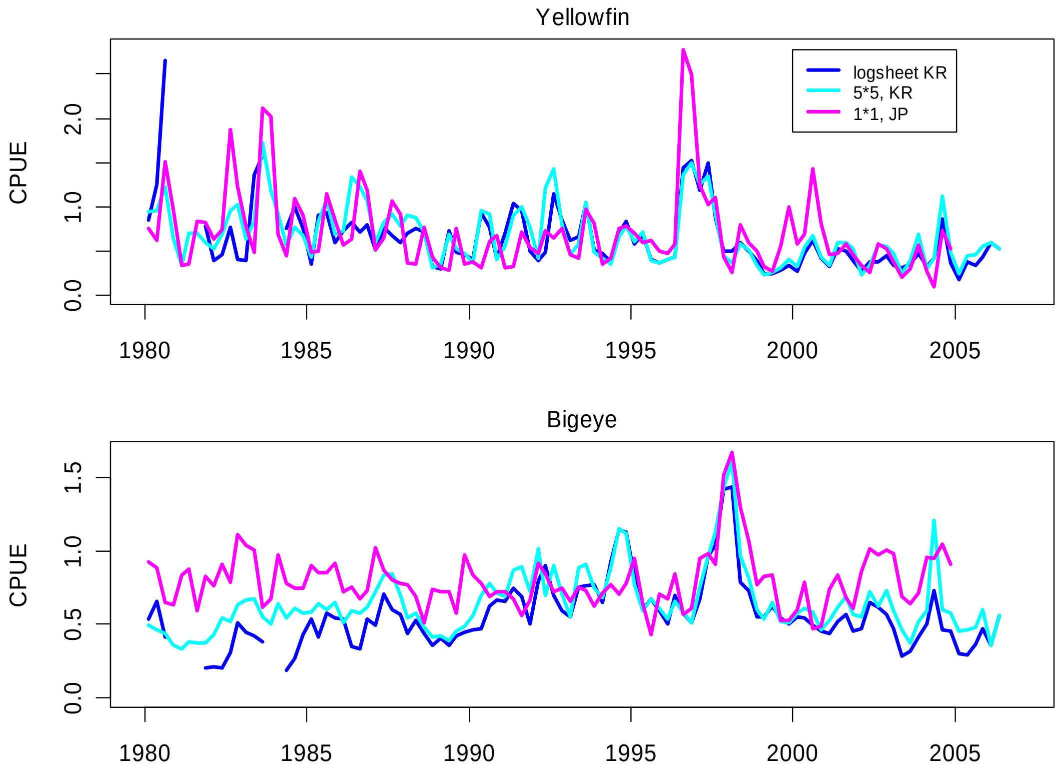


Figure 6. Quarterly nominal yellowfin and bigeye CPUE (number of fish per 100 hooks) from various sources of Korean and Japanese longline data from Region 4 of the yellowfin/bigeye MFCL assessments, 1980 to 2006. Data held by OFP databases (as at 3 April 2007).

4 Standardised CPUE indices

Temporal trends in catch rate from the various sets of logsheet data were further investigated using a generalised linear modelling (GLM) approach. This approach incorporated the additional information available from the logsheet data (principally unique vessel identification code, date of set, and time of day of set) and local-scale oceanographic data as potential explanatory variables in the GLM. A list of the potential explanatory variables is presented in Table 4.

Five separate data sets were included in the analysis and CPUE indices were derived for both yellowfin and bigeye from each of the data sets.

i. Japanese distant-water longline logsheet MFCL region 3 (excluding time of set), 1980–2006.
ii. Japanese distant-water longline logsheet MFCL region 3 (including time of set), 1999–2006.
iii. Japanese Guam-based longline logsheet MFCL region 3 (excluding time of set), 1987–2006.
iv. Japanese distant-water longline logsheet MFCL region 3 (including time of set), 1999–2006.
v. Korean distant-water longline logsheet MFCL region 4 (excluding time of set), 1980–2006.

The dependent variable in each GLM was the natural logarithm of the catch rate of species (yellowfin or bigeye) from the individual set, expressed as the number of fish caught per hook set. Zero catch records were included in the model data sets; a small nominal value was added to the catch rate of all records.

The explanatory power of the potential predictor variables was assessed using a stepwise (forward and backward) fitting procedure. At each iteration, the improvement in the model was assessed using AIC. Due to the large number of records included within several of the data sets and memory limitations of the statistical software, it was necessary to conduct the fitting procedure on a randomly selected subset of the data (20,000 records).

Core vessels in the Japanese distant-water longline fleet were defined as those vessels completing a minimum of 10 sets within Region 3 in at least 15 years. For the Guam-based fleet and the Korean fleet, vessels were required to fish for a minimum of 7 years to qualify as a core vessel. Non qualifying vessels were aggregated in a single, separate vessel category.

The resulting year/quarter CPUE indices were compared with the regional species-specific CPUE indices derived from the aggregated Japanese longline data (the principal abundance indices included in the MFCL assessment models).

The relationship between species catch rate and the key variables included in each GLM model were examined.

Table 4. A description of the potential explanatory variables included in the GLM analyses.

Variable	Description	Source
Year,quarter	The year,quarter in which the set occurred (categoric).	logsheet
Vessel	Unique vessel code for core vessels in data set (categoric).	logsheet
Longitude	Location of start of set (polynomial).	logsheet
Latitude	Location of start of set (polynomial).	logsheet
Days since new moon	Number of days between the last full moon and the date of the set (polynomial).	logsheet
Time of set	Hour of the day at the start of the set (polynomial).	logsheet
HBF	The number of hooks between floats on the longline (polynomial).	logsheet
Sst1	Monthly sea surface temperature (at 5m depth) in the one degree lat/long cell where the longline set occurred, in °C (polynomial).	NCEP
Sst2	Mean monthly sea surface temperature (at 5m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in °C (polynomial).	NCEP
Sst3	Range of the monthly sea surface temperature (at 5m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in °C (polynomial).	NCEP
Sst4	Change in the monthly sea surface temperature (at 5m depth) from the previous month in the one degree lat/long cell where the longline set occurred, in °C (polynomial).	NCEP
Sstdepth1	Depth of the 20°C isotherm in the month and one degree lat/long cell where the longline set occurred, metres (polynomial).	NCEP
Sstdepth2	Mean depth of the 20°C isotherm in the month and one degree lat/long cells adjacent to where the longline set occurred, metres (polynomial).	NCEP
Sstdepth3	Range of depth of the 20°C isotherm in the month and one degree lat/long cells adjacent to where the longline set occurred, metres (polynomial).	NCEP
Sstdepth4	Change in the depth of the 20°C isotherm from the previous month in the one degree lat/long cell where the longline set occurred, metres (polynomial).	NCEP
Currentu1	Monthly zonal (east-west) current (at 45m depth) in the one degree lat/long cell where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentu2	Mean monthly zonal (east-west) current (at 45m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentu3	Range of monthly zonal (east-west) current (at 45m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentu4	Change in zonal (east-west) current (at 45m depth) from the previous month in the one degree lat/long cell where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentv1	Monthly meridional (north-south) current (at 45m depth) in the one degree lat/long cell where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentv2	Mean monthly meridional (north-south) current (at 45m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentv3	Range of monthly meridional (north-south) current (at 45m depth) in the one degree lat/long cells adjacent to where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP
Currentv4	Change in meridional (north-south) current (at 45m depth) from the previous month in the one degree lat/long cell where the longline set occurred, in 0.01 m/sec (polynomial).	NCEP

Note: NCEP data sourced from
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.EMC/.CMB/.Pacific/.monthly/.D20eq/

Yellowfin, Region 3

The standardised CPUE indices derived from the distant-water logsheet data (excluding hour) were very similar to those computed from the aggregated Japanese longline data (the principal index for the assessment) (Figure 7). The indices derived from the Guam logsheet data were also comparable to these two series, with the exception of higher CPUE indices during the late 1980s.

The two series derived from the more recent logsheet data with the inclusion of time of set were also comparable to the standardised indices derived from the longer time-series (Figure 7). However, these indices were more variable, principally due to the influence of including the vessel-id (core vessel) variable. The associated vessel coefficients in the GLM were less well determined than for the GLMs with the longer time-series.

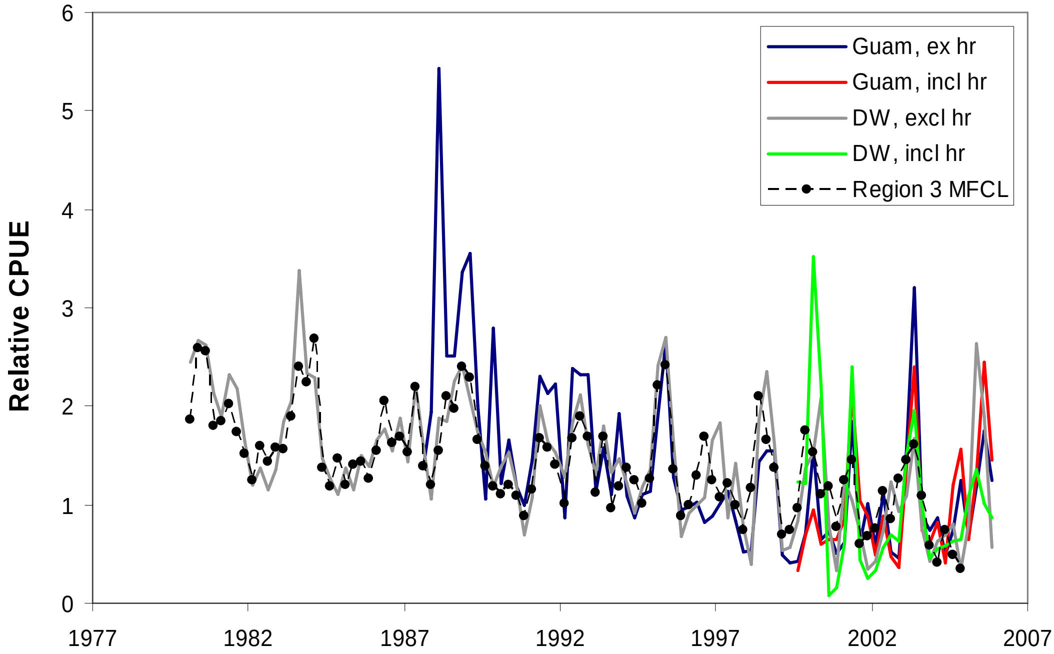


Figure 7. Quarterly standardised yellowfin CPUE (number of fish per 100 hooks) indices for Region 3 of the MFCL assessment derived from various subsets of Japanese logsheet data.

In general, the individual GLMs included a comparable set of significant variables in the step-wise fitting procedure. The most consistently selected variables and the variables with the most explanatory power were: year/qtr, longitude, latitude, vessel, sstdepth1, sst3, HBF, and a number of other oceanographic variables. The oceanographic variables included differed between analyses, although they typically included at least one variable describing the prevailing zonal and meridional currents. An example of the parameterisation of the key variables included in a single GLM is presented in Figure 8.

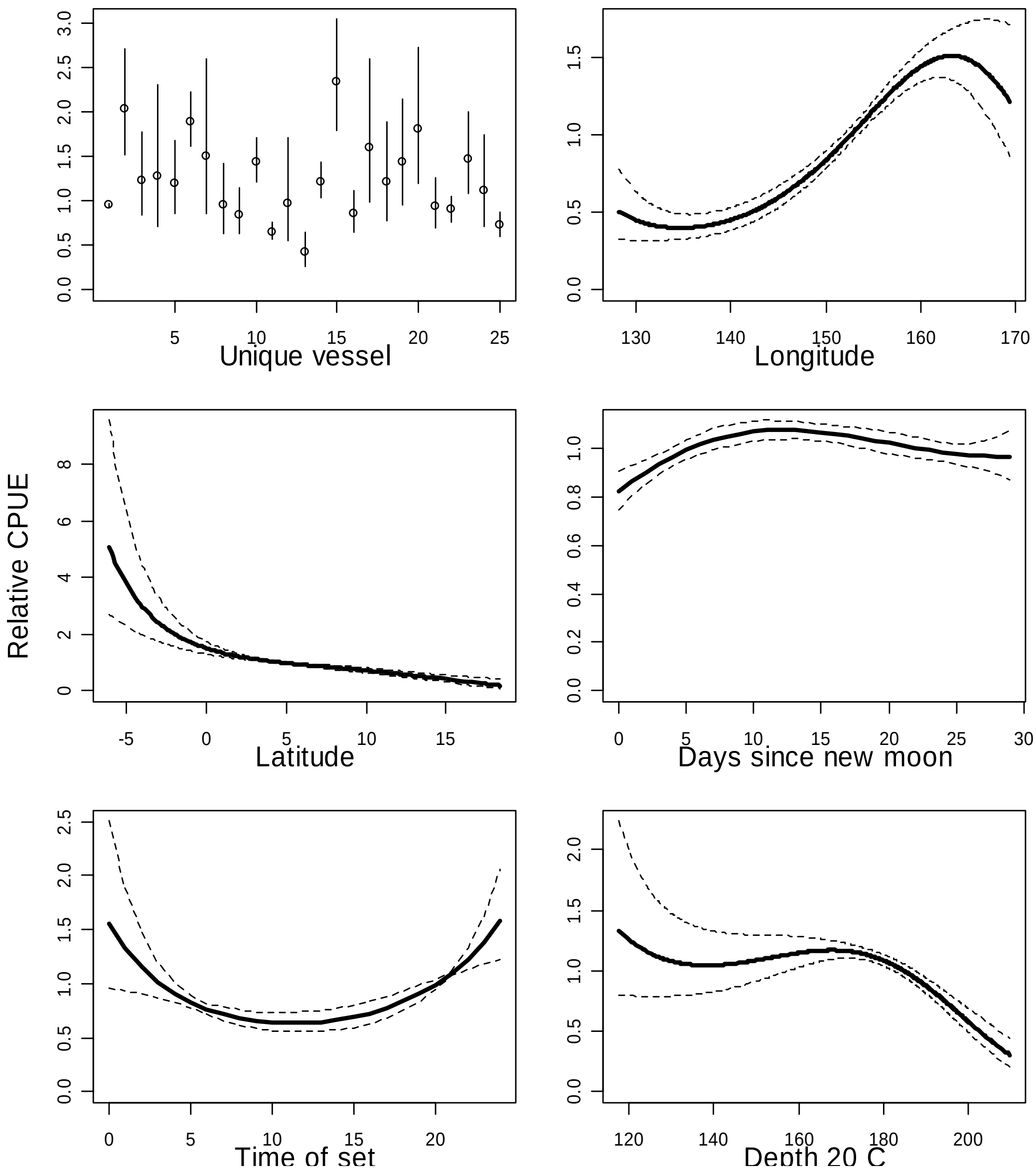


Figure 8. Parameterisation of the variables included in the Region 3 yellowfin GLM derived from logsheet data provided by the Japanese distant-water longline fleet.

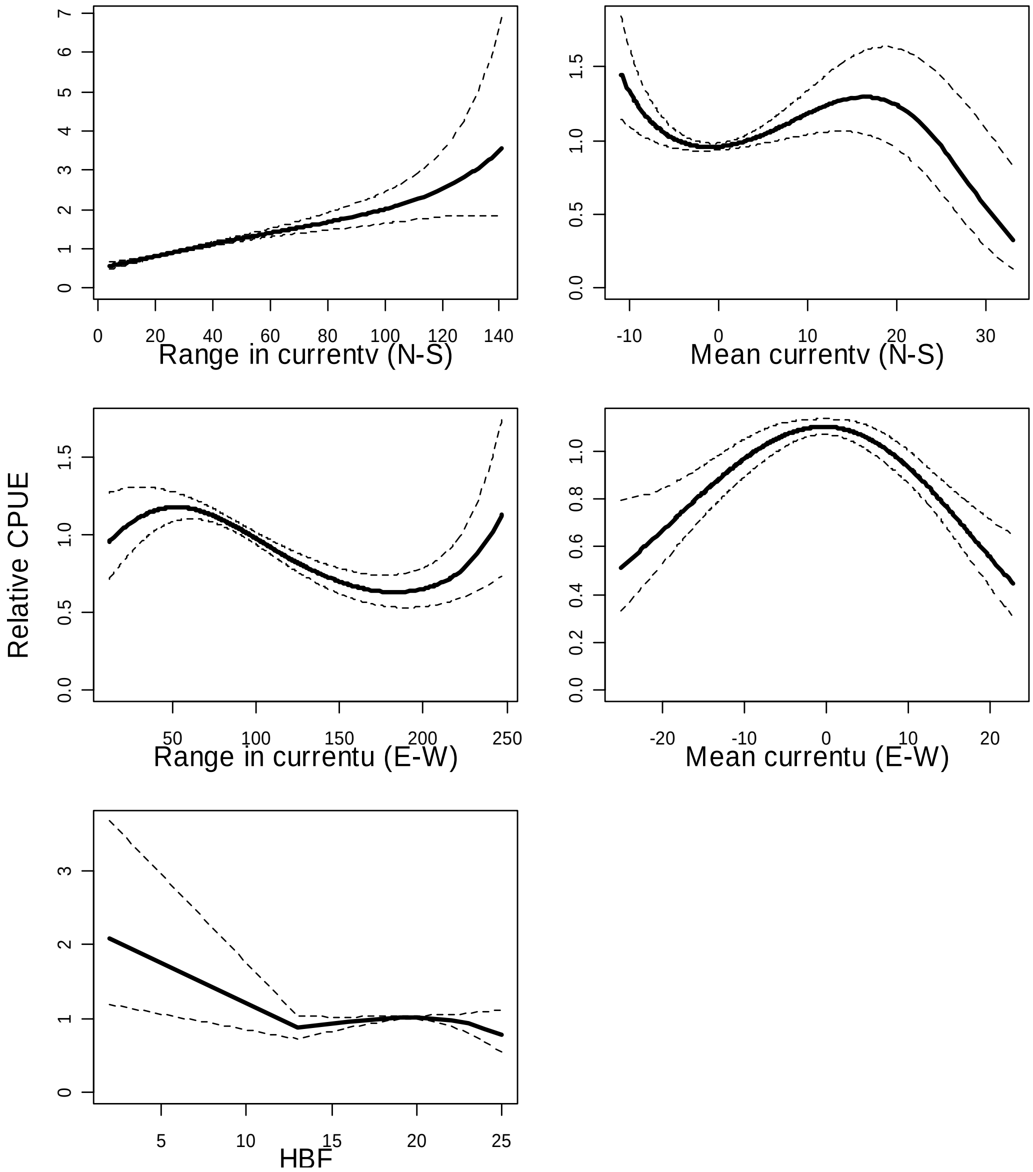


Figure 8 continued.

Bigeye, Region 3
As for yellowfin, the standardised CPUE indices derived for bigeye in MFCL Region 3 from both sources of logsheet data (distant-water and Guam-based) both closely approximate the indices derived from the aggregated Japanese longline data (Figure 9). The only qualifications are the lower CPUE indices derived from the distant-water logsheet data during the early 1980s and the more variable indices for the last decade derived from the same data set.

The two sets of indices derived from the shorter time-series (including start time) were also comparable to the three sets of indices encompassing the longer-time period, although the indices from the distant-water logsheet data were much more variable (Figure 9).

In general, the bigeye GLM models included the same key variables that were incorporated in the yellowfin GLMs, although the parameterisation of these variables differed considerably between the two species.

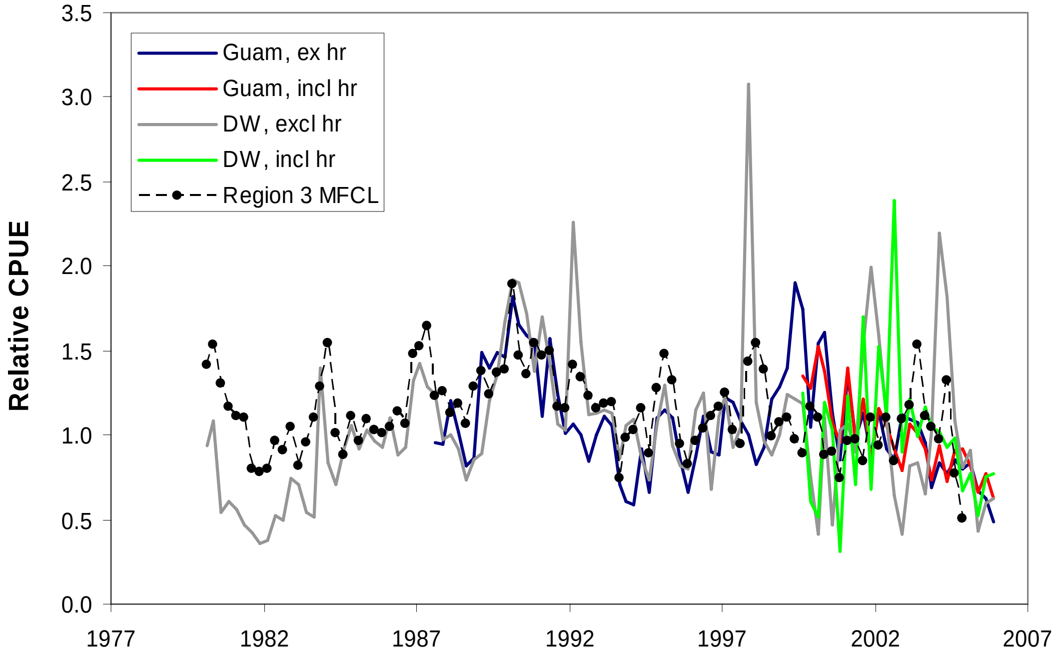


Figure 9. Quarterly standardised bigeye CPUE (number of fish per 100 hooks) indices for Region 3 of the MFCL assessment derived from various subsets of Japanese logsheet data.

Yellowfin, Region 4
Standardised CPUE indices for yellowfin tuna in Region 4 derived from the Korean logsheet data are very similar to the principal index for yellowfin in the region (derived from the aggregated Japanese longline data) (Figure 10).

Bigeye, Region 4
The bigeye standardised CPUE indices derived from Korean logsheet data are comparable to the principal CPUE index for bigeye in Region 4 from the early 1990s onward (Figure 11). However, the indices deviate considerably in the earlier period, with the standardised CPUE indices from the Korean fleet being considerably lower than the Japanese fleet during the mid–late 1980s.

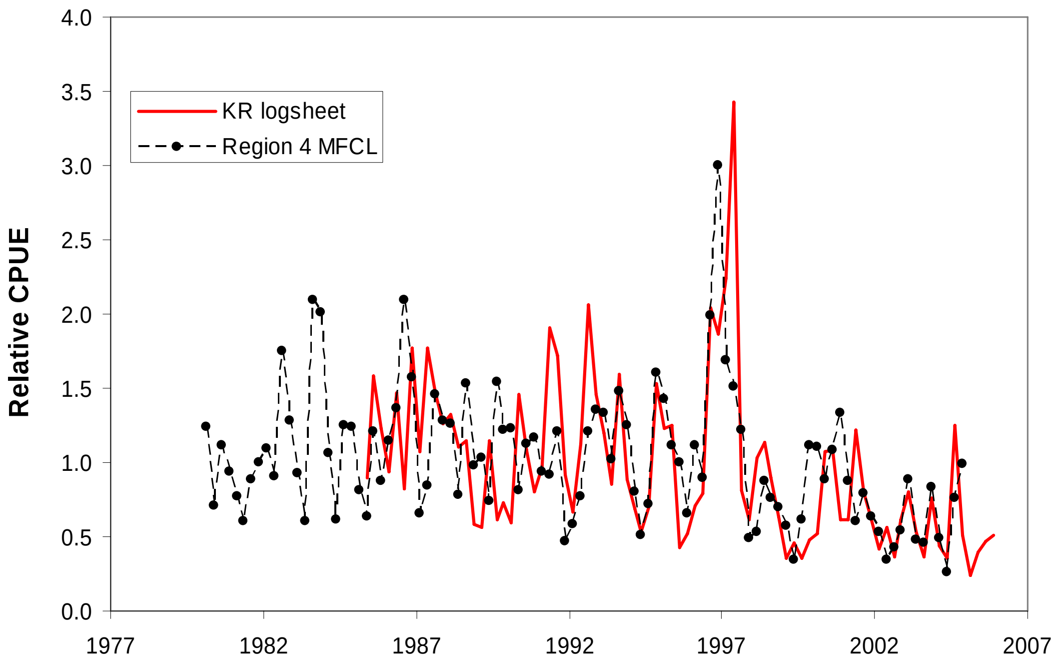


Figure 10. Quarterly standardised yellowfin CPUE (number of fish per 100 hooks) indices for Region 4 of the MFCL assessment derived from the Korean logsheet data. The current Region 4 index is plotted for comparison.

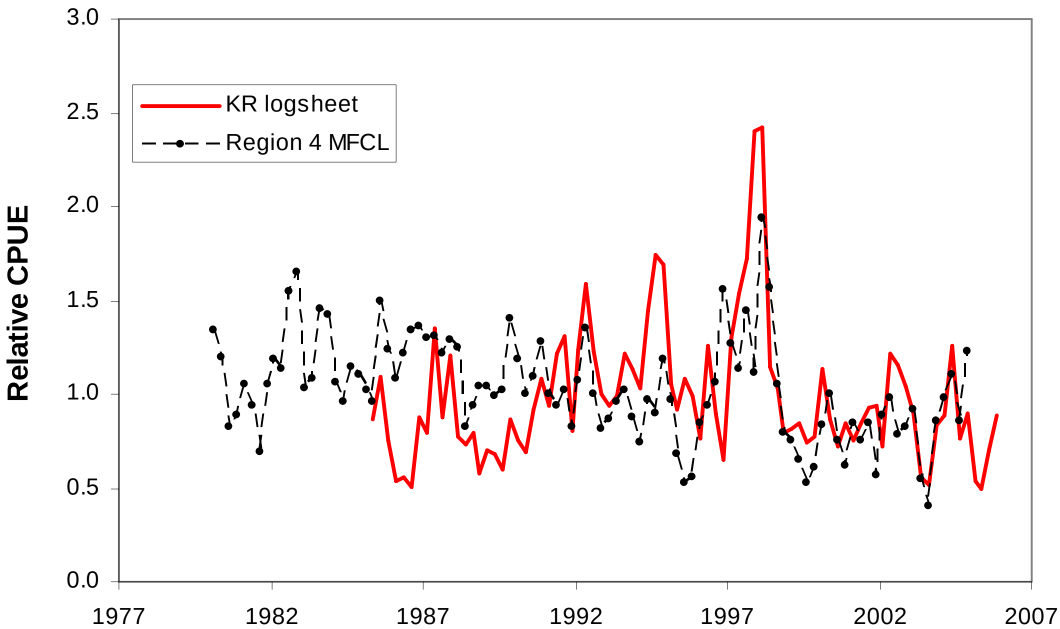


Figure 11. Quarterly standardised bigeye CPUE (number of fish per 100 hooks) indices for Region 4 of the MFCL assessment derived from the Korean logsheet data. The current Region 4 index is plotted for comparison.

5 Cluster analysis

A clustering approach was applied to the logsheet data from the Japanese fleet (Guam and distant-water fleets combined) operating within MFCL Region 3. The approach followed that of He et al. (1997) who applied a clustering approach to separate dissimilar types of fishing effort based on the species composition of the catch from longline sets in the Hawai'i fishery.

The purpose of the current analysis was to compare the trends in catch rate of yellowfin and bigeye tuna from separate fishery groupings as defined by the cluster analysis. Fishery groupings (clusters) were defined using two separate approaches.

a) The catch rate (catch per set) of associated pelagic species (similar to He et al.).
b) Key oceanographic variables (temperature, current, etc) from the location where fishing occurred. This approach was intended to identify clusters of similar habitat type.

The analyses included data from 1980 to 2005. For each analysis, trends in the nominal CPUE of yellowfin and bigeye tuna were compared among clusters.

5.1 Associated catches

The regional longline logsheet has the provision for recording catches of seven key species (yellowfin, bigeye, albacore, swordfish, black marlin, striped marlin, and blue marlin), a generic grouping for sharks, and a separate group of "other" species (see Appendix 1).

Annual trends in the catch of each of these species and species groups were examined, principally to identify which species were consistently reported over the time period. On that basis, the following species and species groups were excluded from the cluster analysis: albacore (very few catch records from equatorial region), sharks and "other" (highly variable reporting between years).

Separate analyses were undertaken for yellowfin and bigeye tuna. In each case, the species of principal consideration (yellowfin or bigeye) was excluded from the cluster analysis and the catch (in number) of the remaining five species were used to define the clusters (swordfish (SWO), black marlin (BLM), striped marlin (MLS), and blue marlin (BUM) and either yellowfin or bigeye). The principal species of interest (yellowfin or bigeye) was excluded because any large change in catch rate of the species would be likely to directly influence the definition of the cluster and, consequently, which cluster that logsheet recorded belonged to. As a result, a decline a catch rate of that species may could, possibly erroneously, be explained by a shift in fishing effort between clusters.

The cluster analysis was implemented in *R* using the *clara* clustering function (within the *cluster* library). The *clara* function was chosen due to the capacity to handle very large data sets (387,552 records in this analysis). The function requires the number of clusters to be defined and this was arbitrarily set at five clusters.

Yellowfin

For the yellowfin cluster analysis, the catch of bigeye was the dominant factor in defining the five clusters. The separate clusters are identifiable differences in the mean level of bigeye catch (Table 5 and Figure 12), albeit, with considerable overlap in the distribution of bigeye catch between clusters, while there is no strong separation of the clusters with respect to the catch of the other four species (Figure 13). There is relatively little difference in the average catch per set of yellowfin in each of five clusters (Table 5).

From 1980 to 2005, there was a considerable shift in the distribution of fishing effort between the fishery groupings defined by the cluster analysis. During the early 1980s, there was a strong decline in the proportion of sets in cluster 3 (moderate yellowfin catch, low bigeye catch) (Figure 14) and an increase in the proportion of sets in clusters 1, 2, and 4 – the clusters characterised by moderate-high bigeye catch (Table 5 and Figure 12). Nevertheless, for the five clusters, the underlying trend in yellowfin catch rate was comparable, declining by about 70% from 1980 to 2000 (Figure 14).

Table 5. Mean values of the records included in each of the five clusters defined from the catch of species associated with the yellowfin longline fishery. Only the five species catch variables were included in the cluster analysis.

Variable					**Cluster**
	1	**2**	**3**	**4**	**5**
BET	37.400	12.611	2.641	20.127	7.740
BLM	0.045	0.048	0.062	0.044	0.048
BUM	0.967	1.313	1.004	1.048	0.756
MLS	0.060	0.052	0.028	0.054	0.034
SWO	0.212	0.209	0.146	0.195	0.176
long	157.192	153.375	151.449	154.711	151.733
lat	3.754	4.937	3.716	4.703	4.655
hour	21.000	21.000	11.000	21.000	20.000
HPB	14.746	13.532	12.072	14.140	13.165
Month	5.921	6.165	6.391	6.067	6.400
SST1	28.916	28.985	29.130	28.930	29.059
SSTdepth1	154.307	151.255	155.441	151.463	151.406
currentv1	2.906	1.994	1.369	2.375	1.692
currentu1	11.647	9.252	6.238	10.842	9.543
SST2	29.077	29.085	29.111	29.061	29.068
SSTdepth2	173.939	172.352	173.428	172.624	172.143
currentv2	0.966	1.254	1.035	1.204	1.292
currentu2	0.795	1.900	1.744	1.653	2.094
SST3	1.882	2.168	2.170	2.078	2.245
SSTdepth3	60.465	64.496	60.751	63.823	64.488
currentv3	23.200	28.362	28.187	26.873	29.908
currentu3	65.504	70.370	64.773	69.981	71.310
SST4	-0.006	0.015	0.015	0.008	0.015
SSTdepth4	0.467	0.057	0.046	0.173	-0.082
currentv4	-0.028	-0.217	-0.103	-0.221	-0.161
currentu4	-0.469	0.539	0.425	0.269	0.713
YFT	27.070	22.957	22.497	23.791	22.056

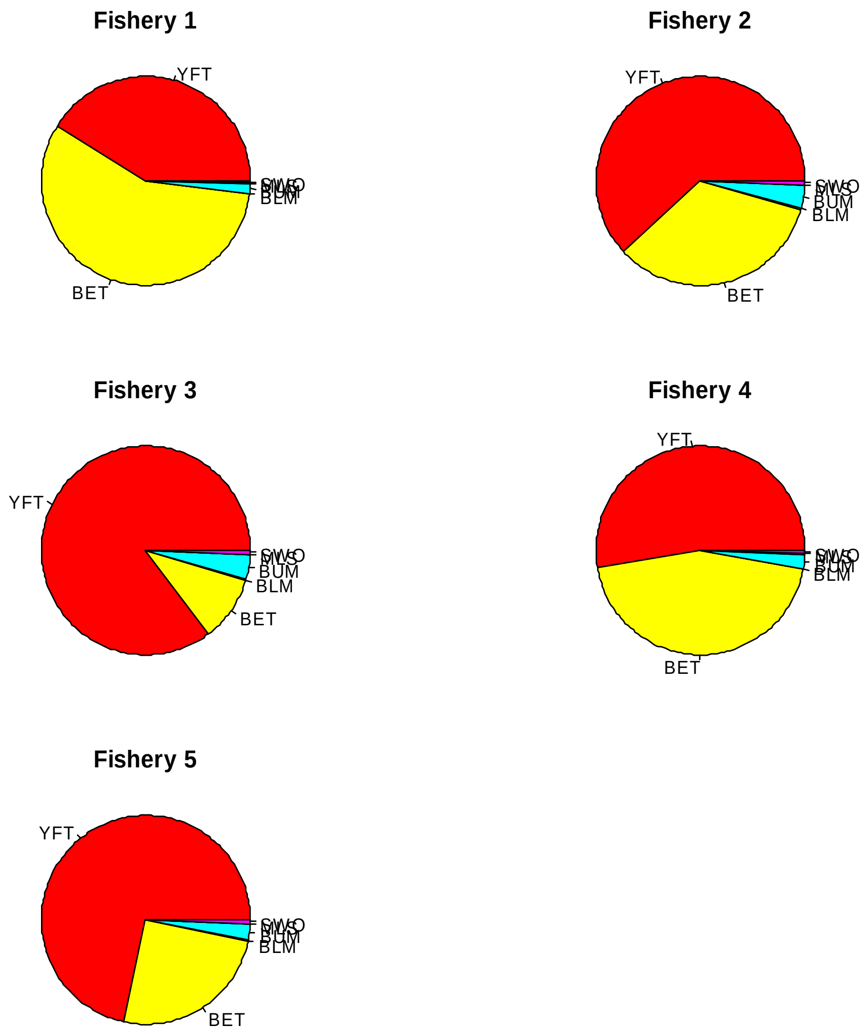


Figure 12. Species composition of the catch for the five fisheries within Region 3 defined based on the cluster analysis of catches of the associated species from the yellowfin longline fishery (bigeye, blue marlin, black marlin, striped marlin, and swordfish). The analysis uses the logsheet data from the Japanese longline fleet (distant-water and offshore).

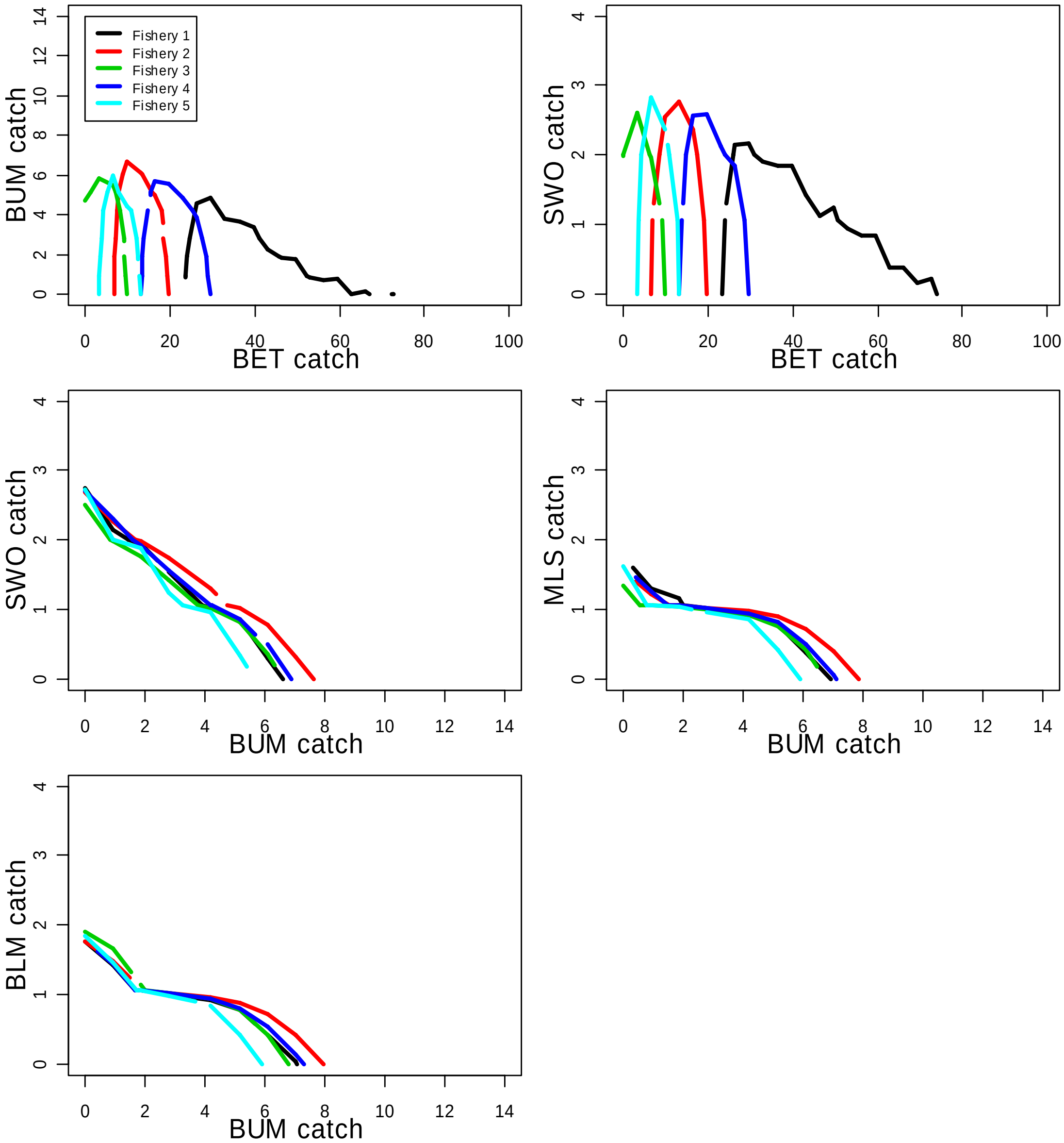


Figure 13. The catch distribution of the species included in the each cluster of the yellowfin longline fishery analysis. The contour lines define the boundaries of each distribution of catch of the species included in the analysis.

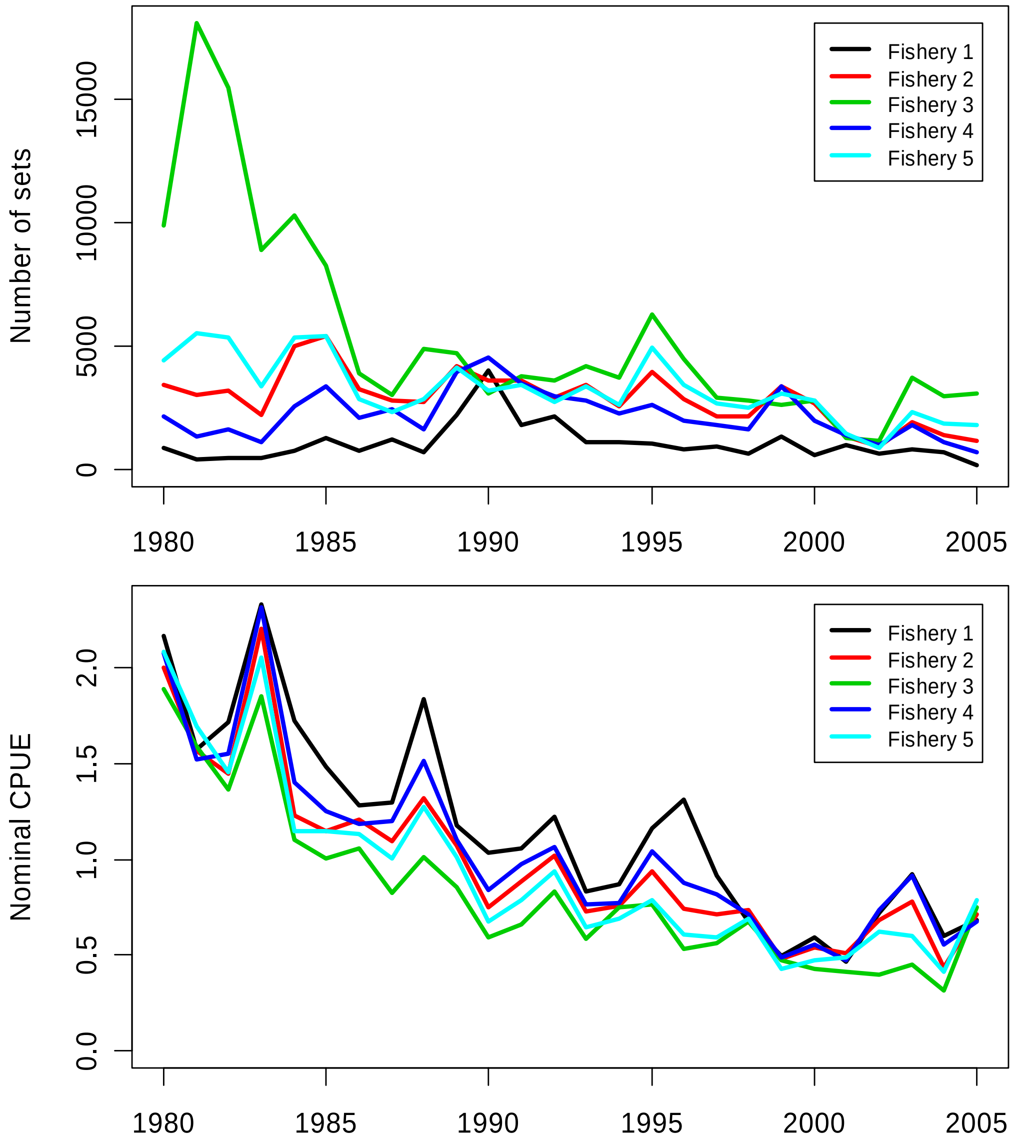


Figure 14. Annual trends in the number of sets in each cluster (fishery) as defined based on the associated catch from the yellowfin longline fishery (top) and the trend in the nominal catch rate (number of fish per 100 hooks set) of yellowfin from each cluster.

Bigeye
The clustering approach was also applied to segregate longline fishing effort based on the non bigeye component of the catch. The resulting five clusters were considered to represent five separate groupings within the bigeye longline fishery. The results were similar to the cluster analysis of the yellowfin longline fishery, whereby, the clusters were defined largely based on the catch of the other principal species; i.e yellowfin in the case of the bigeye analysis (Table 6).

Three fisheries were defined based on the high catch rate of yellowfin (clusters 2, 4, and 5), while cluster 1 had a low catch rate of yellowfin and high proportion of bigeye in the catch (Figure 15). There was no apparent difference in the catch rate of the other species (blue, black, and striped marlin and swordfish) among the clusters (Table 6).

The overall decline in nominal CPUE for yellowfin is likely to be influential in the definition of the clusters (see Figure 5). The decline in yellowfin CPUE (catch per set) results in the temporal shift from predominantly clusters with high yellowfin CPUE (clusters 2, 4, and 5) at the start of the series to clusters with lower yellowfin CPUE (cluster 1) at the end of the series (Figure 17).

The magnitude and trend in bigeye nominal CPUE was comparable for the five clusters, with the exception of slightly lower CPUE for cluster 1 (Figure 17).

Table 6. Mean values of the records included in each of the five clusters defined from the catch of species associated with bigeye longline fishery. Only the five species catch variables were included in the cluster analysis.

Variable	**Cluster**				
	1	**2**	**3**	**4**	**5**
YFT	4.554	32.671	17.227	55.013	106.324
BLM	0.029	0.067	0.052	0.088	0.119
BUM	0.828	1.201	1.119	1.114	1.082
MLS	0.038	0.040	0.050	0.031	0.025
SWO	0.158	0.189	0.193	0.189	0.181
long	150.788	154.472	153.437	154.907	155.215
lat	6.068	2.923	4.542	1.362	-0.293
hour	20.000	21.000	21.000	21.000	21.000
HPB	13.915	12.490	12.942	12.046	11.738
Month	6.439	6.114	6.159	6.182	6.165
SST1	28.928	29.137	29.016	29.250	29.327
SSTdepth1	145.950	159.045	153.201	163.840	166.942
currentv1	1.968	1.770	1.981	1.342	0.971
currentu1	9.296	8.141	9.238	7.046	4.849
SST2	29.015	29.152	29.104	29.169	29.167
SSTdepth2	169.583	175.876	172.824	177.897	178.501
currentv2	1.713	0.708	1.050	0.418	0.312
currentu2	2.647	0.985	1.671	0.600	0.350
SST3	2.340	1.980	2.154	1.876	1.773
SSTdepth3	70.668	56.379	62.305	51.313	46.830
currentv3	32.063	24.763	26.979	23.447	22.332
currentu3	78.400	60.117	66.784	54.417	48.920
SST4	0.005	0.019	0.011	0.026	0.024
SSTdepth4	0.080	0.030	0.158	-0.079	-0.061
currentv4	-0.061	-0.187	-0.216	-0.198	-0.274
currentu4	0.052	0.722	0.515	0.900	0.864
BET	9.903	11.577	11.506	11.307	11.506

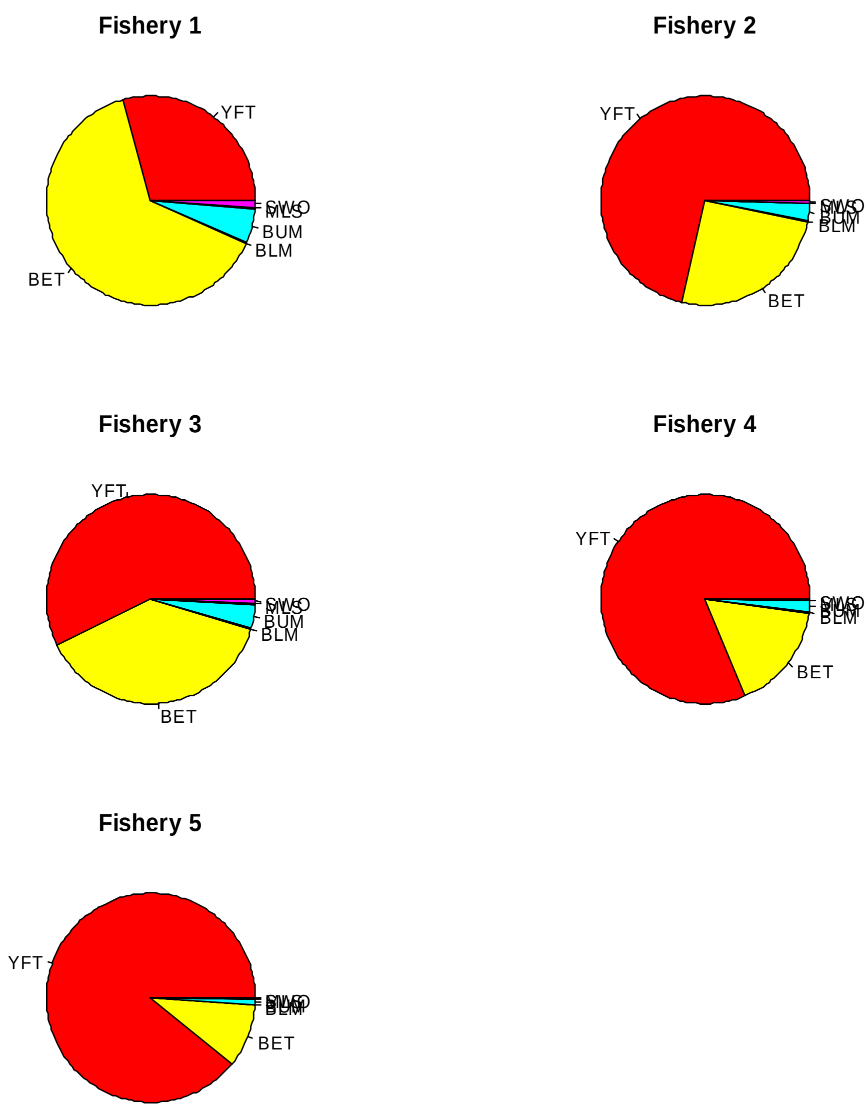


Figure 15. Species composition of the catch for the five fisheries within Region 3 defined based on the cluster analysis of catches of the associated species from the bigeye longline fishery (yellowfin, blue marlin, black marlin, striped marlin, and swordfish). The analysis uses the logsheet data from the Japanese longline fleet (distant-water and offshore).

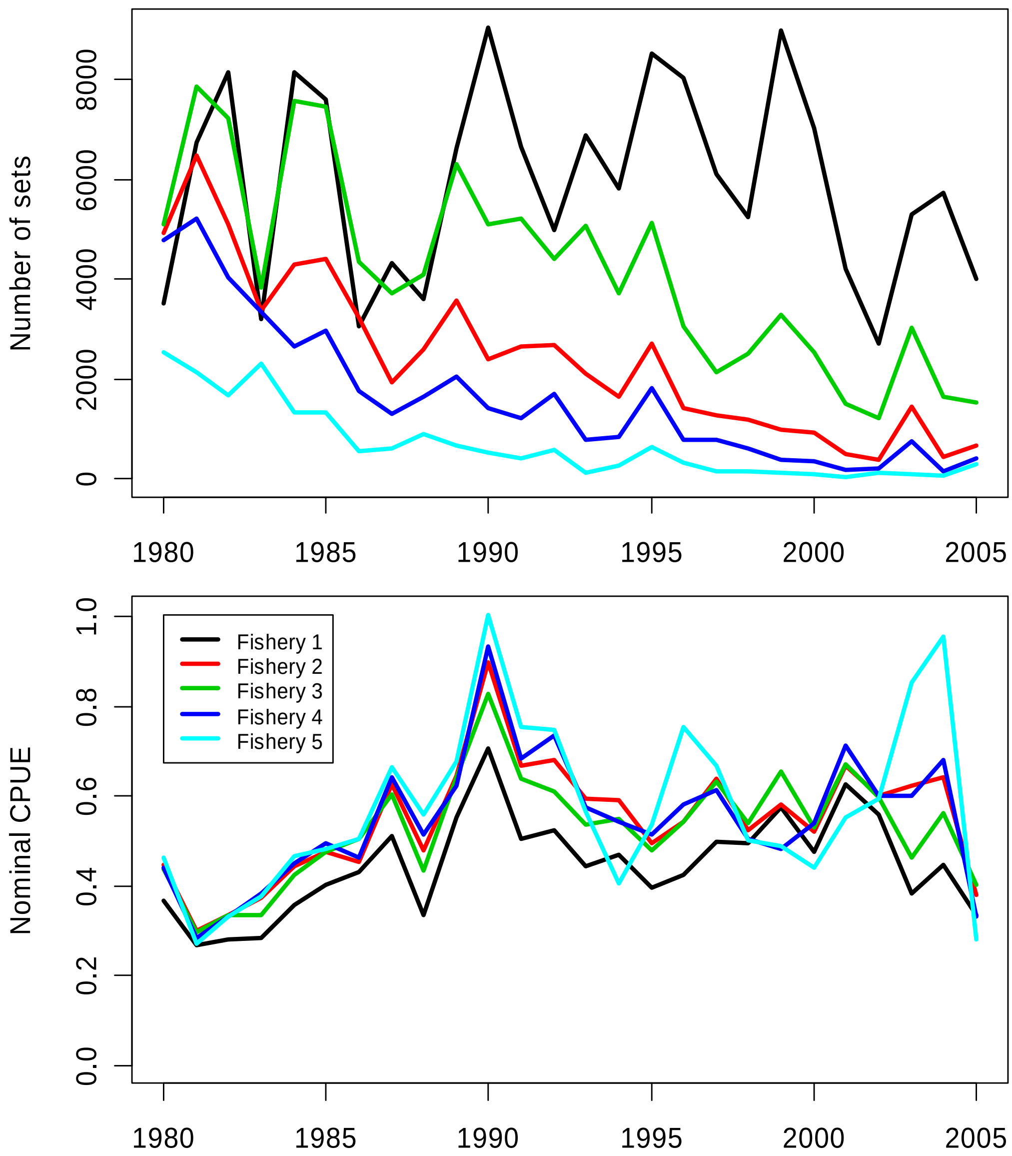


Figure 16. Annual trends in the number of sets in each cluster (fishery) as defined based on the associated catch from the bigeye longline fishery (top) and the trend in the nominal catch rate (number of fish per 100 hooks set) of bigeye from each cluster.

5.2 Oceanographic data

The oceanographic data associated with individual longline sets were used as a separate basis for classification of distinct fishery types, essentially relating fishing activity to different habitat types. A similar clustering approach was applied to the oceanographic data sets described in Table 4.

Compared to the cluster analysis using associated catch, a larger number of variables were available for inclusion in the analysis and the distribution of the individual records was more variable. The number of clusters in the analysis was arbitrarily set at seven.

The principal variables defining the clusters are the average depth of the 20°C isotherm (*sstdepth1*), the range of the depth of the 20°C isotherm (*sstdepth3*), and the average east-west current (*currentu1*) (Table 7 and Figure 17).

A high proportion of fishing activity has occurred at locations defined by three types of oceanographic conditions (clusters 1, 2, and 7) (Figure 18). These clusters can be defined, in broad terms, by the three variables *sstdepth1*, *sstdepth3*, and *currentu1* (Figure 17).

a) Cluster 1: relatively neutral east-west current flow, moderate depth of 20°C isotherm, and moderate variation of depth of 20°C isotherm
b) Cluster 2: relatively neutral east-west current flow, relatively shallow average depth of 20°C isotherm, and relatively high variation of depth of 20°C isotherm.
c) Cluster 7: strong easterly current flow, broad range of average depth of 20°C isotherm, and moderate variation of depth of 20°C isotherm.

These definitions will to some extent explain spatial variation in the distribution of fishing effort, although there is considerable spatial overlap in the distribution of the seven clusters defined (Figure 19). For example, there is a high level of spatial overlap between clusters 1, 3, and 7, while considerable differences in oceanographic conditions may occur in these two areas.

From 1980 to the early 1990s, there was a decline in the proportion of sets in areas with oceanographic conditions defined by cluster 1 and a corresponding increase in effort in cluster 2. In the early 2000s, there was an increase in effort in cluster 7, at the expense of cluster 2 (Figure 18). This temporal trend in the distribution of fishing activity may represent a change in targeting activity and/or represent changes in the oceanographic conditions over the study period and hence changes in the availability of certain types of habitat.

For yellowfin and bigeye, annual trends in nominal (number of fish per hook) were examined for each of the seven oceanographic clusters. For yellowfin, nominal CPUE was generally higher in clusters 4 and 6 and lowest in clusters 2 and 7 (Figure 20). Nevertheless, overall relative trends in yellowfin nominal CPUE were comparable for the seven clusters, with nominal indices declining by about 60–70% over the time series (Figure 20).

For bigeye tuna, nominal CPUE was less variable between the seven clusters than observed for yellowfin and catch rates were generally comparable between clusters (Figure 20). The exception was during the latter period (post 2000) with catch rates consistently higher in cluster 1 and lower in clusters 2 and 7.

Table 7. Mean values of the records included in each of the seven clusters defined from the oceanographic data associated with the longline fishing effort.

Variable	Cluster						
	1	2	3	4	5	6	7
SST1	29.029	28.743	29.265	29.502	28.990	29.369	29.273
SSTdepth1	163.910	130.762	147.597	193.921	137.445	186.014	155.187
currentv1	3.236	1.687	2.908	-1.729	1.233	2.521	1.468
currentu1	12.620	-5.504	43.673	1.994	-0.602	-26.687	60.924
SST2	29.180	28.996	29.022	29.119	29.159	29.287	28.972
SSTdepth2	180.896	161.503	173.770	192.847	147.338	193.731	179.304
currentv2	0.948	2.349	0.590	-1.216	0.372	-0.363	3.962
currentu2	-1.205	3.167	4.868	1.913	3.285	-4.406	4.106
SST3	1.903	2.544	2.261	1.389	2.385	1.801	2.435
SSTdepth3	52.852	90.476	62.627	26.583	45.207	37.798	72.866
currentv3	22.037	37.711	28.325	12.767	19.677	20.732	54.198
currentu3	56.999	86.316	78.638	23.012	54.577	55.181	129.974
SST4	0.042	-0.009	-0.015	0.011	0.022	0.020	0.027
SSTdepth4	1.199	-0.138	-2.268	0.213	-0.358	2.485	-1.028
currentv4	-0.596	-0.007	0.900	-0.293	-0.669	0.370	-0.126
currentu4	-0.070	-0.081	1.537	1.887	0.107	-7.106	6.940
YFT	25.025	15.779	20.286	38.789	24.604	37.629	12.999
BET	11.613	10.675	11.821	9.603	11.407	8.524	10.798
BLM	0.044	0.026	0.033	0.174	0.060	0.131	0.022
BUM	1.219	1.088	0.693	0.903	1.049	0.942	0.520
MLS	0.031	0.085	0.016	0.015	0.066	0.010	0.008
SWO	0.178	0.187	0.174	0.196	0.208	0.190	0.147
long	155.593	150.330	152.654	156.157	151.087	153.795	148.295
lat	4.079	8.564	4.082	-5.553	5.765	-1.220	4.129
hour	20	19	20	21	7	21	21
HPB	12.44	13.97	14.10	12.26	13.12	10.31	13.42
Month	5.49	6.34	7.16	6.69	6.40	5.44	7.59

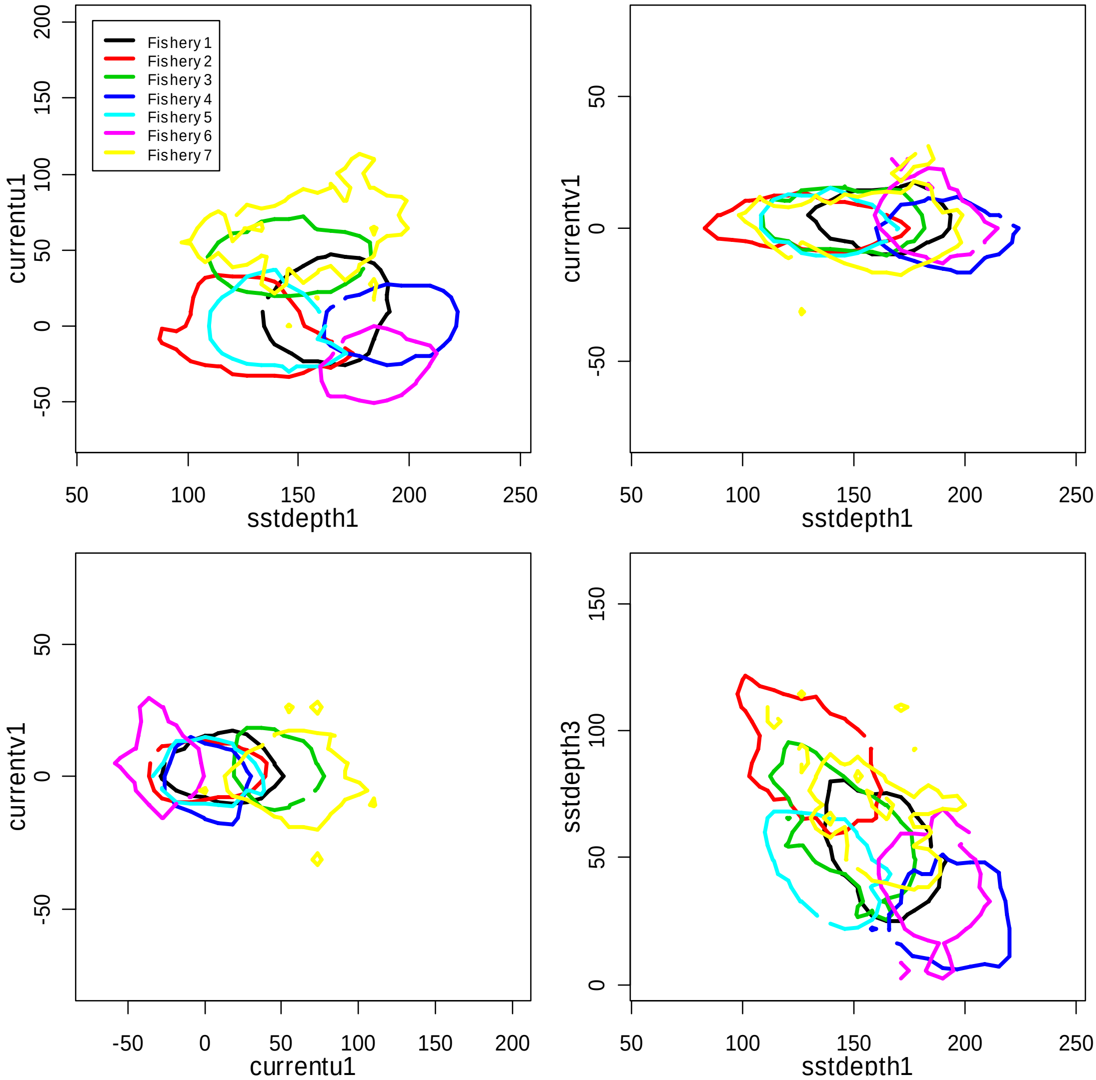


Figure 17. A comparison of the range of the key variables defining each of the clusters of the oceanographic data associated with the logsheet data. The contour lines encompass the domain that include at least 0.5% of the logsheet effort.

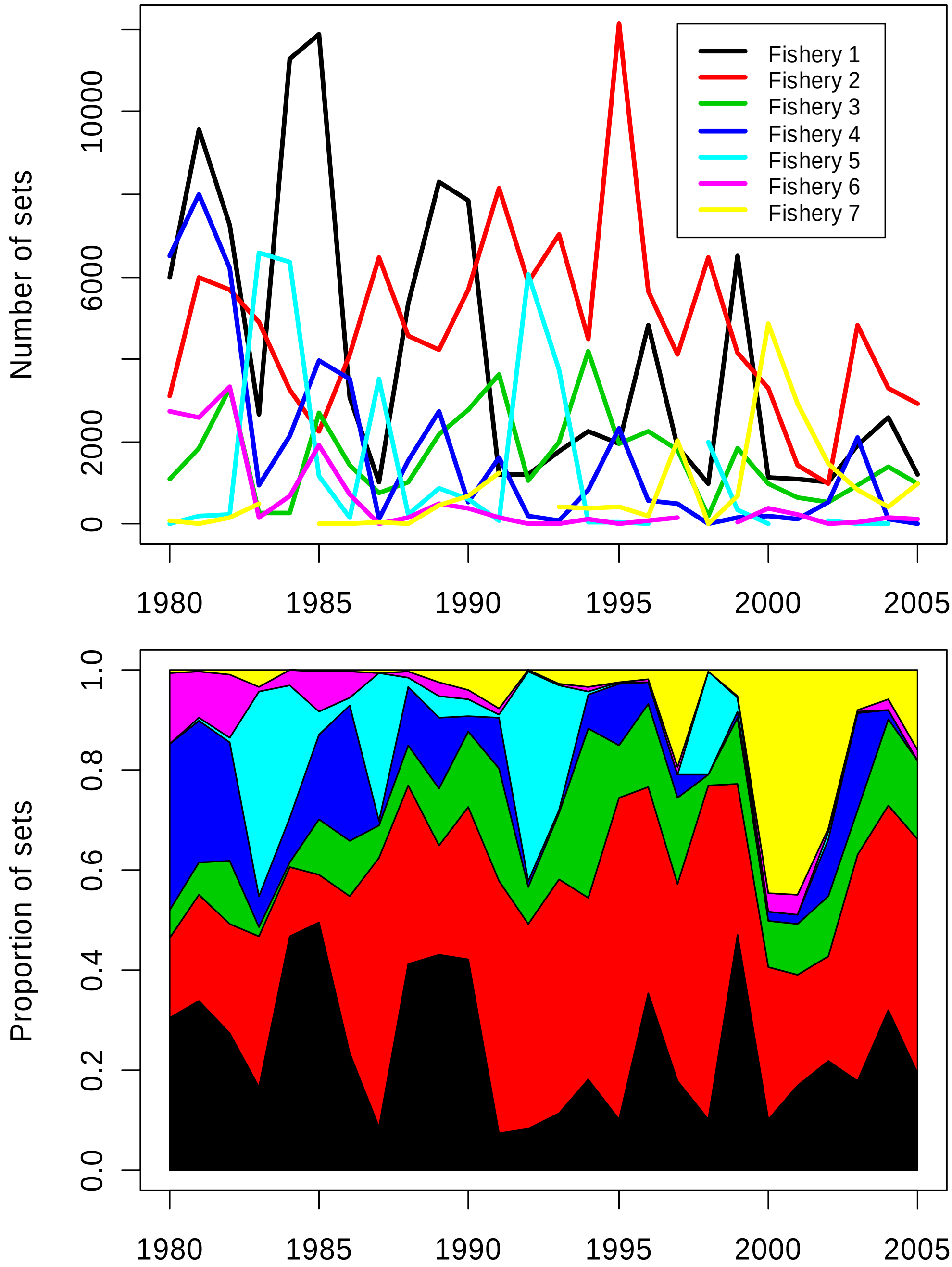


Figure 18. Annual distribution of logsheet sets in number (top) and proportion (bottom) by individual clusters defined based on the oceanographic data.

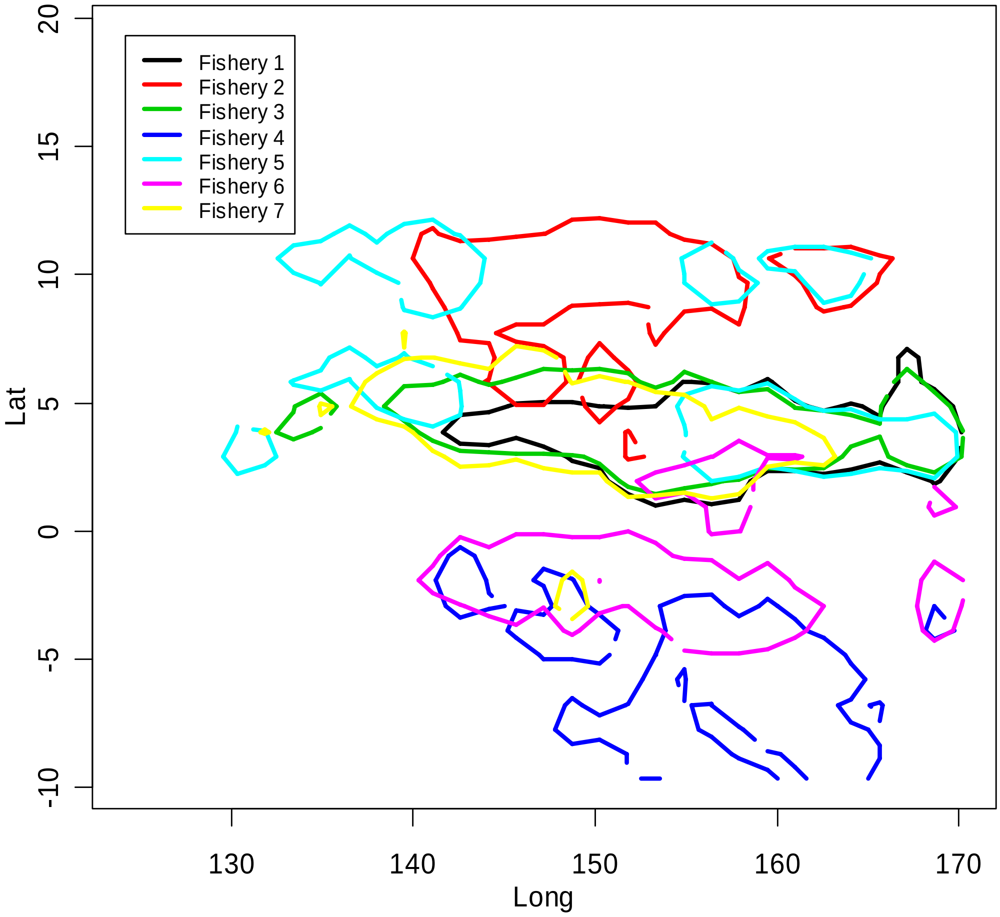


Figure 19. Contour plot defining the spatial distribution of logsheet data assigned to each of the seven clusters defined based on oceanographic data. The contour lines encompass areas that include at least 0.5% of the logsheet effort.

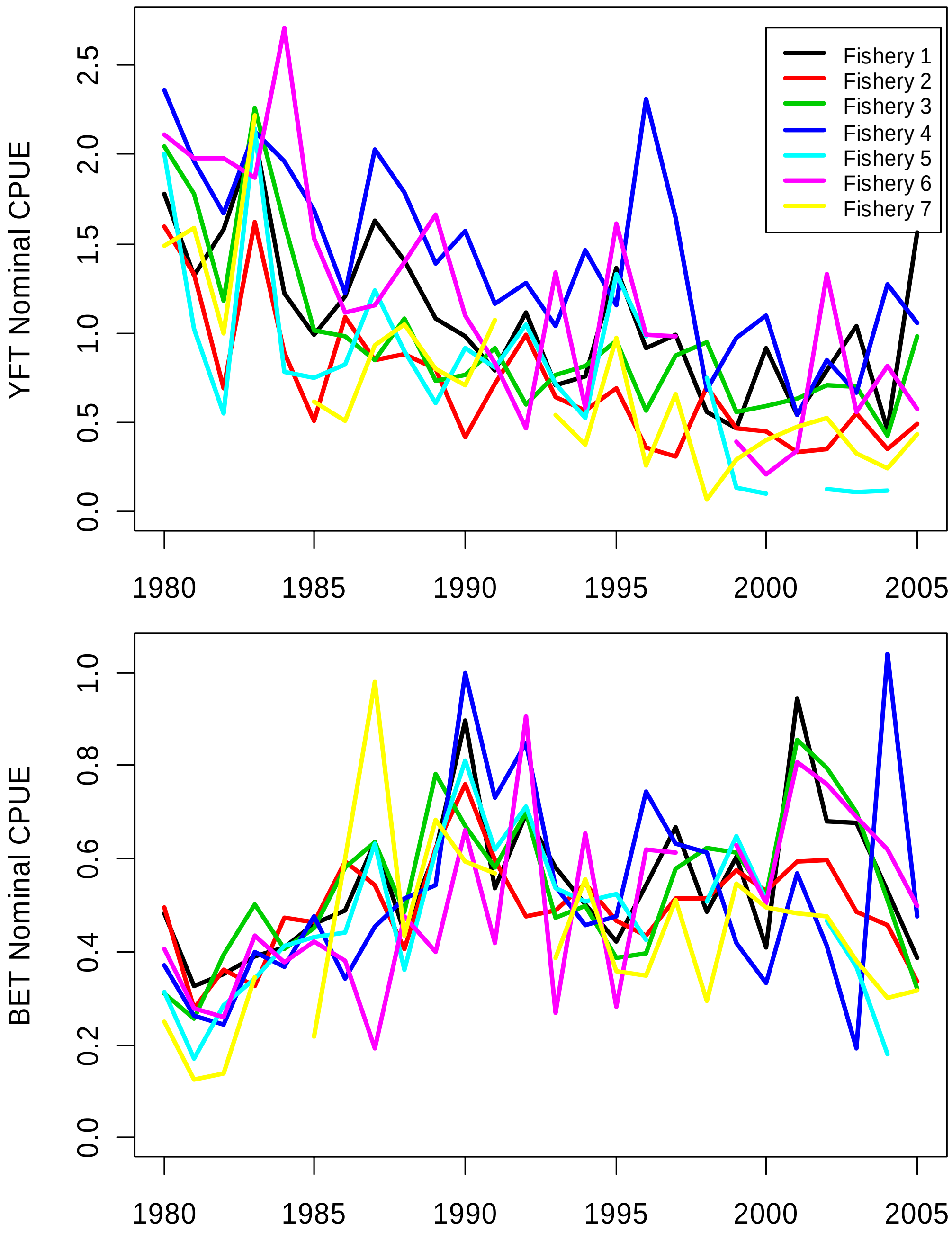


Figure 20. Annual trends in nominal CPUE (number of fish per hundred hooks) for yellowfin tuna (top) and bigeye tuna (bottom) for each of the seven clusters defined based on oceanographic data.

6 Spatial statistics

Logsheet data collected in set-by-set format enables an analysis of aspects of the operation of longline fishing. For example, information on the successive locations of longline sets by an individual vessel or fleet of vessels enables an assessment of the extent to which longline effort is concentrated in certain areas. An increase in the aggregation of fishing effort at a local scale (increased patchiness) may indicate a degree of “hyperstability” in the abundance index derived from longline CPUE data; i.e. catch rates may be maintained despite a decline in the underlying stock abundance.

A preliminary analysis was undertaken using the logsheet data from the Japanese distant-water longline fleet operating within MFCL region 3. The data set was limited to those trips that fished for a minimum of 20 sets in the region. Trips conducted over a very long period (greater than 150 days) were excluded. Only trips were included where sets were conducted on 70% of the days between the start and end date of fishing in the region. This ensured that most of the selected trips represented successive days of continuous fishing activity within the region.

The data set included a total of 158,983 sets conducted during 5,539 trips. An average of 28.7 sets were conducted per trip during an average period of 33.6 days within MFCL region 3.

For each trip, the following statistics were computed. The mean and the 5% and 95% quantiles of each statistic are also presented.

Statistic	**mean**	**q5%, q95%**
Median distance (km) between sets during a trip.	43.0	15.0, 82.4
Mean distance (km) between sets during a trip.	82.5	38.2, 137.1
Proportion of sets in trip within 30 km of previous set (in region).	0.413	0.143, 0.762
Proportion of sets in trip greater than 60 km from previous set (in region).	0.343	0.105, 0.632
Mean catch rate (number fish per hook) per trip of bigeye from sets that occur immediately before moving a distance of greater than 60 km from the previous set (in region).	0.0038	0.0011, 0.0080
Mean catch rate (number fish per hook) per trip of bigeye from sets that occur within a distance of less than 30 km from the previous set (in region).	0.0057	0.0017, 0.0114
Mean catch rate (number fish per hook) per trip of bigeye from sets that occur immediately following a movement of a distance of greater than 60 km from the previous set (in region).	0.0048	0.0014, 0.0099
Mean catch rate (number fish per hook) per trip of yellowfin from sets that occur immediately before moving a distance of greater than 60 km from the previous set (in region).	0.0093	0.0019, 0.0215
Mean catch rate (number fish per hook) per trip of yellowfin from sets that occur within a distance of less than 30 km from the previous set (in region).	0.0142	0.0030, 0.0321
Mean catch rate (number fish per hook) per trip of yellowfin from sets that occur immediately following a movement of a distance of greater than 60 km from the previous set (in region).	0.0117	0.0026, 0.0267
Mean nearest set between all sets during a month (km).		
Mean number of sets (per trip) conducted by other vessels within a 50 km radius and within a day (+/- 1 day) of a set conducted following a movement of at least 60 km from the location of the previous set.	1.43	0.0, 4.33
Mean distance (km) (per trip) to the nearest set conducted by other vessels within a day (+/- 1 day) of a set conducted following a movement of at least 60 km from the location of the previous set.	131.32	21.04, 412.05
Number of other vessels fishing within a 50 km radius and within a day (+/- 1 day) of a set conducted following a movement of at least 60 km from the location of the previous set.	0.92	0.0, 2.74

Set locations were based on the start position of each set. Longline sets by distant-water vessels were assumed to span a distance of 30 km. Sets within a radius of 30 km of the start position of the previous set (based on the start position of the following set) were considered to be conducted within the vicinity of the previous set, while a set location greater than 60 km from the previous set was considered to represent sets at a separate location. The definitions of adjacent and distant sets are somewhat arbitrary and the assumptions will be influenced by the direction of the set.

Temporal trends in these metrics were examined by deriving the annual median and quartile range of each variable (assigned to a year based on the trip start date). The key observations from these trends are as follow.

a. The annual median distance between sets remained relatively constant from 1980 to the early 1990s (Figure 21). From 1992 to 2003, there was a general decline in the distance between sets, with the exception of a longer distance between sets in 1997. The median distance between sets was also higher in 2004 and 2005.
b. The general decrease in median distance between sets from 1992 to 2003 is consistent with an increase in the proportion of sets within 30 km of the previous set and the decrease in the proportion of sets exceeding 60 km from the previous set during the corresponding period (Figure 21). Again, 1997 is an exception to these trends and there is a reversal of these trends in 2004 and 2005.
c. The annual catch rate of bigeye by the fleet is approximately 50% higher from sets that are within 30 km of the previous set compared to sets that are greater than 60 km from the previous set (Figure 22). This illustrates the interdependence of subsequent sets, whereby, vessels are inclined to remain in a location when catch rates are high (high CPUE, short movement to next set; low CPUE, higher movement to next set). These results suggest that the level of CPUE that triggers a longer movement represents a constant proportion of the CPUE attained when fish density is high.
d. While the magnitude of bigeye CPUE differs from sets conducted prior to a short movement (less than 30 km) or prior to a longer movement (greater than 60 km), the relative trend in CPUE from the two set types is comparable (Figure 22). This indicates that the vessel has knowledge of the overall CPUE level that can be achieved; i.e. the vessel will continue to fish in an area of relatively lower CPUE level in a year when the overall level of CPUE is low. The results also indicate that the proportion of fish in the relatively high density areas does not change between years.
e. The catch rate of bigeye from the set immediately following a change in fishing location (greater than 60 km) is intermediate between the high catch rate attained from sets in the same vicinity (less than 30 km) and the low catch rate attained from sets that preceded a longer movement (greater than 60 km) (Figure 22). This indicates that the fleet can locate new areas of moderate CPUE and will shift to these locations following encountering low CPUE. The CPUE attained at the new fishing location is arguably less dependent on prior knowledge than sets undertaken in a similar location. On this basis, the sets at the new location may represent a more random fishing event and, consequently, the resulting CPUE from these sets may represent a more reliable index of relative abundance. In general, the relative trend in bigeye CPUE from the first set at a new location is comparable to the trend in the nominal CPUE indices derived from the other set classifications (the CPUE prior to either remaining in the location or moving from the location).
f. Similar trends are apparent for yellowfin tuna. Nominal catch rates from sets prior to moving to a new location are lower than those when the vessel remained at the same location, while initial catch rates at the new location are intermediate (Figure 22). However, the magnitude of the difference between the levels of CPUE has decreased over the study period; since the late 1990s catch rates from the three types of sets have converged. This suggests that the catch rate of yellowfin tuna is no longer the prime determinant as to whether a vessel remains at a location or moves to a new location.
g. However, the assumption that CPUE at the new location has a lower interdependence (on other fishing activities) and is, therefore, more random, may be violated if the vessel(s) is provided with external information guiding the selection of the new location. Such sources of information may include remote sensing information revealing suitable nearby

fishing locations and information relating to fishing success from other vessels. The likelihood of the second situation was examined by determining the frequency of fishing activity by other vessels in the vicinity of the new fishing location (i.e. in the area where the vessel arrived after moving at least 60 km) (Figure 23).

h. In the early 1980s, the new fishing location of a vessel was frequently within the vicinity of fishing activity (within a 50 km radius) of another vessel. This suggested that the vessel was moving to a new location based on some prior information, possibly through the contact with other vessels in the vicinity. However, the occurrence of other vessels at new fishing locations declined through the mid–late 1980s. During the 1990s, on average there was only one other vessel at the new location fished every second time the vessel moved (median value of 0.5 vessels) (Figure 23). This decline in the level of association between vessels is probably largely due to the substantial decline in the number of vessels operating in the fleet between the early 1980s and late 1990s (see Table 1).
i. The fleet size (number of vessels) has remained at a relatively low level since the late 1990s. However, during that period, there was an increase in the occurrence of other vessels at new fishing locations. This is most evident when the number of sets by other vessels has expressed as a proportion of the total number of sets conducted by other vessels in the region on the days adjacent to the first day of fishing in a new location (Figure 23). This statistic increased sharply from the mid 1990s from about 1% of sets by other vessels (within 50 km radius) to about 8% of sets in 2001. The statistic remained relatively high (about 4% of sets) over the subsequent years, with the exception of a very low value in 2003.
j. There appears to be a higher level of associating behaviour of the distant-water longline fleet in this region in the last decade compared to the preceding period. This undermines the presumption that sets that occur following a shift to a new location represent a more random sample of the underlying fish density and, thereby, are less likely to generate biased CPUE indices. Many of these sets appear to occur in a particular location based on prior knowledge (i.e., the catch rates from other vessels) and, thereby, are likely to occur in areas where catch rates are considerably higher than at a random location. Nevertheless, it may be possible to further refine the data set of "sampling" sets by excluding sets that occurred at new locations where other vessels were operating.
k. The statistics presented in Figure 23 represent minimum values for defining the level of vessel interaction due to the incomplete logsheet coverage of the distant-water fleet (see Table 1). Since 2000, annual logsheet coverage rates fluctuated between about 30% and 60%, but in general were lower than during the earlier period. Definitive statistics summarising the degree of vessel interaction within the fleet would require almost complete logsheet coverage of the fleet.

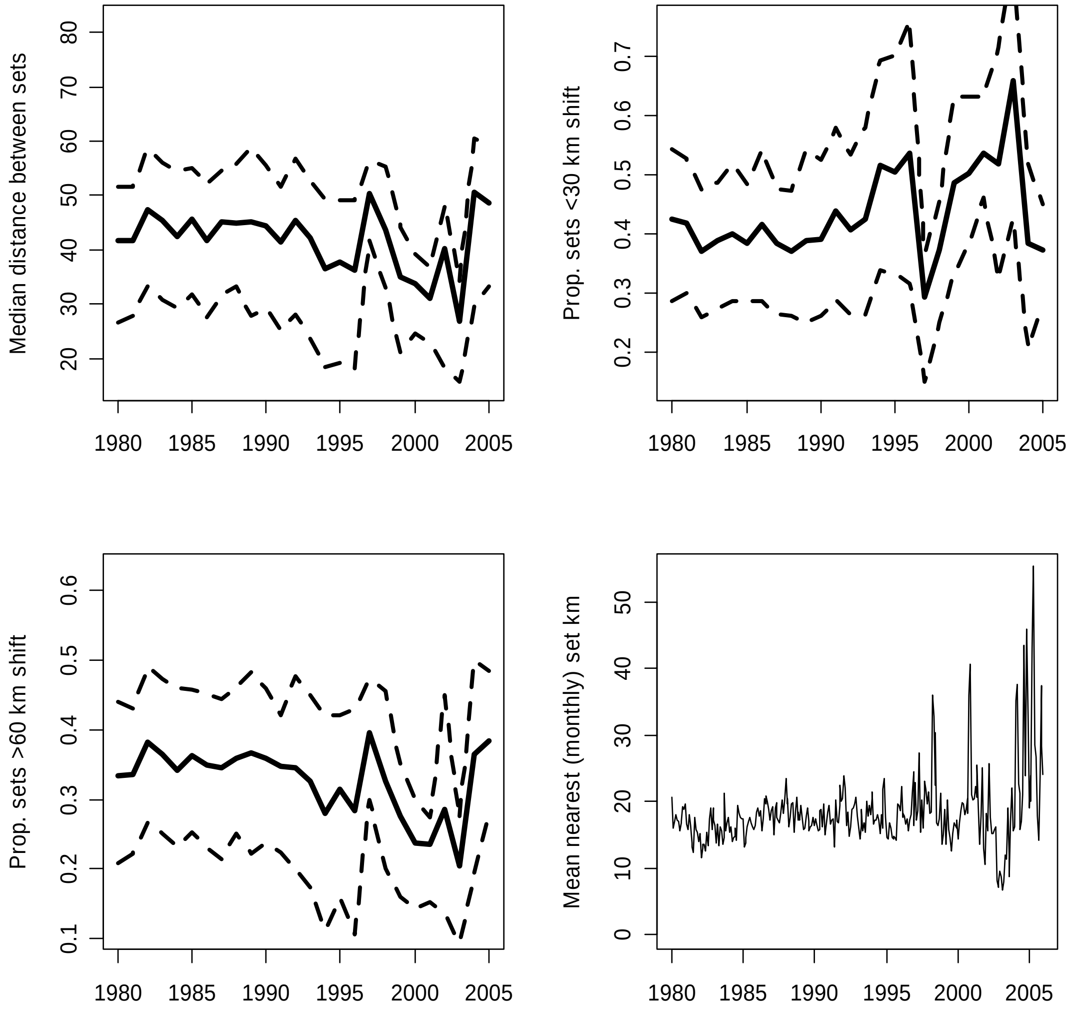


Figure 21. Summary statistics describing the annual trend in the distance between successive sets during a trip and the proportion of sets that occurred at a similar location (within 30 km of the previous set) or at a new location (greater than 60 km from the previous set). The solid line represents the median value. The dashed line the 25% and 75% quartiles.

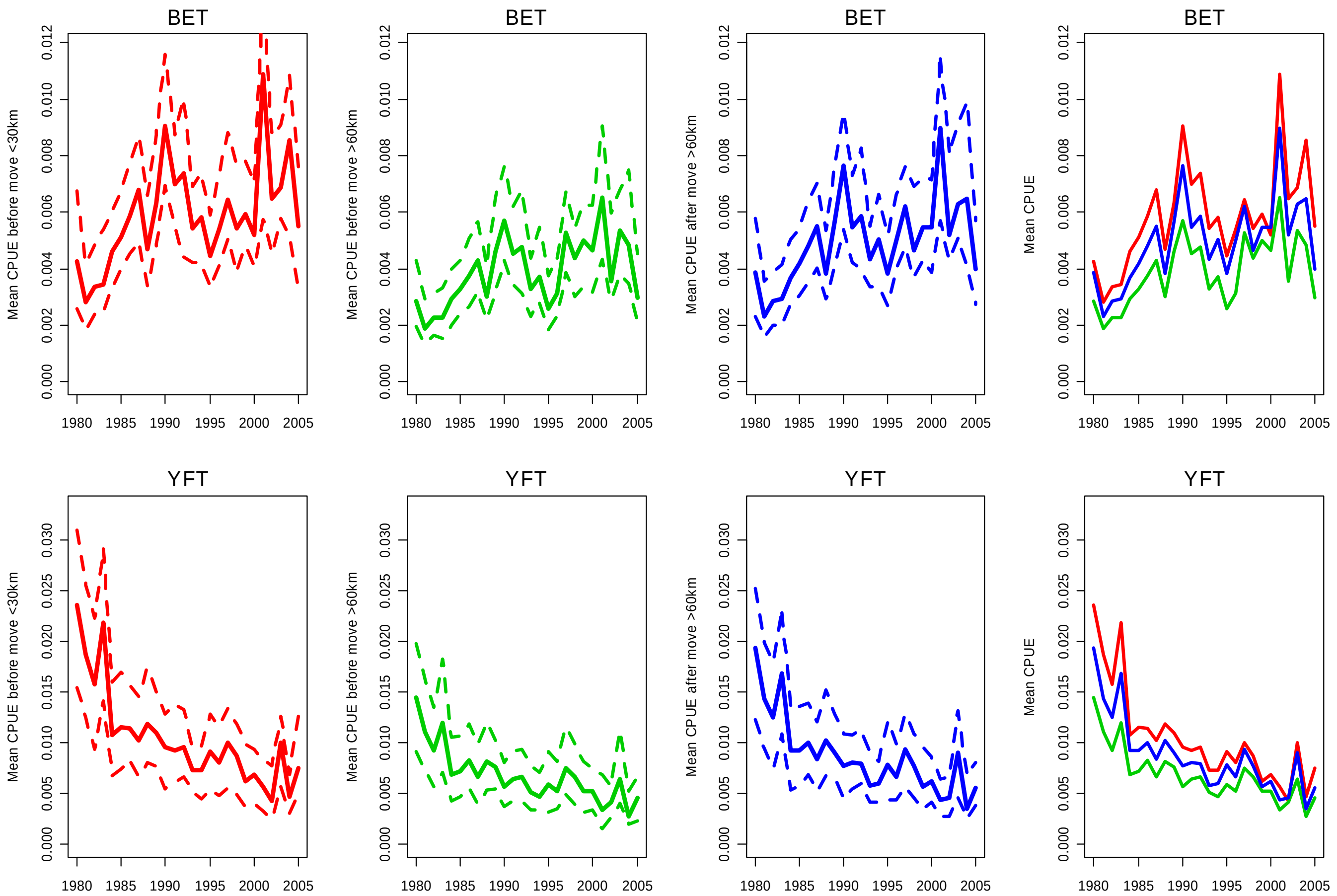


Figure 22. Statistics summarising the nominal catch rate (number of fish per hook) of bigeye (top) and yellowfin (bottom) from sets prior to a movement of less than 30 km from the previous set (first panel), prior to a movement of more than 60 km from the previous set (second panel), and following a movement of 60 km from the previous set (third panel). The solid line represents the median value. The dashed line the 25% and 75% quartiles. The fourth panel plots the comparison of the CPUE from three other panels.

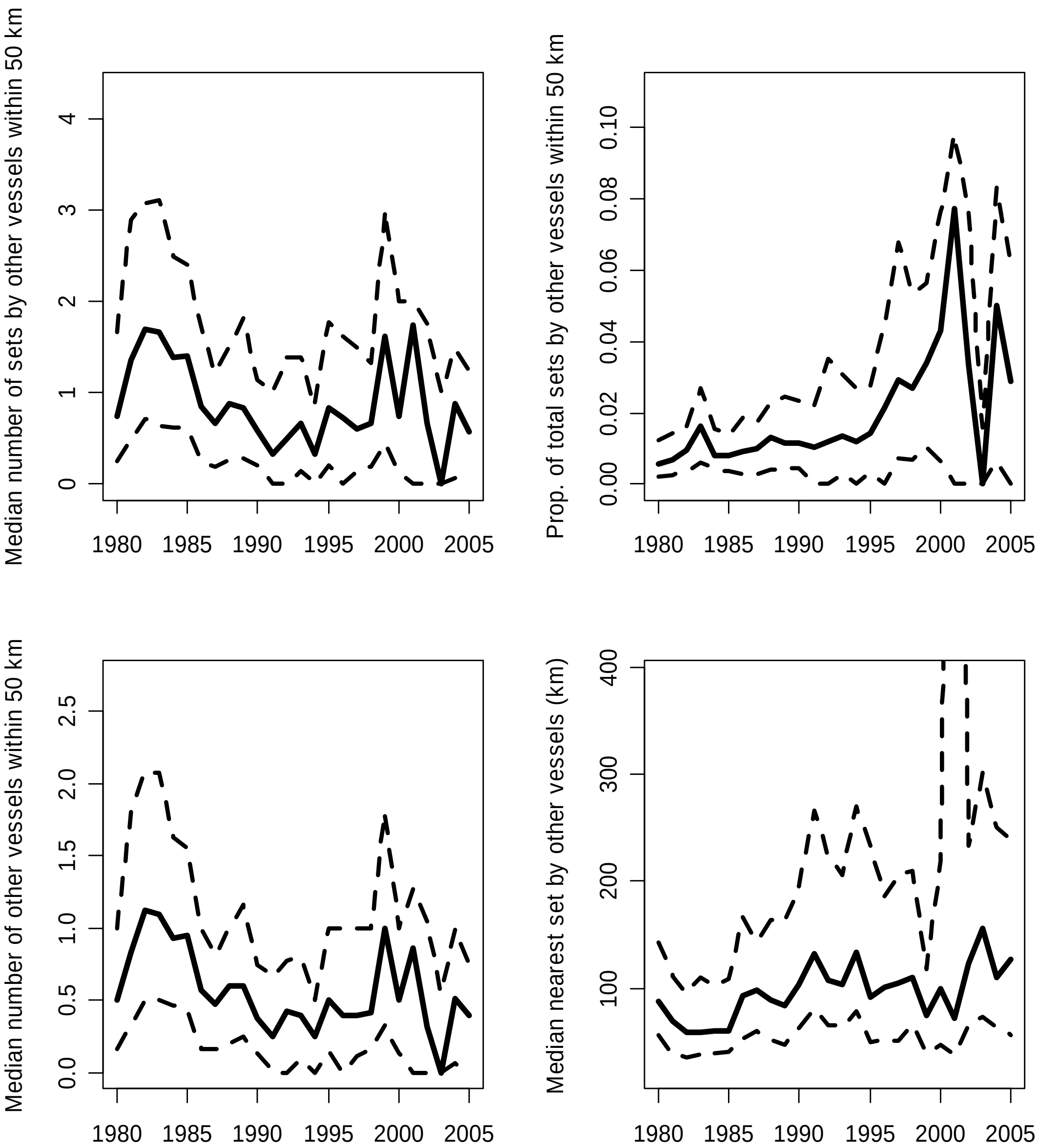


Figure 23. Annual trend in the proximity of fishing activity by other vessels for longline sets by an individual vessel that occurred at least 60 km from the location of the previous set. The solid line represents the annual median of values from individual trips, the dashed lines represent the 25% and 75% quantiles.

7 Main conclusions

Logsheet data

i. Logsheet data represents a significant (at least 30–40%) proportion of Japanese (Guam-based and distant-water) longline fishing activity within the western equatorial region of the WCPO. Similarly, a high proportion of the Korean fishing activity in the eastern equatorial region of the WCPO is reported on logsheets.

ii. Since the early 1990s, there has been a decline in the total level of fishing by the Japanese distant-water fleet in equatorial region of the WCPO (regions 3 and 4). In the eastern equatorial region (region4), this has been countered by an increase in fishing activity by the Korean distant-water fleet.

iii. For region 3, nominal and/or standardised catch rates of yellowfin and bigeye tuna derived from Japanese logsheet data (Guam-based and distant-water) are comparable to CPUE indices derived from the aggregated data set provided by Japan (the principal CPUE index). Therefore, logsheet data may be used to augment and/or extend the CPUE time-series, if recent aggregated data are unavailable.

iv. For region 4, standardised catch rates of yellowfin and bigeye tuna derived from Korean logsheet data are comparable to CPUE indices derived from the aggregated data set provided by Japan from 1990 onwards. On this basis, recent Korean logsheet data could be incorporated into the Japanese data aggregated dataset, thereby, augmenting and extending the CPUE time-series.

Cluster analyses

v. For region 3, a cluster analysis was applied to the Japanese longline logsheet data. Two approaches were used defining clusters based on a) species catch composition of the longline set and b) the prevailing oceanographic conditions at the location of the longline set. It was intended that these analyses may identify separate constituent groups within the region 3 fishery. Trends in CPUE of yellowfin and bigeye tuna were compared between constituent groups.

vi. Cluster groups derived based on species catch composition were essentially derived based on the catch of the other key tuna species caught; i.e. where yellowfin was the species of principal interest the clusters were largely determined based in the catch of bigeye and vice versa. This indicates that there are no sets that are specifically targeting other species, such as swordfish or marlin.

vii. Cluster groups based on oceanographic data largely resulted in defining clusters with a different spatial distribution of fishing activity, although there was a high degree of spatial overlap between some of the main clusters.

viii. For both yellowfin and bigeye tuna, trends in nominal CPUE were comparable among all clusters identified (catch-based and oceanography). This indicates that the trends in relative CPUE of both species are consistent throughout the region and they are relatively independent of the species being targeted (yellowfin or bigeye) or the prevailing oceanographic conditions. Nevertheless, there are differences in the magnitude of the catch rate of each species depending on the species targeted and the prevailing oceanographic conditions (correlated with location).

Spatial statistics

ix. The availability of operational level logsheet data provides the opportunity to undertake a range of analyses to explore the underlying presumption that changes in longline catch rates are proportional to changes in overall fish density. A preliminary analysis of Japanese distant-water logsheet data from region 3 was conducted, principally to assess the extent of interdependence between successive longline sets and between individual vessels within the longline fleet.

x. The analysis revealed considerable interdependence between subsequent sets with the behaviour of an individual vessel principally influenced by the catch rate of bigeye from the most recent set. Vessels tended to remain at a location where high catch rates were achieved and move from the area when catch rates were below a threshold.

xi. For both bigeye and yellowfin tuna, there are comparable annual relative trends in the level of nominal CPUE that either triggered a vessel moving to a new location or resulted in a vessel remaining at the location. This may indicate that there is no increase in the relative patchiness of the distribution of the target species between years and there are broad scale fluctuations in the overall density of the species between years. However, these observations should be tempered with other observations relating to the operation of individual vessels.

xii. Since 1995, there was a general decline in the distance moved between successive sets. This may indicate that vessels are better able to locate areas of higher CPUE and need to move to new locations (in search of higher CPUE) less frequently than they have in the past.

xiii. Since 1995, there has also been an increased level of fishing activity that is associated with the operation of other vessels in the fleet. This is evident from the increase in level of fishing activity by other vessels in waters adjacent to where an individual vessel operates, particularly when a vessel moves to a new location. This suggests that vessels in the fleet are increasingly sharing information to enable affiliated vessels to achieve higher catch rates.

xiv. This analysis of the spatial dynamics of the longline fleet is preliminary and is somewhat hampered by the relatively low logsheet coverage in some years. A comprehensive analysis of this type would require virtually complete logsheet coverage of the longline fleet (and possibly other fleets operating in the same area). Nevertheless, the analysis does provide evidence to suggest that the longline fleet is increasingly able to locate higher CPUE areas (more sets in areas where CPUE is higher, less frequent movements from higher CPUE areas). This may occur either through increased communication within the fleet or from other external information available to individual vessels. Such trends are likely to undermine the naive presumption of CPUE representing an index that is directly proportional to stock abundance. This may be particularly the case for the principal target species (bigeye) and of lesser significance for yellowfin over the last decade.

xv. Further analyses of these data, or comparable data sets, are required to identify subsets of the data that may be less likely to violate some of the underlying assumptions relating catch rates to fish density.

References

Hampton, J., Langley, A. & Kleiber, P. 2006a. Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an analysis of management options. WCPFC SC2 SA WP-1, Manila, Philippines, 7–18 August 2006.

Hampton, J., Langley, A. & Kleiber, P. 2006b. Stock assessment of bigeye tuna in the western and central Pacific Ocean, including an analysis of management options. WCPFC SC2 SA WP-2, Manila, Philippines, 7–18 August 2006.

He X., Bigelow K.A., Boggs C.H. (1997) Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. Fisheries Research 31 (1997) 147-158.

Hoyle, Bigelow, Langley (2007) CPUE workshop.

Appendix 1. Regional longline logsheet.

REVISED: DEC 2004

SPC / FFA REGIONAL LONGLINE LOGSHEET

PAGE ____ OF ____

NAME OF VESSEL		FISHING PERMIT OR LICENCE NUMBER(S)	YEAR
NAME OF FISHING COMPANY	FFA REGIONAL REGISTER NUMBER	NAME OF AGENT IN PORT OF UNLOADING / PRIMARY TARGET SPECIES	TRIP NUMBER THIS YEAR
COUNTRY OF REGISTRATION	FFA TYPE APPROVED ALC (Y/N) ?	PORT OF DEPARTURE	DATE AND TIME OF DEPARTURE
REGISTRATION NUMBER IN COUNTRY OF REGISTRATION	INTERNATIONAL RADIO CALLSIGN	PORT OF UNLOADING	DATE AND TIME OF ARRIVAL IN PORT

- ALL DATES AND TIMES MUST BE UTC / GMT
- ALL WEIGHTS MUST BE KILOGRAMS

MONTH	DAY	ACTIVITY CODE	01:00 UTC OR SET POSITION LATITUDE DDMM	N S	LONGITUDE DDDMM	E W	SET START TIME	NUMBER OF HOOKS	HOOKS BETWEEN FLOATS	ALBACORE No RET	ALBACORE KG RET	ALBACORE No DISC	BIGEYE No RET	BIGEYE KG RET	BIGEYE No DISC	YELLOWFIN No RET	YELLOWFIN KG RET	YELLOWFIN No DISC	SHARK No RET	SHARK No DISC	STRIPED MARLIN No RET	STRIPED MARLIN KG RET	BLUE MARLIN No RET	BLUE MARLIN KG RET	BLACK MARLIN No RET	BLACK MARLIN KG RET	SWORDFISH No RET	SWORDFISH KG RET	OTHER SPECIES NAME	OTHER SPECIES No RET	OTHER SPECIES KG RET
							PAGE TOTAL																								
							TRIP TOTAL																								

ACTIVITY CODES
1 A SET
2 A DAY AT SEA BUT NOT FISHED OR TRANSIT
3 TRANSIT
4 IN PORT - PLEASE SPECIFY

NAME OF CAPTAIN	SIGNATURE OF CAPTAIN	DATE